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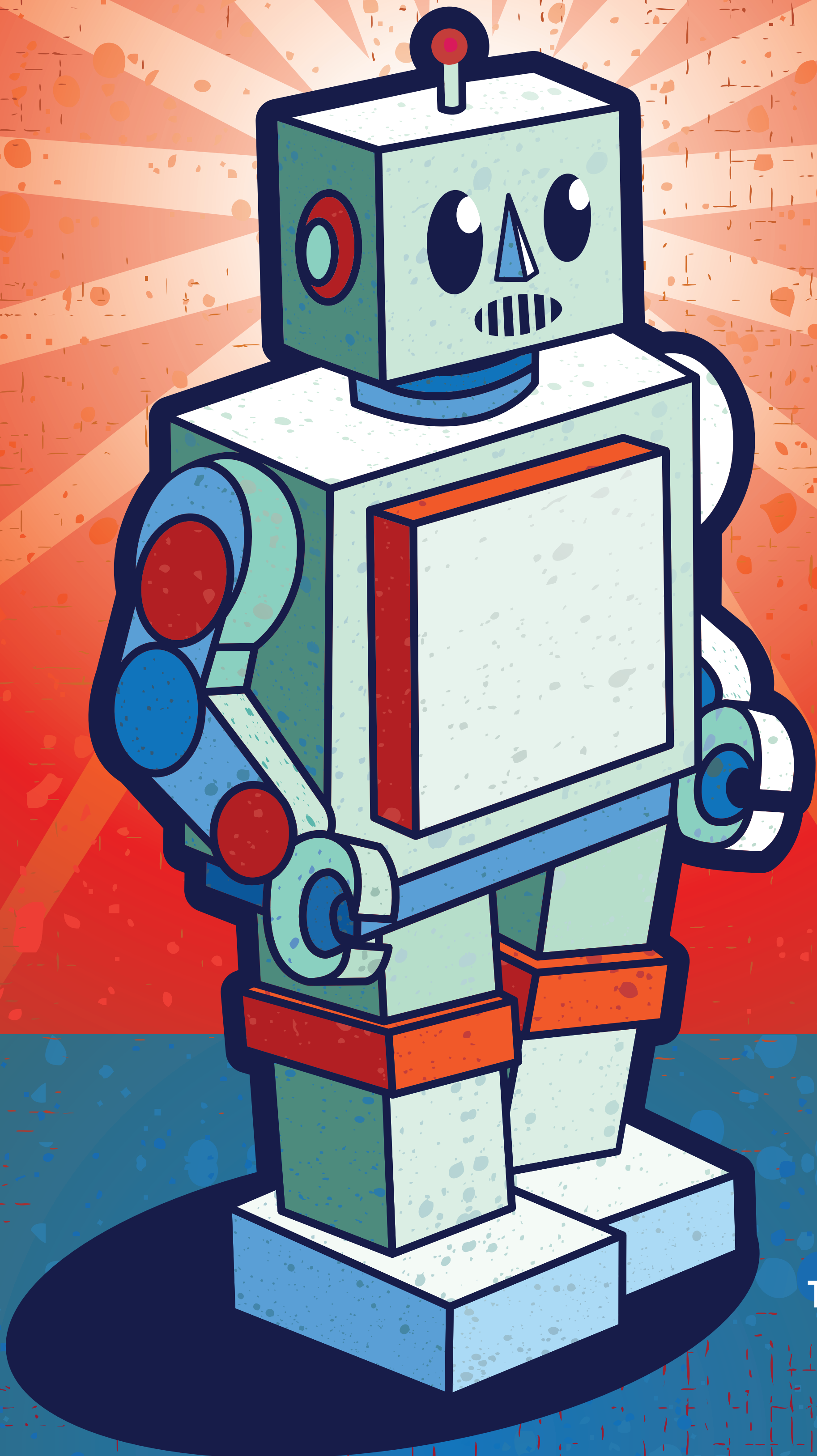

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The PATT 26 conference
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Technology Education in the 21st Century

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Welcome to the PATT 26 conference
Technology Education in the 21st Century
in Stockholm, Sweden, 26–30 June 2012

PATT 26 will be held at the Royal Institute of Technology (KTH) in Stockholm, the beautiful capital of Sweden. The PATT 26 conference is part of a two-conference arrangement organized by the Royal Institute of Technology and the Centre for School Technology Education, CETIS, Linköping University, under the common heading Technology Education in the 21st Century. We hereby welcome international colleagues to this golden opportunity to share and learn more about the latest on-going and completed research in the field of technology education research, spanning from early years through to upper secondary education and teacher education.

The overarching theme for PATT 26 is Technology Education in the 21st Century. The papers in this peer-reviewed conference book all reflect this broad theme, but they also relate to a variety of key areas in school technology education. Research topics include, for example, aspects of learning, teaching, and assessing; pupils' attitudes; global issues such as sustainability, ethics, values and culture; interdisciplinarity; Science, Technology, Engineering & Mathematics (STEM); links with creative and performing arts; links with arts and social sciences; links with languages; the impact of technological developments on learning, teaching and assessing in technology education; the potential of a design approach; technological artefacts and systems; food technology; historical, sociological and philosophical perspectives on technology education. Together all these areas form a wide spectrum of research of relevance for technology education in the 21st century.

Thomas Ginner, Jonas Hallström & Magnus Hultén,
editors and organisers

June 2012

PATT
Pupils' Attitude Towards Technology

The PATT conference started back in 1985 when a small-scale workshop on attitude research for technology education was held. This led to a series of international conferences that still continues. In that year colleagues from a variety of countries came together to discuss the possibilities for exploring the attitudes of young people toward technology, using an instrument that had been developed in the Netherlands (we still use this instrument today all over the world). The format of the first PATT conference provided ample opportunity for discussion and this is a feature that still characterizes PATT conferences today. Over the years the scope and the issues for discussion have been extended and all aspects of technology education can now be found on the agenda.

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Artifacts for all and for each, boys and girls in technology schoolbooks: some precaution for the 21^{st} century

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Key words: gender, technology education, artifacts, school book

Abstract

For a long time, we have known that only a small part of female students chose technical or industrial carriers. Studies about this question have mainly focused on socio-cultural factors. The specific aspects about academic content remain less studied. We know nothing or very little about the issue of masculinity or femininity underlying knowledge and about material artifact used in teaching technology.

This contribution shows the content evolution of schoolbooks used in technology education and more precisely the neutrality or not of the artifacts that illustrate schoolbooks.

Introduction

Technology education in France is compulsory for all the pupils from 3 to 15 years age. At elementary level (3-11 years) scientific and technological education are associated. Later (for 12-15 years old) technology education becomes a discipline per se. For these two school levels, technology is defined by national curriculums, which specify for each cycle and each level: objectives, competences, contents and the suitable teaching approach. The programs are renovated every ten years according to the educational policy and the social evolutions (new knowledge, discoveries, and evolutions of the references and contents of employments).

In spite of this framework, the sectors and the trades scientific and technological remain deserted by the girls since decades (Robine, 2006; Rosenwald, 2006; Wach, 1992). Many sociological studies showed how the socio-cultural stereotypes reinforce the differences between girls and boys (Mosconi, 1994; Baudelot & Mossuz-Laveau, 2004; Marry, 2004; Duru-Bellat, 2005.).The social norms are built through the activity of the pupils in the process of differentiation from a socio-cultural point of view or socio-professional and socio-economic point of view. Is it possible to identify factors likely to generate or attenuate differentiations in technology?

In GESTEPRO team, several researchers have been interested for many years by the role of technical artifacts in the construction of properties of the physic environment and by their effect on the pupils' learning according to whether they are girls or boys (Andreucci, Brandt Pomares, Chatoney & Ginestié, 2009; Chatoney & Andreucci, 2009; Ginestié, 2005; Roustan-Jalin, Ben Mim, Dupin, 2002). Does the school reinforce the differentiation between girls and boys? If so, which kind of mechanisms are implicated? For example, does the choice of artifacts which support study in technology education contributes to strengthen the feeling among girls that technology is best suited for boys? In sciences and particularly in biology, we know that the content of textbooks are gendered (Caravita & Al, 2008; Castéras & Al, 2008,). In technology only one book has been designed to answer to questions of gender in the classroom (Sadker, D., Silber, E. S. 2007). In our article the question of gender is studied from the point of view of the artifacts which illustrate the schoolbooks. These artifacts are they no gendered or representative of each gender? A large number of technical objects are used to illustrate the content of the school handbooks. These artifacts are presented alone or in situation of use. The contents of these books change with each new program. Are these evolutions in line with a better balance between objects seen as feminine and those considered masculine? This paper presents two empirical studies involving college (middle school pupils) to inform these issues.

2. Characteristics of the studied schoolbooks

The study carries on four schoolbooks of technology all four published by the same editor (Delagrave). All these four schoolbooks are addressed to pupils of 11-12 years These 2 factors are constant and not responsible of any observed differences. The number of pages of these four books is also the same, except for the last of them which contains a higher number of pages. By contrast, the manipulated variable refers on the date of publication of these various books as indicated in the table below.

Year of publishing	Titles	Authors	Nb of pages
1986	Technology with the college level 1	Biancotto A & Boye P.	127
1996	Technology 6°	Pawl J, Gaigher G.	127
2000	Tools and concepts - Technology	Pawl J, Gaigher G.	127
2005	Eureka technology! - Technology 6°	Pawl J & Al	159

These various dates correspond to successive stages of the history of technology education which marks the evolution of its knowledge content. Thus, in 1986 technology “takes its first steps” in the sense where the discipline has just been introduced under this name into the programs where it replaces the EMT (manual and technical education). Ten years later, in 1996, the program is modified. It breaks up from now on into four distinct parts: working of materials, electronic construction, marketing of a product and textual information processing l. In 2005 the whole of the program of the 11-12 years is reorganized with a focus on the thematic of transport, three activities (design, production, communication) and two central 2 concepts (materials, energy).

3. Procedure of examination and categorization of the artifacts which illustrates technological education in four schoolbooks

3.1 The repertory of technical objects present in the schoolbooks

For each one of these books we carried out an exhaustive inventory of the technical objects being used as illustrations (figurative photographs and drawings). For each handbook a list of all distinct objects was made with their respective occurrence (many times where each object is represented). The results of this first census (table 1) show that the first published schoolbook of technology (in 1986 ie only one year after the implementation of the discipline) was very poor in illustrations: only 32 distinct objects were present in this schoolbook including three artifacts with an occurrence higher than the others: the electronic component (6 times), the computer (5 times) the multimeter (5 times). The two following schoolbooks (editions of 1996 and 2000) are, at first sight, rather quantitatively and qualitatively similar in terms of illustrations: the objects most frequently represented are the computer (8 times on both sides) and the electronic component (5 times and 8 times). Finally, it is noted that the most recent handbook (edition of 2005) contains a less number of artifacts and that the thematic of transport is dominant here (19 times the bicycle, 14 times the boat, 12 times the car).

	Number of illustrations	Number of distinct artefacts
Schoolbook 1	55	32
Schoolbook 2	202	120
Schoolbook 3	180	109
Schoolbook 4	164	75

Table 1 – Quantity of illustrations and of objects represented in the various schoolbooks

After elimination of the doubled blooms inside these four repertoires, there are 167 distinct objects which were finally indexed within the examined schoolbooks.

3.2 Categorization of the artifacts by the pupils

- **Problems**

Obviously, the use of certain objects is preferentially reserved to the women (for example all utensils of make-up) while others (for example utensils of fishing) are primarily intended to the men. However this criterion of the use (or the frequency of the relationship of men and women with such or such object) remains most of the time ambiguous. For example, the car does not have a raison to be gendered taking into account the fact that there are as many drivers of the two sexes. On the other hand, if one looks at the car from the point of view of the sex of the people which conceives it, repairs it, or which reads the specialized car magazines, the relationship with the cars appears wider among men than among women. So, it is difficult to carry out a categorization "a priori" of the artifacts. Furthermore, let us note that contrary to English, in French the name of the objects is itself gendered. Some names are masculine (example: a bicycle, a settee...) and others are feminine (a pan, a dress...). However that does not suppose anything on the kind of their users as testify other examples: a crane, an excavator, a nail varnish, a hair-curler, etc.

On this question, it should anyway take into account the point of view of students as they are the main users of textbooks. So, to clarify how pupils conceive the gendered character of artifacts presented in the schoolbooks of technology, we made a preliminary study.

- **Method**

98 pupils took part in this study on categorization of artifacts. This sample includes twenty 12 years old boys and twenty boys of 14 years old and twenty-nine girls of each age level. The sample is thus composed of four independent groups of pupils. The task submitted to the pupils (see questionnaire in appendix) consists to indicate if the 167 artifacts (alphabetically listed) are more for boys, or more for girls, or for both. More precisely, pupils received following instructions "*For each quoted object indicates, according to you, if it corresponds rather to an object for the girls (F), rather to an object for the boys (G) or rather to an object as well for the girls as for the boys (F+ G)*". They must simply put a cross in the ad hoc column (F, G or F+G). A last column (?) is reserved for the unknown objects by pupils. Each pupil thus formulated 167 judgments whose analysis presented below.

4. Data analysis and results

4.1 Distribution of boys' and girls' judgments at each age

The distribution of the various types of judgments inside the four groups (table 2) reveals several significant differences:

Among boys, we observe that the number of artifacts considered as feminine increases with age (174 to 12 years vs 305 to 14 years, khi 2 = 38.08 sign.001). And the same result applies to the objects considered to be masculine: on 3340 answers 605 answers to 12 years compared with 812 to 14 years (Khi 2 = 37.69 sign. 001). The boys thus become more and more discriminators or sensitive to the fact that many technical artifacts are sexually marked.

Among girls, we note no significant evolution according to the age for objects considered to be feminine (442 vs 475, Khi = 1.13, NS). On the other hand the number of objects considered as masculine increases considerably between 12 years (626 answers out of 4843) and 14 years (994 answers, Khi = 102.06, sign. 001). The sensitivity of girls to the gendered character of the artifacts increases also with age, but in a selective way. For them, the artifacts for boys are increasingly numerous whereas the number of apprehended artifacts as feminine remains stable.

Objects for:	Girls		Boys	
	12 years (N= 29)	14 years (N= 29)	12 years (N= 20)	14 years (N= 20)
Girls	442	475	174	305
Boys	625	994	605	812
Two sexes	3220	2826	2188	1944
I do not know the object	541	547	365	274
non-responses	15	11	8	5
Total answers	4843	4843	3340	3340

Table 2 - Distribution of the various types of judgments inside the four groups

This stability can be explained by another important difference between girls and boys at 12 years. Indeed, at this age girls are definitely more numerous (442 answers) that boys (174 answers) to allot to the objects a female connotation. This difference (Khi 2 = 103.8 sign.001) is very clear. We note that at 12 years on average, more than 15 objects are considered to be female by the girls against less than 9 objects among boys. At 14 years, this variation is definitely less important (475 vs 305 answers) and no significant (Khi 2 = 1.04 NS). Does the opposite tendency exist for the objects considered as masculine? The answer is yes. At 12 years, the objects are more often regarded as masculine by the boys that by the girls (khi 2 = 41.98, sign. 001). Thus, at this age, the girls judge on average 21.5 objects of the list like masculine against more than 30 objects on average among boys. This tendency persists at 14 years: there are more answers in favor of the masculinity of the objects among boys than girls (Khi 2 = 16.48 sign. 001). Furthermore, there is a reinforcement of this phenomenon with age: 34 objects of the list on average at the girls and a little 40 among boys.

However, the majority of the objects remaining considered to be neutral. With the age their number regresses for the girls (khi 2 = 68.32, sign.001) as among boys (Khi 2 = 37.77 sign.001). But at each age, girls and boys estimate in the same proportion the neutral objects.

Lastly, we note that the objects unknown by pupils are very numerous, proof of the didactic interest of their presence in the schoolbooks. Between 12 and 14 years the number of unknown objects by the girls, remains constant. At 12 years, this number is equivalent for boys and girls. But at 14 years unknown objects are fewer among boys than for girls. So, the girls' acculturation of the artifacts represented in schoolbooks would be also less large.

The non-responses are in very restricted number, showing that students responded to the survey with a great care.

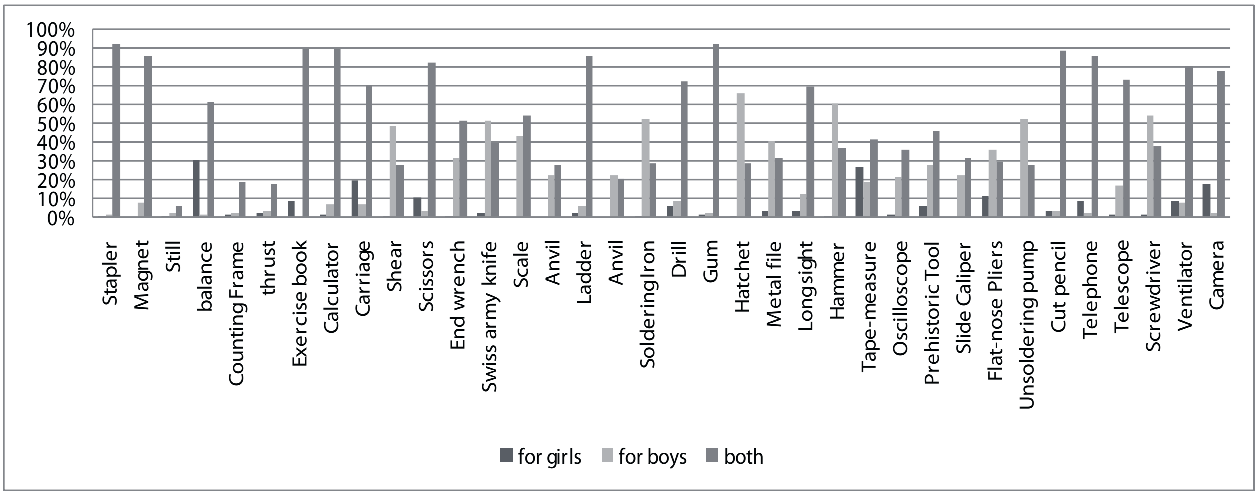
4.2 Categorization of the objects by family

Certain objects produce a strong consensus (C++: higher than 75%) and others a consensus less marked (C+-: between 50 and 74%). We find only 62 C++ considered to be "mixed" (i.e. not gendered) among the 167 objects subjected to categorization, no object C++ categorized masculine, and only one object C++ categorized feminine (it is the "pair of boots" that pupils represent themselves spontaneously as boots of city and not as professional safety boots). For the objects C+ -, we find 48 artifacts mixed, 17 masculine and 3 female.

For a better legibility, in the following, data are gathered under eight great thematic categories[1]: tools and instruments, ITC, transport, electric objects, gears and machines, food, utensils, habitat, plus a category various. We will focus primarily on gendered objects into these various categories

- **Tools and instruments**

It is found that among the 36 items grouped in this family (see graph 1), many are considered predominantly as "for men" : shear, end wrench, swiss army knife, anvil, ladder, soldering iron, hatchet, hammer, unsoldering pump, ... Only two artifacts are judged as more feminine than masculine: balance and tape-measure.

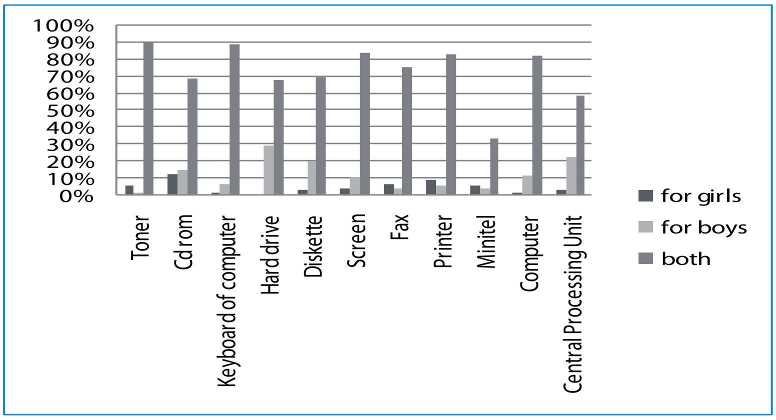


Graph 1: Tools and instruments family

- **ITC**

The gendered character of ITC objects is less obvious: the majority of gendered responses involve less than 15% of judgments (cf graph 2). ICT objects are mostly considered non-gendered. Only two objects give a difference: The hard drive and the central processing unit are significantly seen to be more masculine.

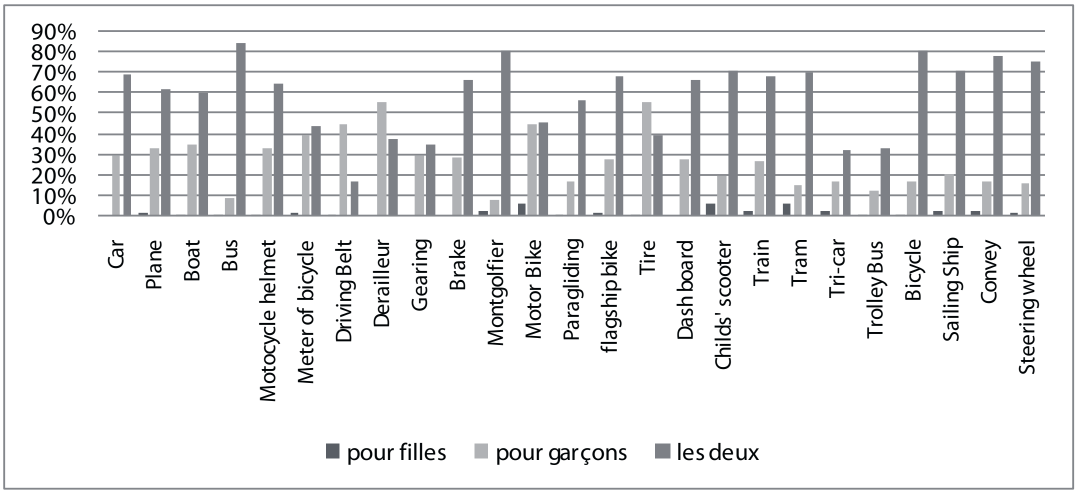
1 This classification is not entirely relevant because the categories are not exclusive of one another, but it actually helps to organize the presentation of results.



Graph 2: ITC family

- **Transport**

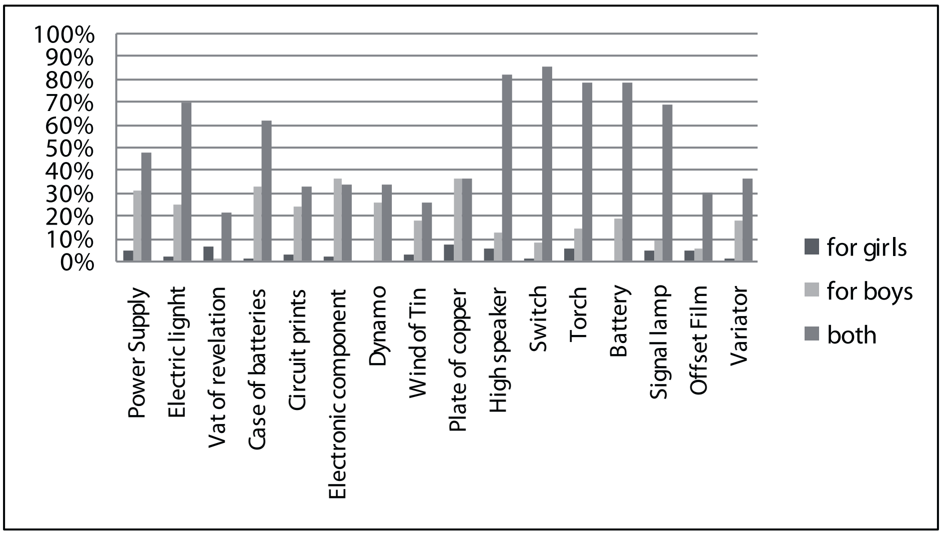
Among the 25 artifacts of this family, 16 are considered non-gendered: car, plane, boat, bus, motorcycle helmet, brake, montgolfier, flagship bike, dash board, tram, child's scooter, train, tram, bicycle, sailing ship, steering wheel. However, it appears clearly (see graph 3) that as a whole, transport systems are systematically estimated nearer to the boys than of the girls.



Graph 3: Objects of Transport family

- **Electric**

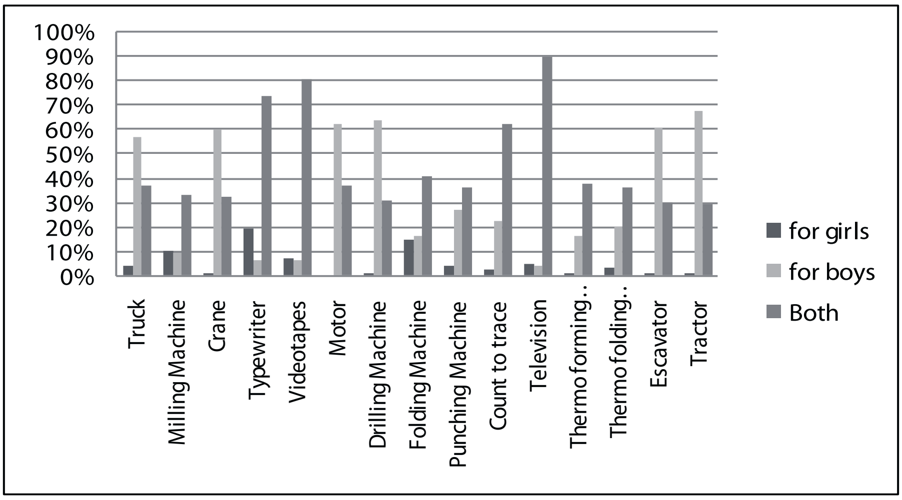
Among the 16 objects grouped here only 7 are massively seen as mixed : electric light, case of batteries, hight speaker, switch, torch, battery, signal lamp. One of them is largely unknown (the offset film). As previously all the others are estimated more for men than for female but in a less proportion.



Graph 4: Electric family

- **Gears and Machines**

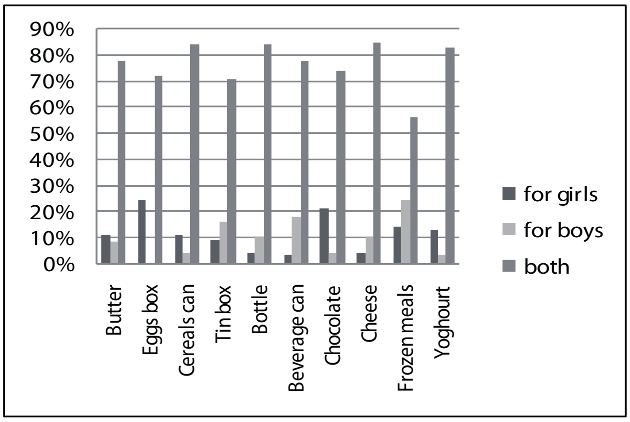
On the 15 objects of this family (see graph 5) four are primarily considered to be mixed: typewriter, videotapes, table to be traced and television. Six are massively judged as masculine: crane, motor, drilling machine, truck, excavator and tractor. The others are less discriminating.



Graph 5: Machine family

- **Food**

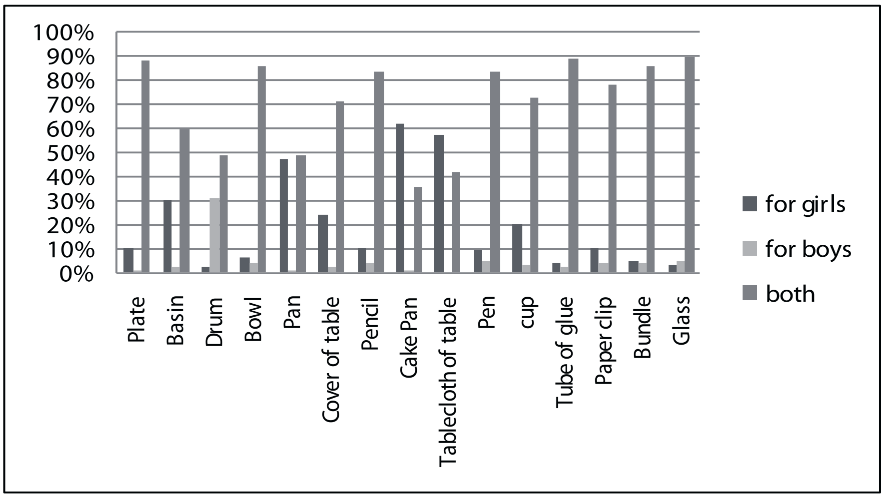
Mixed character of food objects gives a strong consensus. But pupils think that girls are more concerned with the chocolate and eggs boxes and boys by frozen meals, and beverage cans.



Graph 6: Food family

- **Utensil**

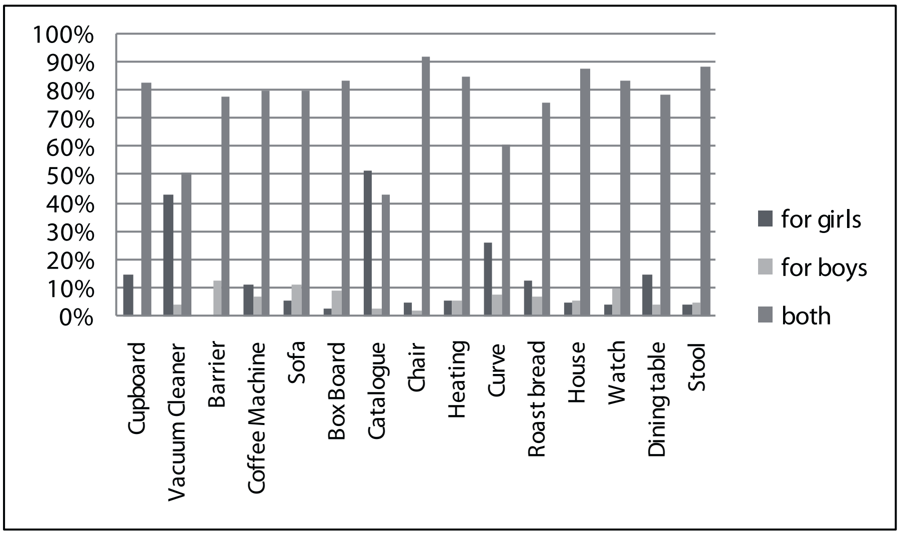
In our list, most utensils are seen as non gendered (see graph 7). However, children think that two of them are typically feminine: cake pan and tablecloth, and in a less proportion the pan (47%). The only utensil to be considered more male than female is the tin (31%).



Graph 7: Utensils family

- **Habitat**

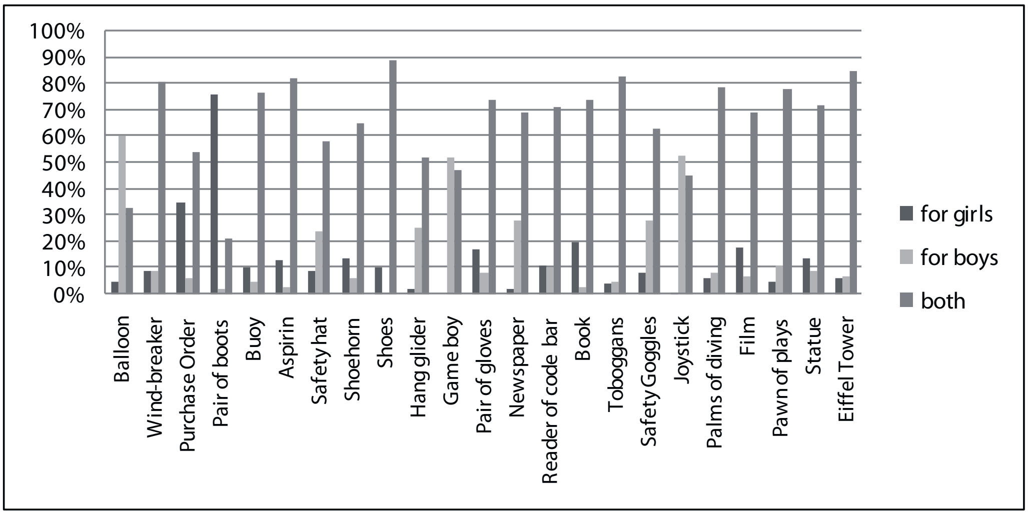
All the objects of this family are mainly mixed (see graph 8). Tree objects are classified like definitely more female than male: the catalog (52% female against 3% masculine), the vacuum cleaner (43% female against 4% masculine) and the clothes hanger (26% female against 8% masculine).



Graph 8: Habitat

- **Others**

In this category, six objects relate to the clothes and professional protections. All of them are largely seen as mixed except for the pair of boots (76% for the girls)[2]. 8 objects belong to the field of the sport and the leisures. 3 of them (balloon, range servant boy and joystick are considered to be more male than female significantly. The others are isolated. We note that among them that the newspaper is rather male (28% against 2%) contrary to the rather female book (20% against 3%). The purchase order is significantly marked female (35% cutter 6%).



Graphic 9: Others

2 This result shows the limitations of our study. Indeed it indicates that for students that name evokes city shoes instead of work shoes. But it is a bias in the presentation of objects. The name is often more ambiguous than the image.

5. Temporal evolution of the artifacts represented in the school books

It is noted that only eight objects are co-present in the four successive handbooks (1986, 1996, 2000, 2005): tape-measure, computer, oscilloscope, drilling machine, bicycle, car, slide caliper.

Eight artifacts appear in the last three handbooks: bottle, circuit print, shear, scissors, vice, tire, thermo forming machine, and screwdriver. Four are present in the two last years: house, shoes, square, glass. Nine are present in 1996 and 2005 but absent in 2000: camera, boat, truck, wrench, shifting track of bicycle, drill, high speaker, pawn, and stool.

Finally, 24 objects appear in 2005 for the first time: plane, balance, wind-breaker, bus, meter of bicycle, driving belt, hang glider, gears, brake, toboggan, montgolfier, motor bike, paragliding, pen, dashboard, child's scooter, Eiffel Tower, tractor, train, tram, tri-car, trolley bus, steering wheel. Thus, among them we have a majority of objects which relate to transport, which is coherent with the introduction in 2005 of this topic of study into the curriculum for the 11-12 years. However, we have observed that contrary to what one might have expected, artifacts related to transportation are often seen as masculine. Introducing a specific thematic of knowledge therefore includes the risk to enhance the girls' lack of interest towards technology education.

This introduction of new supports of study goes hand in hand with the disappearance of others artifacts. Among them are many objects related to the field of electronics and mechanics which occupied a dominating place of 1985 to 2005: electronic component, tin reel, soldering iron, milling machine, plate of copper, battery, motor, punching machine. But we note also the disappearance of many heteroclite objects which were charged to show to the pupils the nature and the extent of the cultural dimension of technical environment.. Thus, the first handbooks , gave a broad impression of technology with representatives of many classes of artifacts : furniture (table to be eaten, settee,) means of communication (television, newspaper), food products, tin box, beverage can,...) domestic utensils (pan, tablecloth, basin, cake pan...), computer and calculation tools (cd-rom, hard drive, computer) usual instruments (stapler, watch, torch,...), domestic equipments (vacuum cleaner,...), gears (crane, excavator), toys (joystick, game boy, balloon...) and buildings (statue).

Thus, we see that a certain number of typically male objects disappear (crane, range servant boy, balloon...). The same applies to rare items typically feminine (tablecloth, bathes, cake pan, pan...). In this respect we can consider that the supports of study gain in neutrality in term of gender. We hope that the diversity of the thematic studied at this level succeeds to compensate the loss of variety and richness of study supports involved. This should be the case, at least in part because themes of the habitat and the house automation are introduced just after this level.

Conclusion

Pupils appear sensitive to the gendered character of many technical artifacts and the handbooks of technology refer well to a majority of artifacts perceived like more masculine than feminine. This undoubtedly contributes to reinforce the feeling which the girls have that technology is more appropriate for boys. In addition, we saw that between 12 and 14 years the number of objects regarded as male gendered increases significantly for girls. So this makes our findings even more problematic.

These results should draw the attention of the curriculum designers and the editors of handbooks. The concept of parity should also apply to this question. Indeed if it is difficult to refer only to non gendered objects, it would be advisable to balance the number of objects male and female. Moreover, teachers remain often free to choose their supports of study. So, they would gain with being formed with this question of gender. It is obvious that a topic as that of the house automation which is supposed to interest the girls loses on this level all its interest if it is focused on artifacts such as the garage, the automatic gate rather than on the balneotherapy and the hotplates.

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Reconstructing the Pupils Attitude Towards Technology-Survey

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Keywords: Attitude measurement, technology education, technological literacy

Abstract
In knowledge based economies technological literacy is gaining interest. Technological literacy correlates with the attitude towards technology, therefore, when measuring technological literacy as an outcome of education, one should take the attitude towards technology into account. This requires a valid, reliable instrument that should be as concise as possible, in order to use it in correlation with other instruments. We therefore reconstructed the Pupils' Attitude Towards Technology (PATT) instrument. We validated and piloted this and used it in a large study.. This resulted in an instrument with six subscales and 24 items of attitude towards technology that is easy to use and evaluate. The six items are: Career Aspirations, Interest in Technology, Tediousness of Technology, Positive Perception of Effects of Technology, Perception of Difficulty and Perception of Technology as a Subject for Boys or for Boys and Girls.

Introduction
In western countries technology, defined as any modification of the natural world done to fulfill human needs or desires, is gaining interest as a subject in the school curricula. Different nations are investing in the development of teaching programmes, research, and the establishing of platforms for the promotion of technology. The American National Assessment Governing Board ,for example, is making a framework for Technology and Engineering Literacy in 2014 (National Assessment Governing Board, 2011); in the Netherlands a platform for Beta-science is established aiming to achieve a structural increase of 15 per cent more pupils and students in scientific and technical education (Stichting Platform Bèta Techniek). Although industries and policy makers think technology education is far more relevant these days than it was ever before, the public opinion about studying technology and technical jobs is not very positive (Johansson, 2009). The Organisation for Economic Cooperation and Development (OECD) reports on student interest in Science and Technology Studies (OECD, 2008) states that, although absolute numbers of S&T students have raised, the relative share of S&T students among the overall student population has increased. The report shows that encouraging interest in S&T studies requires action to improve the image and knowledge of S&T careers. A report ordered by the department of education of the Flemish ministry (2006) points this out as follows: the image of technological studies and professions is rather low, which seems to be in contrast with the enthusiasm young people have for new technologies.

The image is strengthened by some prejudices like: 'the working conditions in industrial environments are not interesting, boring, they are hard and dirty labour, moderate payment, bad working hours.' More general people think science and technology are hard and boring to study. Technology is also often associated with danger. These are widely spread ideas about technology and the public opinion. How interested young people really are in technology and how this interest evolves during their school career has not yet been examined in the Flemish context. To be able to do this on a large scale we need an instrument to measure pupils' attitude towards technology with a manageable number of questions. In this paper we will clarify the revalidation of such a survey instrument. First a theoretical base will be described, followed by the methodology used in the research. Finally results of the study will be written down in a concluding chapter.

Theoretical base

Attitudes towards technology

It could be assumed that if students have a tendency to act positively toward a subject, for example technology, they will have more interest in that subject (Krathwohl, Bloom, & Bertram, 1964). Thus students exhibiting a positive attitude towards technology would be more likely to attain technological literacy through technology education (Bame, Dugger, de Vries & McBee, 1993). Therefore, a good interpretation of students' attitude toward technology is important. Attitude is a broad concept with different interpretations and definitions. For this research we use the concept 'attitude' as defined by Eagly and Chaiken (Eagly & Chaiken, 1993) "Attitudes are psychological tendencies that are expressed by evaluating a particular entity with some degree of (dis)favour", which is commonly regarded as the most conventional definition (Albarracin, Zanna, Johnson, & Kumkala, 2005). This is in line with the view of The Committee on Assessing Technological Literacy from the National Academies on attitudes (Garmire & Pearson, 2006). Attitude towards technology is explicitly conceptualized not to contain a cognitive dimension. What a person knows about a –technological - subject can however be correlated with his attitude towards that subject. Hereby a person's attitude can provide a context for interpreting the results of an assessment on technological knowledge as an outcome variable for educational effectiveness.

How do we measure attitudes?

A review study on attitudes towards science (Osborne, Simon, & Collins, 2003) notes that such attitudes – towards science – do not consist of a single unitary construct, but rather of a large number of sub-constructs all contributing in varying proportions towards an individual's attitudes towards science (e.g. anxiety; value; motivation; enjoyment; achievement; fear of failure…). Hence, producing a unitary score on attitude is useless. The best that can be done is to ensure that the components are valid and reliable measures of the constructs they purport to measure and look for the significance of each of these aspects. A good instrument needs to be internally consistent and unidimensional (Gardner, 1995). Internal consistency is often expressed with Cronbach's alpha. Commonly, attitudes have been measured through the use of questionnaires that consist of Likert-scale items where students are asked to respond to a number of statements. Despite the fact that these scales have been widely used and extensively tried in the domain of science education (Osborne et al, 2003) only few instruments have been made for measuring attitude in the domain of technology as defined above.

The PATT instrument

A number of instruments have been made for measuring an attitude in the field of technology (Garmire & Pearson, 2006). Considering the fact that we investigate students of age of 12 to 14, one instrument can be retained: the Pupils' Attitudes Towards Technology instrument (PATT) (Bame et al, 1993), consisting 58 statements on a five-point Likert scale. Since 1984 researchers have been assessing students' attitudes toward technology by using the PATT instrument. This instrument was first conducted in the Netherlands and is the first instrument specifically made for this purpose. Results in the Netherlands were so striking that an international extension of the research was the logical next step. In 1987 twelve countries decided to start using the PATT instrument or a part of it. A work conference was put together in the Netherlands to initiate the collaboration (Raat, Coenen-van den Bergh, de Klerk Wolters, & de Vries, 1988). Participants came from all over the world (e.g. India, Nigeria, Mexico, Australia but also West-European countries like France, UK and Belgium). In this report, due to the fact that not all participating researchers had the opportunity or knowledge to use statistical programmes (e.g. SPSS), the suggestion is made to create a shorter instrument. The idea was to investigate the possibilities of using a 'subset of scales' with maximum 5 items for each scale. Such an instrument yields many advantages (easier to apply, less time consuming, teachers can use it in the classroom). But the major objection of the participants was that a high reliability is required. Ever since there has been no reported research concerning a possible reduction of the PATT.

Research questions

In the West-European and, more specifically, in the Flemish context research in the field of technological literacy is rare but necessary, as is indicated by the Flemish ministry of education. It is important to be able to measure attitude towards technology. The absence of a concise but powerful instrument to measure this leads us to the following research questions:

- Is the PATT instrument suitable for the Flemish context?
- Can we adapt and reduce the PATT instrument and still retain validity and reliability?

Methodology

Principal components of the test

In order to be able to answer these questions we needed an instrument that was validated in the Flemish context. The most recent PATT survey contains questions (1-11) about demography of the pupil. Items 12-69 are the affective components of attitudes towards technology and items 70-100 are about the concepts of technology. An open-ended question at the end asks for a description of technology.

We will focus on the items concerning attitude towards technology. These 58 questions about attitude are dividable in five scales. 'Technology is difficult' and 'Consequences of Technology' contain five items each. 'Technology as an activity for Both Boys and Girls' and 'Attitude Towards Technology' each contain eight questions. 'General interest in Technology' contains sixteen questions (Bame et al, 1993). This results in a total of 42 questions which are withdrawn from the original 58.

The validation of the instrument contains different steps. First there is the translation. The PATT-USA test items 12-69 had to be translated into Dutch. Because the original PATT questionnaire developed by de Vries (1988) was in Dutch, a good translation was available.

The second step was the pilot study (n=251). An explorative factor analysis (EFA) was conducted on the data of this study. Although we had a clear idea of the different subscales it was interesting to see how all 58 items corresponded. The scales composed by Bame (1993) contained only 42 of the 58 items. Therefore we chose to analyse these results with an EFA with oblique rotation because this allowed us to undertake a data driven exploration taking into account the fact that latent variables might correlate and could contain some unexplained variance. In a scree plot we looked at the 'elbow point' (Pallant 2001). In interpreting the factor analyses we did not take loadings of items between -.30 and .30 into account.

Based on the outcome of this EFA and substantive arguments, factors were defined and tested on their reliability. Cronbach's alpha on each factor and the remaining impact of each item was taken into account to assure reliable scales with a reasonable number of items. To define a reliable scale Cronbach's alpha of .70 and higher are acceptable.

In the third step the remaining items from the pilot study were used in the main study on a larger group of students (n=3039). Allowing us to confirm our first analysis, this time a confirmative factor analysis (CFA) was used to confirm the measurement model. Goodness of fit indices helped us find the most appropriate model. In the analysis the Comparative fit-index (CFI) and Root-Mean-Square-Error-of-Approximation (RMSEA) will was taken into account. For the CFI a score >.95 indicates a good modelfit (Hu & Bentler, 1999) for RMSEA the maximum score is .05 for a good modelfit between .05 and .08 is still acceptable (Hoyle, 1995).

Different models were compared with a Chi² test on the -2 LogLikelyhood differences and Akaike's Information Criteria (AIC) to determine the best fitting model. The test not only showed the Chi² score for each model but the model' significance (p<.05).

Data collection

The pilot study was conducted with 251 pupils (111 Girls, 137 Boys , 3 missing) from first grade of secondary education (12-14 years old) divided over first and second year in five different schools – both rural and non-rural environment and public and non-public schools. All had to achieve the same national goals for technology but had different curricula. Each school however had at least two hours of technology a week.

In the main phase the slimmed version of the PATT test was conducted in 17 schools with a total number of 3039 pupils. Students from the first and second year of secondary education were represented. Students had different curricula (e.g. Latin, economy, social sciences, electricity,...). This survey allowed us to confirm previous findings from the pilot and framed a fitting model for this instrument.

Results

In our pilot study we used all 58 items (items 12-69) from the original questionnaire. An Explorative Factor analysis (EFA) was applied. We also performed a scree test and plotted the parallel analysis (fig.1). The parallel analysis suggests a solution with five factors and the scree plot shows an elbow point between the fifth and the sixth factor. Therefore an EFA with oblique rotation was applied with a fixed number of five factors. The cumulative explaining variance of the five factors was a satisfying 43% (table 1).

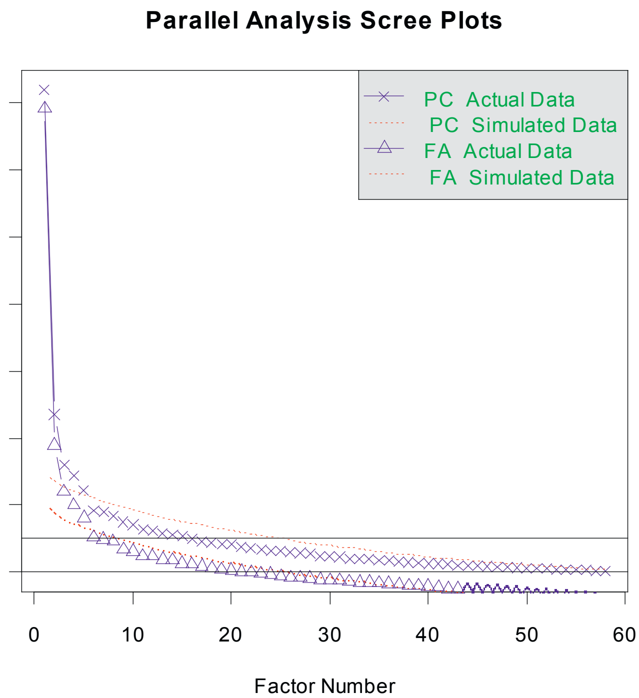

Fig. 1:
screeplot Parallel factor analysis with 58 items

	Factor 1	Factor 2	Factor 3	Factor ‘	Factor 5
Eigenvalue	9.41	4.70	3.90	4.12	2.67
Proportion explained variance	0.16	0.08	0.07	0.07	0.05
Cumulative explained variance	0.16	0.24	0.31	0.38	0.43

Table 1: eigenvalues, explained variance per factor and cumulative explained variance of the five factors after oblique rotation.

Analysing the standardized factor loading for each we learn that the results show great resemblance with the factors as defined by de Vries (1988). Table 2 shows all the items for the different factors in our data.

Factor	Description	High score indicates	Items
1	Interest in technology	more interest	12, 16, 17, 18, 23, 27, 28, 32, 34, 39, 45, 46, 50, 51, 52, 57,58, 62, 63, 69
2	Attitude towards technology	more positive attitude	22, 28, 29, 33, 40, 46, 51, 57, 58, 60, 64, 65, 68
3	Technology as an activity for both girls and boys	technology is for both genders	13, 19, 24, 30, 35, 41, 47, 53
4	Consequences of technology	more positive consequences	14, 20, 25, 27, 31, 38, 42, 56, 60, 66
5	Technology is difficult	technology is more difficult	26, 43, 44, 49, 61, 67

Table2: items with a loading >.30 in the different factors

According to the number of items in the first factor ‘interest’ (20) and the theoretical background of the test one can wonder whether this really is an unidimensional construct or whether it is an artefact of conducting an EFA on the total number of 58 items. To test this new hypothesis we conduct a new EFA with only the items of the factor ‘interest’.

Results of the screeplot of the analysis (fig. 2) and the parallel test confirm the first analysis, leading to the conclusion that these 20 items measure general interest.

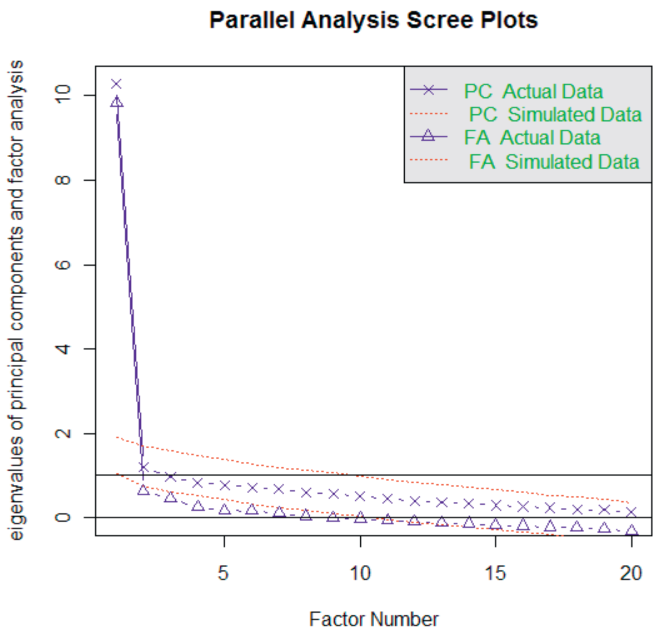

Fig.2: Scree plot Parallel factor analysis with 20 items from factor 1 'General interest'

Although the scree plot showed a unidimensional scale, the eigenvalues of the first two factors were above 1 and content analyses indicate that there were two sub factors, which will most likely be highly correlated. Thus a factor analysis with two factors and oblique rotation was conducted. From the results we derived two clearly different factors. Because of the clear distinction in content (see factor description below) the first sub factor of 'general interest' was defined as 'technological career aspirations' and the second as 'interest in technology'.

With a total of six factors we started analysing the internal consistence of each factor. And if possible items were dropped either to raise reliability or to make an equal reliable factor with less items. Results for each factor are explained below.

Technological career aspirations

Seven items form the factor technological career aspirations. A reliability analysis on all items learns us that the factor reliability for all items is .91. When eliminating less consistent items one by one we become a reliability for these four items of .92, which is considered as excellent. The remaining items are 17, 39, 45 & 63.

Interest in technology

The number of items with a loading above .30 was nine. These items have a Cronbach's alpha of .87. Dropping item per item we can bring the number of items back to five with an alpha of .84. Eliminating more items would decrease the reliability too much. These five items are: 32, 42, 46, 50 & 52.

Attitude towards technology

The original attitude scale consists of eight items (Bame Dugger, 1993). The EFA results in a nine item factor (α=.83). Exploring the specific content of these questions and a new reliability analysis of a shorter list of items delivers us a factor with an absolute minimum of four questions for this factor, with a reliability quasi equal to the scale with nine items and still defined as 'good' (α=.81). The remaining four items are: 33, 57, 58 & 64.

Technology is for both, Boys and Girls

Eight items compose the scale 'technology is for both'. An equally good reliability (α=.80) can be obtained with only half the number of items. Therefore we will only retain the four following items: 24, 30, 41 & 47.

Consequences of technology

Compared to the original scale of five items we derived a double number of items. Reliability remains above .70 when excluding 6 items step by step to finalize the diminishing at four items. (α =.72) The remaining items are: 20, 25, 27 & 31.

Technology is difficult

The original scale provided an answer to whether pupils thought technology was difficult based on five questions. In our analysis the factor contains six items. Because of the low Cronbach's alpha (.60) the data are analysed again based on the content of the items and the theoretical frame made by Bame et al (1993). Items 15 and 21 are included. The reliability of the scale containing eight items (15, 21, 26, 43, 44, 49, 61, 67) is .65. A further analysis learns that this reliability can't be made higher than this. However, excluding four items doesn't effect the reliability a lot. The following four items remained with an alpha score of .64: 21, 26, 43, & 49.

Conclusions of the pilot study

The original factor 'General Interest' (Bame, et al, 1993) containing 18 items was slimmed to two factors, career aspirations and interest in technology, with four and five items in each scale respectively and alpha's above .80, which are considered to be good.

The factor 'Attitude' contained in his original version eight items with a variety of questions about prosperity, environment, the need of mathematics, etc. The slimmed version with only four questions defines attitude as 'the degree in which someone finds technology boring or not' and all of the items are negatively stated. Therefore it could be appropriate to change the title of the factor in 'tediousness'.

The factor 'Technology as an activity for both boys and girls' was perfectly slimmed to only four questions of the original eight with a good reliability (.80)

For the factor 'Consequences of Technology' one of the four remaining items was not in the original factor. Nevertheless our analysis showed a bigger internal consistency of the items (α_{new} =.72; $\alpha_{original}$ =.67).

For the factor 'Technology is Difficult' the results are not as straightforward as for the other factors. A reliability score between .60 and .70 is questionable but we retain this factor with four items to maintain a questionnaire including six different aspects of attitude towards technology.

With a total number of 25 items divided over six factors this analysis of the first pilot study results in a questionnaire with sufficient reliability and less than half the number of items of the original PATT questionnaire.

Main run

We used a CFA to examine the dimensionality of the questionnaire in more detail. This CFA explored the different models for the six factors until a good fitting model was found in line with theoretical evidence for this model. The different steps will be subscribed below, starting with an overview of the data in table 3. This displays the model number, the comparative fit index (CFI), the Root Means Square Error of Approximation (RMSEA), Akaike's Information Criteria (AIC), Chi², and the p-value for significant improvement with the previous model.

Model	CFI	RMSEA	AIC	Chi²	df	P -2LL test
1	.928	.050	190904	2007	260	
2	.939	.046	190639	1740	259	<.001
3	.951	.043	184456	1402	236	

Table 3: The fit indices for the different models

Model 1

The first model includes all factors as defined after the first pilot study. The factor 'structure' is shown in figure 3. The fit indices for this model don't reach the critical values (CFI>.95; RMSEA<.50). Therefore we used the function modification indices to inspire us for any improvements on the model. This resulted in the suggestion to implement item 27 '*Technology lessons are important'* as a factor loading for 'interest'. Because both internal consistencies for the factors 'interest' and 'consequences' will improve we implement this item in the factor 'interest'. This results in a second model.

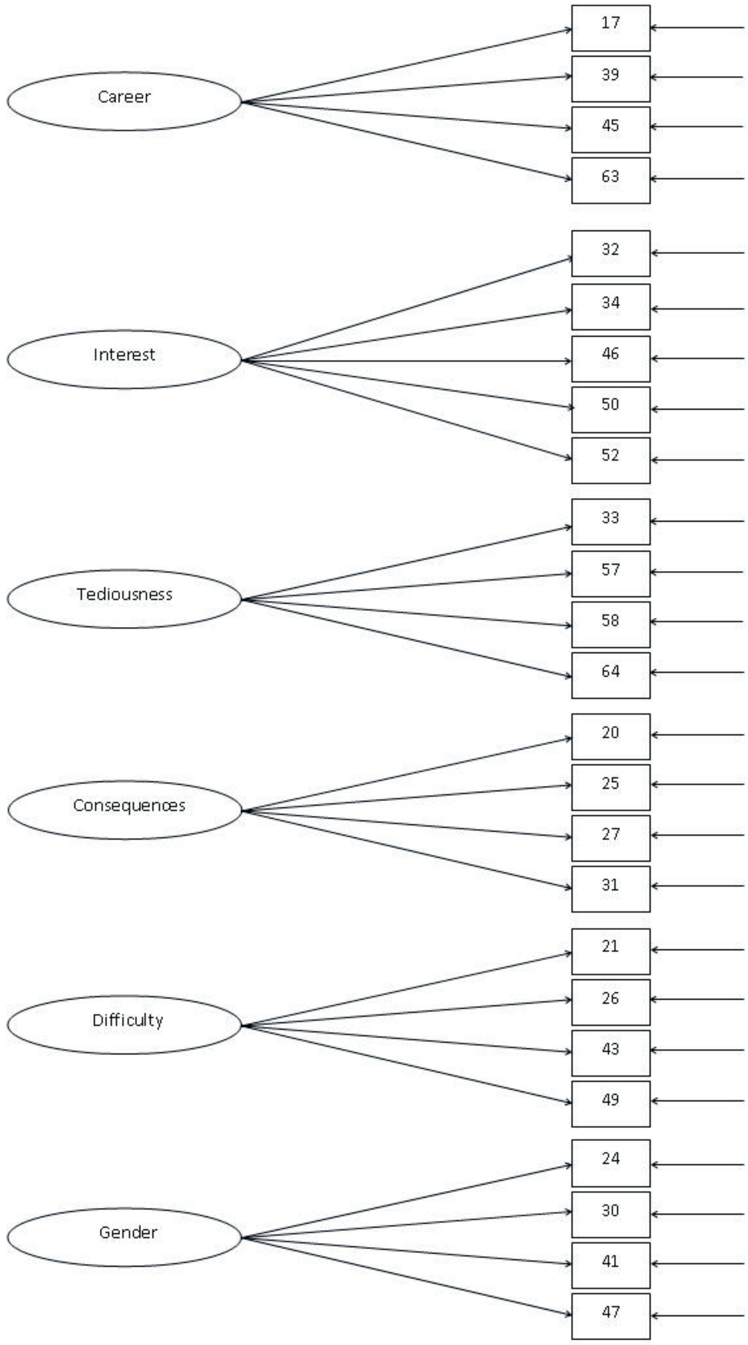

Figure 3: Model 1

Model 2

As shown in table 3, the second model containing the cross loading of item 27, significantly improves the fit. The RMSEA has dropped under .05, which is considered to be good but the CFI still is under .95, which indicates the model can improve some more. Modification indices suggest that a loading for item 24 should be added for 'consequences of technology'. However this seems not to have any kind of logical reason. Therefore we think it might be a better idea to drop the item. The internal consistence of the factor 'gender' would increase from α=.74 to α=.82 without item 24 for the second pilot group. This leads to a third model to analyse.

Model 3

Based on the first and second model but without item 24. Goodness of fit indices show now an acceptable CFI and RMSEA and also Akaike's Information Criteria is a lot lower than in model 2 , which indicates a better model. All fit indices taken into account we conclude this is the best model.

Conclusion

With our research we follow the opinion of Osborne, Simon, and Collins (2003), that a scale for attitude towards a subject actually consists of a number of subscales. And the best that can be done is to ensure that the sub-factors, which form the concept of attitude, are valid and reliable measures of the constructs they purport to measure and look for the significance of each of these aspects. We found six of these so-called sub-factors in the PATT questionnaire. All of these six sub-factors are highly in accordance with the original scales made by Bame, Dugger and de Vries (1988), although all of them contain less items. Five of the factors have at least an acceptable internal consistence (>.70) and only one of them, 'Difficulty' has a dubious internal consistence. Overall, the questionnaire seems to be useful as an instrument for measuring different aspects of attitudes towards technology.

Discussion

To future researchers who would like to work with the PATT-survey we suggest to randomize questions in order to avoid the bias due to the fact that questions on similar topics are influenced by each other when appearing together. Factors that are measured by less than four items can be improved by adding more items we dropped after our first pilot study.

It might be worth investigating if the variance explained by these factors is equal for sub-groups in the population like boys and girls, or whether the items are linguistic or gender dependent.

Future research could point out what the correlations are between the factors in the attitude questionnaire and aspects of technological literacy, or what the effect of education could be on attitude towards technology. This cohort could be followed through their educational career to investigate the evolution of attitude towards technology.

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Prevention activity, design activity: to the emergence of creative design in the prevention of risks

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Keys words: prevention of risks,
activity of design, teaching-learning process

Résumé

Depuis une quinzaine d'années a été introduit en France un Enseignement relatif à la Santé et à la Sécurité du Travail (ES&ST). Il s'agit de former des professionnels qui adoptent des conduites qui intègrent la prévention des risques dans leurs activités ordinaires. Ce qui suppose de penser la maîtrise des risques comme une composante de la qualification professionnelle. De nombreuses études ont montrées qu'il existe des écarts entre les savoirs mis en jeu par les professionnels dans leurs pratiques et ceux portés par l'institution scolaire. En situation professionnelle, l'opérateur doit s'adapter au contexte et prendre des décisions face à des situations nouvelles. L'élève doit alors évoluer entre une école qui ne transige pas avec la sécurité et celle de l'entreprise qui s'en accommode en fonction des situations rencontrées. Dans un contexte théorique d'ergonomie cognitive et d'analyse de l'activité de conception, nous envisagerons les activités de prévention des risques comme des activités de conception et nous proposerons une réflexion sur les caractéristiques des situations et des activités qui sont susceptibles d'être proposées par l'enseignant afin de favoriser la capacité d'adaptation en situation professionnelle des élèves.

Mots clés : prévention des risques, activité de conception, processus d'enseignement - apprentissage

For the last 15 years, Education relating to the health and safety of the work (ES&ST) has been introduced in France. It is to train professionals who adopt behaviours that integrate the prevention of risks in their ordinary activities. This presupposes to consider the control of risk as a component of the professional qualification. Numerous studies have shown that there are differences between the knowledge put at stake by professionals in their practices and those worn by the educational institution. In professional situations, the operator must adapt to the context and take decisions in new situations. The student must then evolve between a school that does not compromise with the safety and the safety of the company which accommodates according to the situations encountered. In a theoretical context of cognitive ergonomics and analysis of the activity of design, we will consider the activities for the prevention of risks as the activities of design and we will propose a reflection on the characteristics of the situations and activities which are likely to be proposed by the teacher in order to foster the capacity for adaptation in professional situation of students.

Introduction

The prevention of risks related to the practicing of a profession takes an increasing place in the strategies of definition of employment. This dynamics of integration of the conduits of prevention in the intimacy of the gestures represents a major stake of evolution of the practices of the professionals; it is a question of training professionals who adopt behaviours which integrate the prevention of risks in their ordinary activities. From the vision of the professional who observes rules to ensure his safety, it is necessary to substitute that of the professional who develops skills in order to control the risks, whatever is the professional situation met. This presupposes to consider the control of risks as a component of the professional qualification.

For a great part, this dynamics of integration and generalization of prevention of risky behaviours rests on the training of the future professionals, in particular within the framework of the education. Consequently, about fifteen years ago was introduced, a Teaching relating to the Health and the Occupational safety (ES&ST). This teaching, which does not constitute "a new" discipline, is built around a traditional triptych of formation in France and rests on the articulation between two places of formation: the school and the company. This organization which reflects a dichotomy relatively old between theory and practical rests on fields of different knowledge of reference (Cheneval-Armand, 2010). Thus, the analysis of the various levels of knowledge concerned in the founding texts, the programs and the practices of the professionals show that differences exist between the knowledge of the professionals in their practices and those carried by educational establishments. For the professional who confronts concrete, real and daily problems, safety must be thought in terms of compromise between the need for applying the regulation to ensure its own security and the obligation to carry out the interventions. At school, the report to the standard will settle in this confrontation. So the pupil will be subjected to this double injunction, that of the school which does not compromise with safety and that of the company which puts up with it. That brings about a shift between school activities which say how it would be necessary to do (and that explains it and largely justifies it) and the occupations in which it is necessary to do by preserving the productivity. It thus has there a tensioning between two worlds with the radically different purposes, put under tension which supports the adoption by the references pupils to the practices of the professionals, which considerably limits the claim to make the practices of prevention evolve in the direction of institutional waitings (Cheneval-Armand, 2010).

For all that, this variation, between the ideal model carried by the school and the pragmatic models of the professionals, can be close to the capital distinction presented by Ombredane & Faverge in 1955:

> *"Two perspectives are to be distinguished from the outset in the analysis of the work: what (what is to do), and how (how the considered workers do it ?)"* (J. Leplat, 2011).

According to De La Garza & Fadier (2004), the variations with the prescribed task (what there is to do) represent the top of human skills. Thanks to their intelligence, the operators play fast and free with the rules which they find expensive, unsuited or inapplicable with the need for the situation. This adaptive capacity based on the actors remains essential to regulate all the unusual situations (Amalberti, 2007) or when the objectives of safety and production are contradictory (Hollnagel, 2004). Consequently, it is advisable to wonder : how the school, in conjunction with the company, can develop the pupils' capacity to adapt to situations, this intelligence at work which is necessary to adapt to varied situations, even to new situations that the operator never met or when the objectives of safety and production are contradictory (Pastré, 2005).

Of a descriptive and understanding nature, the committed work will make it possible, initially, to analyse the activity of the pupils, the tutors in companies and the teachers in order to establish the feature of the didactic situations in the prevention of risks which will make it possible to develop the capacity of adaptation of the future professionals. In the long run, the led analyses will enable us to think of the innovating situations of teaching-training likely to be proposed by the teacher in order to support the pupils' capacity to adapt in professional situations. In this study, we will present the analysis of the activity in risk prevention as well as the methodology considered which is part of the theoretical framework.

Prevention activity – design activity

Herbert Simon in his work The Sciences of the Artificial, was the first who suggested to approach the design either as a professional status or as a particular type of cognitive activity. According to this author, the design is an activity aiming at imagining and at realizing in ver time of the things called "artefact", with which the finality is to satisfy the needs for the Man (Simon, 1969/1996). In this definition of the design, we find two key words: imagine and realize. The first one refers to a cognitive activity. The second one to a productive activity. This definition thus makes it possible to characterize the activity of design, on the one hand as a cognitive activity (internal) and on the other hand as a productive one (external). According to Visser,

> *"if we agree with this definition, design activities are not the monopoly of BE Engineers anymore. In that case, other operators are also encouraged to engage in activities which, in an analysis in cognitive ergonomics, fall within the design"* (Visser, 2002)

Thus, from a cognitive point of view, the design can be characterized by properties of the problem to solve, representations and processes of resolution implemented to solve it, and to finish developed solution (Falzon, et al., 1990; Visser, 2002).

So we will consider the activities of risk prevention like activities of design. For example, at the time of the phase of setting in safety on a task of maintenance of the refrigerating systems, the technician proceeds to the implementation of preventive measures which can be of organisational nature like the presence of a second technician, but so technical with the setting not under tension of the installation, the placement of protective equipment collective (life line) or individual (wearing of glove, use of insulating tools). Thus an important part of the activity of the operators in prevention in the same way that any activity of design consists in specifying the couple problem-solution. As of the moment that the operator/originator starts to build a representation of the initial specifications of problem and that he undertakes their analysis, he starts to specify a solution. Starts a process of design then. The professional reflects front, during and after the action and during its reflection, it mobilizes representations and knowledge of various sources. Thus, a technician who carries out a task of commissioning of an air-conditioning proceeds in successive phases:

i. Building planning phase: depending on the specifications, the technician assesses the workplace in order to organize the work that is to be done. Knowledge of the places and the equipment to be installed must allow him to evaluate the inherent risks in the place of work. This risk evaluation allows the operator to decide upon organizational procedures (personnel or machines to handle and carry equipment based on weight and bulk of heavy machinery, specifically adapted tools to carry out the work), collective protection measures (permission to turn off energy supply voltage anticipated for linkup) and individual protection procedures (gloves, earplugs).

ii. Implementing equipment phase: this phase has two stages: the first one allows for the preparation of supports destined to receive machinery parts and connection zones. The second is the fixing of the parts onto the supports as anticipated. Depending on risks and constraints, the technician decides how to assemble the parts in the building planning phase.

iii. Connecting parts and electrical circuits phase: depending on the planned voltage alteration (total, partial or none), the technician can move on to the connection without any risk, or taking them into account if there are any.

To implement methods and procedures, it has resorts to cognitive resources of the designs of thought, in other words designs of reasoning, interpretation, creation of assumptions, evaluation and decision (Vergnaud, 1995). These designs make it possible to identify the relevant knowledge, to differentiate them to face a singular situation. The professional returns then in a process of creative design. There is no single solution with a problem of design. The solution adopted finally is not either "correct", or "incorrect": it is an acceptable solution among others. The "final" specifications at which an originator arrives can be disputed, not because they would be incorrect, but because, following different criteria, another solution could be adopted, by the same originator or another (Bisseret, Figeac-Letang, & Falzon, 1988). Facing a security problem, two professionals will not inevitably choose the same solution or the same procedure (Duboscq & Clot, 2010) whereas at the school one often learns to the pupil a single procedure facing an identified problem. The actions can be reproduced as they are if, with the same interests, correspond similar situations, but are different or combined in a new way if the needs or the situations change. Thus the professionals must develop a capacity of adaptation and plunge themselves in a situation of creative design to quickly find a solution: the emergence of creative ideas.

From professional behaviours to the emergence of creative ideas

The occupation makes a professional meet a large number of known and unknown situations. Leplat (1985) qualifies these activities of execution, which involves mechanisms already made up at the subject, of "routines". Concurrently to that, when the subject is confronted with a non-routine and unusual occupation, it must "invent" a process of resolution by mobilizing knowledge and practices available. The designs of actions are, in an action, which is transposable, differentiable or can be generally applied to one situation or to a following one, in other words what is common to the various repetitions or applications of the same action (Piaget, 1973) and which makes it possible to bring about an adapted solution. The design is thus the structure of the action - mental or material -, the invariant which are preserved of a singular situation at another, and is invested, with more or less adjustments, in similar situations. It is what one can call "the operational form of knowledge", that which makes it possible to act as situation.

This development process led to the development of new knowledge or the implementation of new practices. This occupation becomes in its routine turn when the knowledge and the practices are controlled and that they make it possible to solve, without mediation, the current problems posed (Ginestie, 1995). This approach joined that which proposes Deforge (1995). Speaking about the production of objects, he says that when the process makes up of continuation operational well defined and that he is based on data delimiting the field of the solutions strictly, then there is no emotional investment on behalf of the men who are in the system of production and they are reduced (always theoretically) with the role of agent. On the other hand, when the data input are fuzzy and that there are no functional indications for the exit nor of formalized process at disposal, the man must invent, to fill spaces of uncertainties, the original processes at best of the data and the result required. One can thus consider that the direction of knowledge, for the expert, is related to the particular context including the problem, in the ecological conditions under which this knowledge will function. So the experiment in the broad sense falls under the development process i.e. the development of new knowledge. For Lubart et *al.*(2003), an "idea can be new for a person given but not the being for another according to its former experiments". In this direction, we can consider an idea as new when the subject is confronted with an occupation unusual and non-routine and that it must "invent" a process of resolution by mobilizing knowledge and practices available. Models contributing to explain the emergence of creative ideas were proposed. We can quote the case of model A-GC "Analogies et Gestion de Contraintes" (Bonnardel, 2000, 2006). According to this model, the dynamics of the creative activities of design is explained in particular by two cognitive processes being able to act in opposite directions: the realization of analogies and the management of constraints. The realization of analogies causes to open the space of search for ideas in order to arrive to solutions more or less creative and adapted to the professional situations met. The management of constraints makes it possible to direct the realization of analogies and to gradually circumscribe the space of research according to knowledge of the originator (designs of action). Thus within the framework of the training of the future professionals in risk prevention, it will be a question of having a reflection on the characteristics of the creative situations of design into didactic of vocational trainings, aiming at developing the capacity of adaptation through the emergence of the creative ideas.

Methodology

Our methodological approach will contribute to associate two methods which, used jointly, will make it possible to finely explore the activity of the pupils, the tutors of training course and the teachers in situation of creative design in risk prevention.

The field of experimentation concerned companies specialized in the installation and maintenance of heating, conditioning and refrigerating equipments. They therefore, and specially in small and average sized business, constitute a sector providing jobs for young people graduates and are regularly held training company for young people in initial education.

The experimental protocol to be implemented for data collection will consist into three phases:

- Choice and analysis of the task of creative design in risk prevention in the sector of installation and maintenance of conditioning and refrigerating equipments.
- Proposition of the same task to a pupil in a school context and to a pupil in a professional context. This stage will be subject to an audiovisual recording of the pupil's activity in both contexts.
- Semi-structured interview of the tutor, of the professional and of the pupil : all the interviews will be subject to a complete transcript of the verbalizations.

Our work will be based on an analysis of the activity by the analysis of the points of view (Wolf, Burkhardt & de la Garza, 2005). In this context, we will use jointly a discursive analysis and a data geometrical analysis (main component analysis) with reference to Burkhardt's studies concerning the analysis of the points of view of designers in production system. Thus, our methodological approach will contribute to explore the points of view of the actors. We will use discussions and verbalization analyses through specific methods allowing the reproducibility and the comparison of various corpora. This approach will enable us to finely analyze the speakers' speech and therefore, to give useable results by means of semi-structured interviews. For all those studies, the teachers' and students' speeches will be transcribed again verbatim.

All the entries of charge collected will be the object of an analysis of contents at the same time from a quantitative and qualitative point of view. From a quantitative point of view, the data collected will be the object of an exploratory analysis from "point of view" (Wolff, Burkhardt, & De La Gaza, 2005) using the software TROPES. From a more qualitative point of view and to come to enrich the quantitative analysis, the linguistic statements, considered as significant from the point of view of the activity of creative design to risk prevention, will be analyzed by the use of formalisms and systems of simple rewriting (Lebahar, 2007).

Conclusion

The analyses led in this study, will enable us to release the operational invariants, the inferences and the strategies, the rules of action and anticipations i.e. the organization of the control of each actor for a class of situation given. This level, the comparison of the levels of organization between the tutor and the teacher must offer an explanatory lighting to us on the characteristics of the didactic situations which will make it possible to develop the capacity of adaptation of the pupils necessary for the control of the risks and to develop suitable professional competences. In the long run, the led analyses will enable us to think of the innovating situations of teaching-training and in particular the formations organizing itself around the training by project.

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A Passion for Designing

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Abstract

"Passion is the energy that comes from bringing more of you into what you do" (Rosengren, 2004)

In the school based subject of design and technology (D&T) a fundamental element is designing and making functional products using critical and creative thinking whilst developing skills in the use of a variety of processes and materials. The links between creativity, intrinsic motivation and passion have been well researched (e.g. Amabile, 1997; Leonard and Swap, 1999; Polanyi 1966). Goleman et al (1992) speak of creativity and intrinsic motivation as the urge to do something for the sheer pleasure of doing it rather than for a prize, and refer to passion's importance in the mix as " ...the element that really cooks the creative stew is passion" (p.30).

Teachers of the subject need to be more then just 'enthusiastic' about the process if they are to develop enthusiasm in their pupils that will sustain them through the exciting but sometimes arduous and difficult process required to achieve outcomes of which they and their teachers can be proud. The polemic work of Polayni (1958) and that of the psychologist Frijda (2000), closely link joy with intellectual passion, supporting the assertion that positive passions affirm that something is precious and that passion can be used as a determinant of what is of higher interest and great.

The intention of this research project, using an initial sample of forty-nine students and a non-probability purposive sample of ten students studying to become D&T teachers was to tease out the factors which appear to enable some students to be passionate about creating a product to a given brief; described by Csikszentmihalyi (1990, p.4) as "the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it" whilst others from similar backgrounds and expectations, given the same brief, and in the same learning situation, do not reach this level of enthusiasm.

The data collection method used was an attitude scale and semi-structured interviews which were qualitatively analysed using HyperReasearch software in order to identify factors involved, with the intention of informing and improving the way we teach our students, to design, and about design, with the additional aim of improving their teaching of that activity once they become D&T teachers. Within the full paper results are discussed and tentative conclusions drawn.

Introduction

The intention of this research project concerning a design-and-make task carried out by students training to become design and technology (D&T) teachers was to try to identify some of the factors that enabled some students to be passionate about creating a product to a given brief whilst others from similar backgrounds and expectations, given the same brief, and in the same learning situation, do not reach this level of enthusiasm.

An initial cohort of forty-nine D&T students studying on an Initial Teacher Training (ITT) programme was identified for data collection purposes. After some preliminary data analysis a non-probability purposive sample of ten students was chosen from the original sample to complete an attitude scale and be interviewed about their design-and-make activity carried out during a thirteen-week Product Development module. Quantitative and qualitative analysis of the data collected allowed tentative conclusions to be drawn with the intention of informing and improving the way D&T ITT students could be taught, to design, and about designing, with the additional important aim of improving the students' teaching of that activity once they became D&T teachers.

Background

The primary purpose of designing is the development of quality outcomes in various forms. The reasons for the inclusion of designing and making within the school curriculum and therefore the reason for training teachers to teach design within D&T was originally the recognition that *'the capability to investigate, design, make and appraise is as important as the acquisition of knowledge'* (DfE, 1989. p.1) and the acknowledgement that D&T was an area of the curriculum which could develop such capability. Designing and making using critical and creative thinking whilst developing skills in the use of a variety of processes and materials are still considered fundamental aspects of D&T in schools today. Therefore it is important that those training to become teachers of D&T must understand (Atkinson, 2009; Miller, 2012) and preferably be passionate about the activities involved. Teachers of the subject need to be more than just 'enthusiastic' about the process if they are to develop enthusiasm in their pupils that will sustain them through the exciting but sometime arduous and difficult process required to achieve outcomes of which they and their teachers can be proud.

Passion is an emotion that can be externally observed, or a feeling that is internally observed. It is a biologically determined process that may be conscious or subconscious and one that can be induced by external events and circumstances. Although passion can have negative connotations, it is the positive power of passion that is the focus of this research. Much has been written about the links between the joy of discovery and intellectual passion (e.g. Fridjda, 2000; Polayni, 1958) and the importance of passion linked to *' ...stretching ones mind to its limits in a voluntary effort to accomplish something difficult and worthwhile'* (Csikszentmihalyi, 1991, p.3). The direct links between passion and creativity as the *'...intense drive to break through to something new'* (Belitz & Lundstrom, 1998, p.57), the belief that *'without passion we soon lose interest in a difficult task'* (Leonard & Swap, 1999, p.78) and the idea that *"passion is the energy that comes from bringing more of you into what you do"* (Rosengren, 2004) are all pertinent thoughts in understanding why the researchers believe that being passionate about designing is an important issue.

Many writers have identified internal and external factors that, to a greater or lesser extent, affect passion and enthusiasm in a learning situation. Much evidence (e.g. Amabile, 1997; Leonard and Swap, 1999; Polanyi, 1966) has supported the relationship that exists between passion, performance and the attributes that a learner brings with them. These variables can include: a learners' general ability, intrinsic motivation, personal goal orientation, creative ability, ways of thinking and working, knowledge base, past learning experiences and the attributes of the task itself: its contextual location, its structure, its likely demands upon the learner. Added to this, as many of the learners in this research project were mature students, were the multifaceted outside commitments such as families, mortgages and part-time jobs. To identify which factor caused, affected or prevented passion in a specific learner is a difficult task and one that would require a longer research project than the time available for this small scale study, however the researchers believed that an in-depth semi-structured interview with a selected sample of students might help them develop a better understanding of some of the factors involved and so enable them to improve their teaching of design activity in the future.

Method

The Sample

The size of the sample is problematic for the small-scale researcher with a conflict between validity and manageability. The researchers were all too aware that a sample needed to be as large as possible and yet in order that the study could be resourced, particularly in terms of time, once some initial data analysis was complete, a small non-probability purposive sample of ten students was selected for further data collection purposes from the original sample of forty-nine students who studied on a thirteen-week Product Development (PD) module during 2011. The researchers used three criteria in order to identify appropriate students for the sub-sample.

The Three Sampling Criteria:

1. Marks awarded: Only students who had been successful in terms of the mark they were awarded for their design-and-make activity in the PD Module were considered for the sub-sample. It was felt that by doing this the data would not be clouded with extra variables such as students who were not motivated in general or did not have the skills required to achieve high marks in the PD module.

2. The two D&T specialisms studied: The full cohort had students studying in each of the four subject areas associated with D&T. Those being: Materials Technology (MT), Textile Technology (TT), Food Technology (FT) and Electronic Communication Technology (ECT), with each student specializing in two areas and choosing a design brief which required both specialisms to be evident in their design activity and solution. The proportion of students studying each specialism in the sample of ten matched the proportion of students studying each specialism in the total sample.

3. Level of Passion shown: The final criterion used to identify the sub-sample was the level of passion that had been shown by the students during their PD module. As the two researchers had taught all the students in their subject studies modules throughout the academic year and in particular during the PD module they believed that they could categorize each student as belonging to one of the following three groups:

   Group A: Those who were extremely passionate about their project. This was evidenced in: the project itself; the processes that they had used; how they had dealt with the ups-and-downs associated with project work; how they had spoken about their activity throughout the module.

   Group B: Those who were competent designers and makers but lacked the type of evidence of passion shown by students in Group A.

   Group C: Those who had succeeded in terms of marks awarded but who lacked design flair and confidence in their project work and in the way that they were able to speak about their activity.

Each researcher in isolation carried out this categorization of the total sample. This was then followed by a comparison of the results that indicated a significantly high level of agreement.

Using the three criteria matrix the researchers discussed and agreed upon the final selection of ten students for the sample (see Table 1).

Group A (n = 12)		Group B (n = 12)		Group C (n = 25)	
Student	Specialism & Mark	Student	Specialism & Mark	Student	Specialism & Mark
Student Z	TT/MT 88%	Student W	ECT/MT 79%	Student S	TT/MT 70%
Student Y	MT/TT 80%	Student V	MT/FT 76%	Student R	MT/FT 68%
Student X	TT/FT 77%	Student U	FT/TT 74%	Student Q	FT/TT 62%
		Student T	MT/FT 72%		

Table 1: The matrix indicating the specialism and achievement of each member of the subsample split by Levels of Passion

The following materials and research instruments were used in the data analysis:

1. Marks awarded: The cross-moderated marks awarded for the PD Module were used for data analysis purposes and as one of the criteria for selecting the sub-sample.

2. Attitudinal Scale: The ten students completed an attitudinal scale to check whether the chosen students did represent the levels of passion to which they had been allocated. The design of the scale was based on research and experience of designing such scales in the past (Atkinson, 1997; 2000, 2003; 2007). The scale used twenty-six statements about how positive they believed they were in various life-situations and during the product development module. A two-dimensional grid classification was designed for student replies. This was based on the Likert system (Likert, 1932). The students were asked to tick one of four boxes which indicated how much they agreed or disagreed with the statements. The scale was given to the student immediately before they were interviewed and took approximately four minutes to complete.

3. Interview data: A semi-structured interview was then carried out with members of the sample separately in order to tease out further the attitudes of the students to designing and making their solution in the PD Module, the processes they had used, what had caused them to become interested, frustrated or disillusioned, what type of thinking they had used, the problems and constraints they had encountered, whether they had coped or thrived, and whether they had found the activity rewarding. An interview schedule of the questions to be asked and the order for delivery was designed, discussed and modified by the two researchers in order that the same understanding of the questions was established. This enabled consistency to be achieved even though the two researchers carried out the interviews separately. The interviews were recorded and then transcribed using voice recognition software (Dragon Dictate). HyperRESEARCH software was then used for qualitative analysis purposes.

The students were not informed about the exact nature of the scale or the interview before hand. They were told that the researchers were interested in hearing how they had each approached the PD module, which they had completed at the end of the previous academic year.

Results from the whole cohort of 49 students

The relationship between achievement and level of passion

Level of Passion	Mean marks
Group A	74.42%
Group B	65.09%
Group C	56.04%

Table 2: The relationship between Level of Passion and achievement for the total sample (n=49)

The results in Table 2 indicate a positive relationship between levels of passion and levels of achievement in the total sample.

Results for the sub-sample of ten students

The relationship between achievement and level of passion

Level of Passion	Mean marks
Group A	81.67%
Group B	75.25%
Group C	66.67%

Table 3: The relationship between achievement and Levels of Passion of the sub-sample *(n=10)*

As explained earlier as well as the level of passion one of the other criteria that the researchers used to select the sub-sample was that they had been successful in their projects. However as can be seen from Table 3 there still remained a positive relationship between levels of passion and levels of achievement. Supporting the belief of the researchers and others (Belitz & Lundstrom, 1998; Csikszentmihalyi, 1991; Leonard & Swap, 1999) that passion is an important factor in successful creative activity *" ...the element that really cooks the creative stew is passion"* (Goleman et al, 1992. p.30).

Results from the Attitude Scale

The attitude scale was pre-coded by the researchers. A sliding scale of score corresponding to a student's level of agreement or disagreement with each statement was recorded. The highest score was given to students who indicated strong agreement with the statement, whilst the lowest score was given to students who strongly disagreed with the statement. This enabled calculations of the mean score for each statement, each student and therefore each 'level of passion' group.

The results from the attitude scale confirmed the researchers' allocation of each student in the sub-sample to a specific 'level of passion' group. Group A, those passionate about their project achieved the highest mean score for attitude and those who lacked design flair and confidence in their project work gained the lowest mean score for attitude (see Table 4).

Level of Passion	Mean Attitude Score (max score 4; min score 1)
Group A	3.154
Group B	3.105
Group C	2.679

Table 4: The relationship between Levels of Passion and mean attitude scores of the sub-sample *(n = 10)*

In twenty-four out of the twenty-six statements the mean scores for each of the three groups indicated that Group A achieved higher mean scores than Group C. The two statements in which the least passionate students achieved the highest rather than lowest mean score were 'I have drive in most of the things I do' and "I find it easy to be purposeful'. This would support the researchers' belief that the chosen sample in group C were indeed motivated to succeed in general and that even though they lacked 'passion' and designerly flair they were able to persevere and achieve outcomes that more than adequately met the assessment criteria for the module.

It was also interesting to note that Group B, those who were competent designers and makers but lacked evidence of passion, had higher mean scores than the students who designed with passion in reply to a number of the statements. However once again these concerned general motivation rather than being design specific. For example: being happy and not pessimistic, being stubborn and persistent. Group B also achieved the highest mean score for the statement regarding not feeling the need to seek approval before making decisions. However the researchers would not necessarily see this as a positive attribute. For they believed that a willingness to share incomplete or untested thoughts and ideas with others indicated a certain level of design confidence, which was evidenced in the work and attitude of those considered passionate about designing. Group A the 'passionate group' achieved the highest mean attitude scores for the following statements: being optimistic, non-conformist, single minded, intuitive when dealing with new situations, happy to set their own standards and values, enjoying most challenges, persevering against all odds when confronted with problems, displaying creative spontaneity and being proud of their outcome in the PD Module.

Results from the interviews with the ten students

The only aspect that all students spoke of at some time during the interviews concerned finding the activity rewarding, whilst ninety percent indicated that they had shown passion in their final outcome, and that they had developed new practical skills during the module. Eighty percent did refer to having been hindered by a lack of time to complete the project, although within that cohort it was the 'least passionate' group who mainly mentioned problems associated with a lack of time, with one student mentioning it on six separate occasions, in comparison to the others who mentioned it only once or twice. A surprising result was that eighty percent of the sample spoke of being frustrated with designing, however when looking at what they were frustrated with it became apparent that 'passionate' students were frustrated by the process they were required to follow to meet the assessment criteria (producing such things as evidence of developing a specification and written explanations of their thinking) whereas the least passionate group were frustrated with their lack of knowledge and understanding of the processes required.

All those in the 'passionate' group and those who were competent but lacked evidence of passion, spoke about the fact that creative thinking was important; and that they had been interested from early on in the design process. They also believed that 'passion' as well as being found in their final product could be found in their design folios, whereas only one student in the least passionate group referred to these factors although she indicated that she was not entirely convinced about finding passion in her folio.

Three quarters of each group believed that the given outline briefs were interesting and enjoyable whereas it was only the 'passionate group' who then went on to make reference to the briefs enabling them to be creative and being able to achieve a unique outcome, which they thought was important. Seventy percent of the total sample suggested that their outcome must be practical and feasible. None of the least passionate group referred to the importance of the aesthetic form, in sharp contrast to all members of the passionate group who spoke at length about the importance of a balance between functionality and form.

Everyone in the passionate group used the words 'excited by' in describing their projects whereas only three students from Group B used those words and none of the 'least passionate' group used 'excited' at any time during their interview. The whole of the 'passionate' group indicated that they believed imaginative thought needed to come before rational thought and that there was a need for perseverance when things didn't go right. They also all indicated that they had used a designer's method rather than a scientific method to come up with their solutions. They all believed that as well as passion being evident in their design folios; and in the product itself it could also be found in the manner in which they had spoken about their product and design activity throughout the project. All the students in this group were also proud of their product outcomes, one because she felt she had really portrayed Russian culture and the history of Russia in the cloak she had designed and made. She was especially proud, as Textile Technology was a new specialism for her. The other two talked about how their products were now being used. One student having designed a very unusual seat that was *'...loved and used'* by his whole family, and the other talked about being proud to use, within a school environment, the puppet theatre and puppets she had designed to teach about inclusivity.

In line with the students who were considered passionate, all those in Group B talked about the following: that they had been interested from the design stage; that they had developed new practical skills; that they thought creative thinking was important, and that they had provided evidence of passion in their design folios, however this group did not talk about 'passion' being found anywhere else. In support of the researchers belief that this group were as successful as they were because they had a good attitude to life in general, all spoke of being determined that all problems must be solved, rather than being negative and complaining about things that did not go according to plan as was evident in the interviews with the least passionate students.

The two positive points raised by everyone in the least passionate group were that they believed that the activity was rewarding and that they showed passion in their product outcome. The six negative issues that all of this group raised were that they recognized that they did not think outside the box, that they were frustrated and disillusioned by designing and all indicated that they needed support and direction before they could make decisions. In terms of their ideas all believed that the outcome must be practical and feasible, that they were hindered by a lack of knowledge about designing to support their idea generation and in particular a lack of manufacturing skills and know-how at the design stage. This was in marked contrast to the 'passionate group' who talked about the fact that being unsure about materials and processes did not worry them and that it was only once they had an idea they wished to use that they would then turn to ask experts to help them to understand how their ideas could be turned into reality if it was a process or materials that they had not used before.

In both the 'passionate' and 'competent but lacking evidence of passion' groups, students talked about enjoying the challenge however no one in the least passionate group mentioned enjoying the challenge. In fact two out of the three in the least passionate group complained on several occasions about how hard their project had been.

Conclusion

The research tools used were appropriate and gave the anticipated exploratory and explanatory information. The size of the total sample was large enough for basic descriptive analysis to take place. The sub-sample of ten students was, as anticipated, too small for any statistical analysis, although information gained provided an informed picture of the relationship that exists between 'level of passion' and design activity in the cases examined.

Factors identified so far would indicate that passionate designers use language that is full of positives, they are on the whole happy within themselves and relish challenging, unknown situations. Whereas students who are not passionate about their design activity tended to have a 'glass-half empty' and a 'can't do' attitude towards their activity that places a barrier, a resistance, preventing them from overcoming their fear of a lack of understanding of the processes involved.

Further studies in this area would seek to explore in greater depth the causal relationships that have begun to be teased out in this small-scale study. The importance of informing and improving the way D&T ITT students are taught, to design and about designing cannot be over-emphasized. Nor should the association between a students' own design activity and their success as teachers of design within D&T in the future be ignored.

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To what Extent does the Pedagogy adopted by Trainee Teachers affect Children's Creativity in Primary Design and Technology Activities?

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Key Words: Primary Education, Initial Teacher Education, Creativity, Pedagogy, Creativity Inhibitors

End of module evaluations from Primary Education trainee teachers in an English university indicate that many trainees lack confidence in supervising practical activities within the classroom. This initial study is part of a larger piece of action research exploring the effects of trainee teachers' interventions and teaching strategies on children's creativity.

This paper presents some initial findings from a small scale study undertaken in June 2011 with students from a first year of a Primary Education undergraduate course based in an English university. The findings from this initial study originated from a design challenge day, when the trainees were asked to work with 60 eleven years old pupils and act as mentors to small groups of pupils. The pupils were asked to adopt a design process inspired by design engineers at Dyson and designed and made design prototypes for a new product using air. The data collection methods used were questionnaires with trainees, photographs of pupil outcomes, observations during the day and trainees' reflective diaries.

The evidence suggests that the trainees encountered a number of creativity inhibitors during the day (Fasciato and Rogers 2005) and these were centred on supporting dynamics of pupil groups, risk taking and collaborative interaction.

Context

This paper reports on an initial study exploring the pedagogical influences upon children's creativity in primary design and technology with a specific emphasis on the influences of trainee teachers' actions. As a lecturer working with Primary Education trainee teachers in an English University, I have often observed trainees relying on formulaic procedures and resources when teaching or planning to teach design and technology.

The Bachelor of Arts (BA) Honours Primary Education with Qualified Teacher status (QTS) is a three year undergraduate route which has a number of elective modules throughout the three years. End of module evaluations indicate that many trainees lack confidence in supervising practical activities within the classroom and from discussions with trainees it is clear that some do not link theory and university based learning to practice within schools. So the elective module for design and technology (D&T) in year 1 of the course was designed to include a school based experience for the trainees.

The trainees were asked to work with a group of sixty eleven year old pupils in a local primary school during a design challenge day. The pupils were asked to work in teams to design and make a product. The trainees were asked to work as mentors to develop their understanding of pupil led activities and gain insight into pupils' creativity during pupil initiated designing and making. When marking assignments, I find that trainees, when asked to teach D&T often make project booklets for pupils to work in and I hoped to demonstrate that valid D&T experiences do not have be based on using formulaic booklets. From discussions with primary education trainees, it is evident that some do struggle with supporting creativity, citing classroom management issues being one of the most common issues. The aim of the study was to explore two research questions.

1. What effect did the trainees' interventions have on pupils' creativity?
2. What difficulties did the trainees encounter when supporting pupil initiated activities?

The design development day took place during June 2011 at the end of a week-long module with nine first year undergraduate trainees who had chosen to study the elective D&T module. During the first year of their degree they had all also experienced an initial module in D&T with four sessions of two and a half hours. The trainees were asked to work with an unknown group of sixty eleven year old pupils of mixed gender and ability. They were supported by two university staff and three teachers from the primary school. The environment in which they worked was a school hall, three classrooms and a corridor with a range of resources and equipment. The pupils were asked to investigate a range of vacuum cleaners and then design a new product that utilised air and to work in a way that mirrored the design process used by design engineers from the James Dyson Foundation.

Literature Review

The document All Our Futures (1999:6) offers a definition of creativity as 'a balance between teaching knowledge and skills, and encouraging innovation' and 'imaginative activity fashioned so as to produce outcomes that are both original and of value' (NACCCE, 1999:29). However Benson and Lunt's (2011) study outlines four essential factors for creativity: ownership and control; relevance; space and time and interaction with others.

Benson and Lunt (2011) outline the need for children to take ownership in order for successful outcomes and outline the importance of peer to peer and peer to adult interactions and their role in supporting creativity. They also cite Jeffrey and Woods (2003) who suggest that a 'hands on' style of learning is vital in making learning significant and which in turn provides ownership; both vital ingredients for creativity. These findings are backed up other researchers Hamilton (2007:27) who argues that 'collaborative interaction and imaginative engagement' together with 'greater independence and risk taking' empower both pupils and teachers. McLellan and Nicholl (2008) found that a lack of freedom or pupils' perception of a lack of freedom also undermines creativity. Kruger (1993) also suggests that pupils working collaboratively make more progress. Twyford and Burden (1997:1) contend that understanding of the learning process is developed through 'considering the dynamic interaction between learners, teachers, tasks and contexts.' This view is supported by Trebell (2007) who drawing on Vygotsky's work considers that designing relies on social interaction.

Research suggests that other factors may be influencing creativity. The use of formulaic pupil booklets frequently used by trainee primary teachers do not support creativity in pupils (Haffenden 2004; Nicholl and McLellan 2007; Trebell 2007). Musta'amal et al (2009) suggest that modelling is also a key process within creativity and that it can support a number of creative behaviours which include risk taking, decision making, change, exploration of possibilities, openness to new ideas, understanding of a problem and reflection. Fasciato and Rogers (2005:29) state that 'creativity inhibitors appear to be as much of a problem for teachers teaching, as for children learning' and these 'inhibitors' prevent creative teaching and learning. Their study found that a number of factors restricted creativity and these included restriction of choice and time, over controlled tasks and a lack of experimental and risk taking. This is backed up by Nicholl and McLellan whose research (2007) argues that teachers and teaching strategies are crucial in the support of creativity and unsupported pupils will find it hard to be creative. However if classroom practice and teachers are influential in supporting creativity, as researchers (Fasciato and Rogers 2005; Nicholl and McLellan 2007) suggest, it could be argued that trainee teachers encounter real problems in supporting creativity within their classrooms.

Nicholls and McLellan (2007) offer the view that pupils need to be inspired at the start of design and making activities to avoid the pitfalls of becoming fixate. Karen (1979) cited in Davies (1996:1) discusses the need to support 'original and expansive thinking' and states that pupils can be asked to be too practical too soon, claiming that it is too difficult for pupils to be original and thinking about practical issues of construction. Davies (1996) puts forward the view that pupils need prior experience of materials and techniques for creativity through modelling to develop creativity. Therefore by using a design challenge day where the pupils would design and make design prototypes as modelled by Dyson's engineers, it was hoped that this would be more supportive of pupils' freedoms (Benson and Lunt, 2011; Fasciato and Rogers, 2005; Hamilton, 2007; Trebell 2007). Mettas and Constantinou (2006) also state that a technology fair is a useful strategy for Initial Teacher Education establishments to use with trainees to promote pedagogy and can contribute to the development of positive values and attitudes.

Methodology

The data was collected from trainees' diaries, photographs of pupils' outcomes and observations during the day. The questionnaires were completed anonymously and were used to collect qualitative data from the trainees using open and closed questions and focused upon their perceptions of the creativity inhibitors and how they perceived these impacted on pupils' outcomes. It would have been useful to further triangulate these results with interviews and to have collected data from the pupils but this was not possible in this study. Ethical issues were major considerations due to the involvement of a teacher as a researcher as it could be argued that the trainees focused upon in this study could feel under pressure to take part (Bell, 1987). The trainees undertaking the elective module were invited to part and it was made clear that they were under no pressure to take part in the study and that all data would be confidential and that they could withdraw at any point during the study. One trainee chose not to take part. All pupil identities were concealed.

Findings

The trainees' written evaluations of the day reveal that they perceived difficulties with establishing relationships with the pupils. This slow development of the pupil teacher relationship acted as a creativity inhibitor (Fasciato and Rogers 2005) and links to Twyford and Burden's research about the dynamic interaction needed (1997). In trying to establish the social interaction the trainees adopted a number of strategies to initiate the product analysis as the first activity of the day (Trebell 2007; Benson and Lunt 2011) (Figure1). Sixty four per cent of the trainees perceived that the pupils were shy or nervous at the start of the design challenge day, although this was contradicted by a member of staff who told one trainee that the pupils were being polite not shy.

Strategies used by trainees to initiate social interaction.	Strategies used by trainees who struggled to initiate social interaction.
Minimal initial prompts but allowed pupils to take charge·	Pupils were asked to sit in a circle and invited to respond one at a time.
Asked pupils to work as one group and did not let pupils split into sub groups·	Very structured questioning
Had positive 'can do' attitude to pupils' abilities, i.e. problem solving and being logical.	Allowed pupils to work in gender groups or subgroups.
Immediately proactive and asked pupils to get involved with investigating the vacuum cleaners promptly.	
Allowed pupil conversations to develop and did not intervene or dominate.	
Only intervened when the pupils were stuck.	

Figure 1: Trainees' strategies used to initiate social interaction.

Problems with managing the social interaction continued into the second stage of the day when pupils were are asked to identify a user and purpose for a new product using air. When asked how successful the pupils were in this, the questionnaires identify a definite split between the trainees' answers. Forty six percent of trainees who thought that the product analysis was more teacher led rather than child led; their teams of pupils only identified 3 to 4 potential users and purposes. Whereas forty six percent of trainees who thought that the first session were child led, their teams could identify at least 7 to 10 and 10 plus potential users and purposes. The creativity inhibitor here appeared to be a lack of ownership and control for pupils (Benson and Lunt 2011; Hamilton 2007; Fasciato and Rogers 2005) and restriction of social interaction between peers (Benson and Lunt 2011; Hamilton 2007; Kruger 1993; Trebell 2007). Eighteen percent of these trainees also identified that they led brainstorming sessions and provided design ideas. The rest of the trainees identified that they only provided procedural support in making techniques and modelling ways forward when the pupils got stuck (Musta'amal et al 2009).

Trainees' diaries and observations during the day reveal that again there were clear differences in the strategies used by trainees who perceived difficulties in managing pupils' decision making and those trainees who perceived they struggled (Figure 2).

Strategies adopted by trainees who perceived they were successful in managing decision making.	Strategies adopted by trainees who perceived they were not successful in managing decision making.
Used initial prompts but insistence on the pupils making the decisions throughout the day.	Pupils were allowed to work in subgroups, often based on gender, which later resulted in conflict.
Restricted choices in order to make it easier for pupils·	Controlled decision making very tightly and as a result the pupils relied on the trainee to support the decision making.
Pupils were allowed to choose where they worked and supported to move around. This allowed pupils to observe and copy other groups' strategies.	Asked pupils to vote but struggled to manage the continuing conflicts.
Happy to adapt activity and allowed pupils to make more than one product to present at the final presentation.	Restricted pupil to pupil interactions and imposed more adult to pupil interactions.
Pupils were each asked to produce a design then asked to vote for the best idea.	Asked pupils to work in one area chosen by the trainee and so were prevented from observing other groups' progress.
Pupils were each asked to produce a initial design, then asked the group to combine all the best features into one product for the final design.	Allowed the group to split into two and ran parallel design and make activities, but could not manage the disappointment of pupils whose design was not chosen.

Figure 2: Trainees' strategies adopted to manage pupils' decision making

There were a number of creativity inhibitors that affected trainees who perceived they were not able to manage pupils' decision making within the pupil groups during the selection of the user and purpose of the new product and the choice of the group's final design. These were an inability to manage the group dynamics due to conflicts; restriction of choice for pupils and a restriction of freedom (Benson and Lunt 2011; Fasciato and Rogers 2005; Hamilton 2007; Kruger 1993).

The trainees were invited to grade their response to the statement 'I was surprised by the way in which the pupils worked'. Two trainees were undecided and one noted that 'the children I worked with did not really work together well; they struggled to come up with ideas.' Another noted that the pupils were 'well behaved, polite, listened to each other's views but the team separated into 4 teams for the task.' Observing one pair of trainees work with the pupils, I noticed that they were unable to master the strategies for supporting independent work as they appeared to be incapable of letting the pupils work independently, thus making these trainees the creativity inhibitors.

Twenty five per cent of trainees who struggled to initiate the product analysis found that the pupils continued to express ideas, investigated the vacuum cleaners on a superficial level and relied on a high degree of prompting from the trainee. Eighteen per cent of the trainees tightly controlled the structure of the day and perceived that their group of pupils struggled with creativity. When investigating potential users and purposes, these pupils could only think of three or four users and purposes for the new product. During the design stage these pupils also produced a limited amount of design ideas and these were generally variations of one idea, (Figure 3).

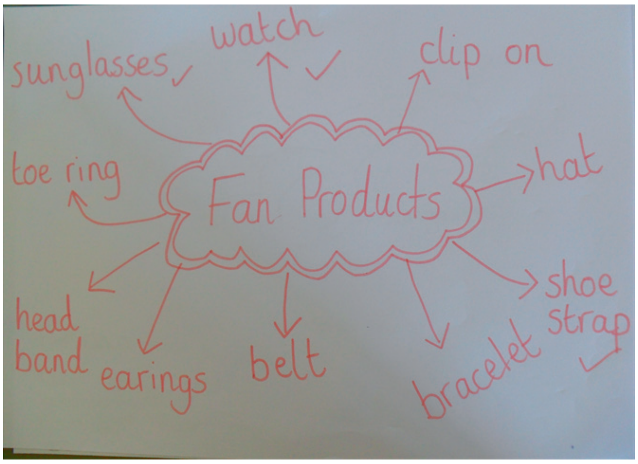

Figure 3: Pupils' ideas from tightly structured activities.

In contrast thirty one per cent of trainees who were prepared to take a risk produced a greater and more diverse range of ideas for potential users and purposes. (Figure 4) This demonstrates a need to work with trainees to find ways to support them to be able to take risks (Fasciato and Rogers, 2005; Musta'amal et al 2009).

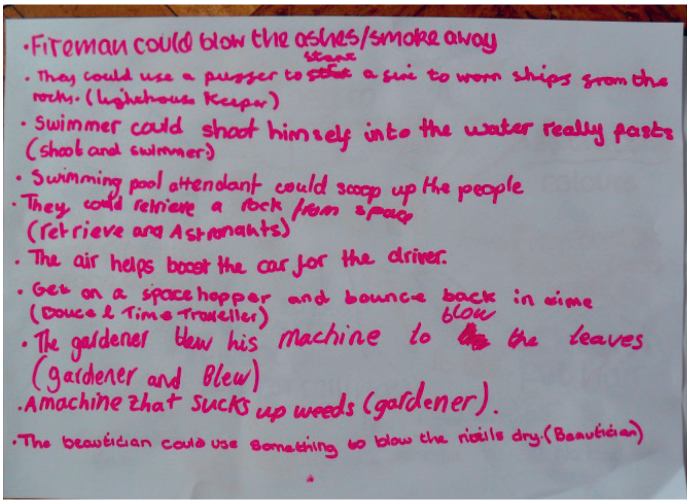

Figure 4: Ideas from pupils who were allowed more freedom.

Trainees who allowed pupils to work in sub groups, often based on gender, then struggled to support the development of initial ideas and as one trainee noted, critical thinking. One trainee expressed the view that it was more important for pupils to be happy than follow the brief for the day again exposing a reluctance to engage with taking risks and losing sight of the need for 'collaborative interaction and imaginative engagement' (Hamilton 2007:27).

However the trainees who managed to support more creativity in the pupils' outcomes used a variety of strategies which included:-

- Restriction of choice at moments of pupil indecision;
- The ability to support pupils' decision making;
- Take risks and let pupils self-direct activities;
- Minimal interventions ;
- Judgement of when to intervene;
- Encouragement of pupils to think or use resources in different ways

It could be argued that success occurred when pupils and trainees were empowered by 'collaborative interaction and imaginative engagement' (Hamilton 2007:27)

One trainee noted that-

> "Allowing the children to control the design process was also beneficial. When I and my partner tried to control the situation, the children's ideas didn't come very easily, but as soon as they were allowed to control the situation and take charge, the design process flourished. Also working in groups was valuable as children saw more ideas and combined them to make a more complex idea."

This statement illustrates how this trainee has used the design challenge to realise that pupil led design and technology activities can support social interaction (Trebell 2007) and thus pupils' independence (Hamilton 2007).

Another trainee realised that risk taking (Musta'amal et al 2009; Fasciato and Rogers 2005) and experimentation were crucial (Fasciato and Rogers 2005) and noted that-

> "I found it difficult to allow the children to experiment with all the materials because I am so used to suggesting ideas. Yet I recognised that this was an opportunity for the children to be inventors and to use investigation to decide the best way to make their prototype. In order to solve this, I took a step back and observed the way in which the

children worked. I was pleasantly surprised to see them trying out new methods of using the unfamiliar materials. Therefore I felt comfortable in a children led afternoon as I trusted the children to work independently. This is an experience that will stay with me for the rest of my teaching career, as I realise that allowing the children to indulge in their natural curiosity can produce innovative and thoughtfully made products."

Conclusion

Using Benson and Lunt's (2011) four creativity factors to examine the pedagogical strategies used by the trainees during the design day, it is apparent that there were some specific areas of difficulty for the trainees. It could be argued that the pupils were provided with an opportunity to be creative through challenging opportunities with self-directed activities and as McLellan and Nicholl (2008) state, this should support creativity. However the trainees perceived a number of creativity inhibitors when supporting pupils and struggled to manage the ownership and control (Benson and Lunt, 2011) and struggled with supporting creativity. Most trainees recognised that more a risk taking approach was needed during the day but a minority of trainees struggled with this approach and reverted to restricting pupil's independence throughout the day and this appeared to have a direct and negative influence on the pupils' creativity. Twyford and Burden (1997:1) discuss 'the dynamic interaction' needed and pupils who were allowed more interaction with each other produced more original work with a greater variety. Pupils who were restricted to peer to adult interactions had less creative outcomes than pupils who were allowed to use peer to peer interaction for the majority of the challenge.

Researchers (Benson and Lunt, 2011; Fasciato and Rogers, 2005; McLellan & Nicholl, 2008; Trebell, 2007) point out the importance of the teachers' influence on creativity. The trainees appeared to encounter a range of classroom management problems during the challenge day and these generally centred on supporting the interaction with others and providing ownership and control (Benson and Lunt, 2011). When supported, collaborative interaction between peers and greater independence empowered pupils and some trainees and in turn provided opportunities for experimentation and risk taking.

One of the main creativity inhibitors in supporting pupils' creativity for trainees appeared to be the support of decision making within the pupil groups during the selection of the final design and managing the group dynamics. Successful strategies used by some trainees included an insistence on pupils initiated design decisions and providing strategies for the selection of a final design and adaptation of the design brief. The few trainees, who really struggled with decision making, resorted to a reliance on strong control and adult dominated activities. This echoes problems identified by Fasciato and Rogers (2005) and Benson and Lunt (2011) and is not the collaborative interaction as described by Hamilton (2007). 'Musta'amal et al (2009) point out that this is a key process within creativity but for a minority of trainees, this appeared to be too daunting.

The environment of the design challenge day produced its own tensions as one of the main creativity inhibitors for trainees was the initiation of the work with pupils. The use of a design challenge day arose from the idea of a technology fair (Mettas and Constantinou, 2006) and while it created its own tensions, it provided a rare opportunity for Primary Education trainees to focus on pupil initiated design and technology activities and provided trainees an opportunity to review and change their own practice (McLellan and Nicholl 2008).

Davies (1996) also puts forward that pupils need prior experience of materials and techniques for creativity through modelling to develop. During the day the pupils were not taught specific skills however some trainees perceived that experimentation with a range of materials combined with curiosity produced imaginative results. Using the NACCCE definition of creativity as 'imaginative activity fashioned so as to produce outcomes that are both original and of value' (NACCCE, 1999:29) the pupils outcomes were at their best imaginative, original and directed at a specific user and purpose. There was a direct relationship between the trainees' pedagogy and the levels of creativity in the pupils' outcomes.

At the start of this study, I wanted to know what effect the trainees' interventions had on pupils' creativity and what difficulties did the trainees encounter when supporting pupil initiated activities. This was a small scale study but it is clear that the trainees in this study had some specific difficulties and so to further investigate trainees' problems with the support of pupils' creativity, this study forms the first part of a piece of on-going action research which aims to provide trainees with a tool kit of pedagogical strategies to overcome creativity inhibitors.

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Engaging design & technology trainee teachers with the nature of technology – a case study

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Key Words Technology Education,
Nature of Technology, Initial Teacher Education

Abstract

The paper describes a small case study in which pre-service design & technology teachers on a one year post graduate teacher training course in London, England were introduced to the idea of teaching pupils in schools about the nature of technology and the relationship between technology and society by means of a one day workshop. Observation of the workshop and the learning outcomes indicated that the trainee teachers were engaged and showed willingness to carry outn such teaching as part of a school design & technology curriculum. The discussion considers the trainees' responses, the significance of such activity in initial teacher education in the light of current revisions to the National Curriculum in England and how such considerations of the nature of technology in initial teacher education might be developed through collaboration amongst those interested.

Introduction

In 1999 the PATT proceedings carried a paper that used two small case studies describing the use of a framework for conceptualizing teacher professional knowledge (Banks & Barlex 1999). The authors argued from the case study data that the approach had considerable potential for enabling those about to enter the teaching profession to reflect on their professional knowledge. Others in the teacher education community then engaged with the conceptual framework and carried out similar case studies leading to a collaborative publication involving case studies from England, Finland and New Zealand (Banks et al 2004). This work became known as the DEPTH (Developing Professional Thinking for Technology Teachers) project. Four years later the International Journal of Technology and Design Education devoted an entire issue to studies involving the DEPTH project in five different countries (Banks 2008). This illustrates the potential for small case studies to provide a starting point for significant developments. The case study presented here builds on the previous work by the author (Barlex 2011) in which he explored teaching young people about the nature of technology. In considering ways forward the paper suggested that it would a useful exercise to discuss the nature of technology with those about to enter the profession so that they can develop their own understanding and consider ways in which pupils can be engaged in this. It is hoped that this case study will provide a stimulus for others in initial teacher education interested in the area to undertake similar work in a collaborative vein in much the same way as happened in response to the initial DEPTH case studies.

The case study describes a one-day workshop session for 18 post graduate trainee design & technology teachers in the first term of their one year course at a university in the south west London. It will be presented in three main parts.

Part 1 will describe the introduction to the workshop and the tasks set to the trainees.
Part 2 will describe the trainees' responses to the tasks and their views on teaching about the nature of technology in secondary school
Part 3 will discuss the following:
The trainees' choice of technologies to explore
The need for trainee design & technology teachers in England to engage with the nature of technology
The possibility of developing an approach to engaging those about to become technology teachers with the nature of technology that can be used by educational researchers in different countries
Finally there is a short conclusion

The introduction to the workshop

At the beginning of the workshop the trainees were introduced to a rationale for including the nature of technology into the school design & technology curriculum. This rational was based on an analogy with recent developments in the school science curriculum in which pupils are taught about the nature of science sometimes referred to as 'how science works' (Millar, R. and Osborne, J. 1998 and Nuffield Foundation 2011). The trainees were then introduced to some of the ideas of the following writers concerning the nature of technology and its impacts on society.

Brian Arthur – viewing technology as the exploitation of scientific phenomena
Kevin Kelly – considering technology to be autonomous with pre-ordained development, influenced by its own history and mediated to some extent by society's collective free will
David Nye – rejecting technological determinism but supporting technological momentum
Brian Christian – asking what does it mean to be human in the light of developing artificial intelligence
Susan Greenfield – giving a a dystopian view in which virtual lives become more significant than real lives, there is access to unlimited information and stimulation, a breakdown of traditional family structure, and complete separation of sex from reproduction
Keri Facer – acknowledging some of Greenfield's fears but arguing that these can be countered if schools act as places where communities conceive and build their own future

The trainees were then introduced to two different classroom activities that could be used to engage pupils with the nature of technology, how it works and possible impacts. The first is derived from the Young Foresight project and requires pupils to consider a technological product from four perspectives: the technology itself, how it works; the society in which the product might be used and the extent to which it is acceptable, the people who might use the product and the extent to which the product meets needs or wants; and the market through which the product is made available (Barlex 2003). The second is a winners and losers identification tool developed by the Nuffield Design & Technology project which enables pupils to identify who might be directly and indirectly affected by a technological product and classify these as either winners (the technology is to their advantage) or losers (the technology is to their disadvantage) (Nuffield Design & Technology 2000).

To prefigure the task in which the trainees would be asked to consider a technology of their choice they were presented with four possible strategies for choosing:

- Take a 'use of technology' e.g. enable mobility, provide shelter, ensure safety and identify technologies used for this purpose
- Take a problem caused by technology e.g. climate change, resource depletion, information availability and reliability and identify technologies for possible solutions
- Consider new and emerging technologies and identify combinations that provoke interest e.g. a combination of nanotechnology and robots
- Choose an everyday activity e.g. making a cup of tea, and identify all the technologies and interconnections that enable the activity to be carried out.

The trainees were then presented with a set of 'crunch' questions to underpin their thinking throughout the rest of the workshop

- Is technology autonomous and beyond our control or is technology under human control?
- Does technology control us or do we control technology?
- Is technology value neutral or does it have implicit values?
- Does the availability of technology change human behaviour?
- Who decides which technologies are developed?
- Who decides which technologies are adopted?

They were then asked to work in groups to tackle the following tasks

- Identify a technology (ies) that you think young people might find intriguing and/or need to understand
- Explain how it works and what it is used for
- If appropriate indicate something of its history
- Use the classroom activities to critique the technology (ies)
- Develop a presentation (no more than 5 minutes in length) that presents your findings and considers the costs and benefits to society of using the technology (ies)

To give some indication of the standard of presentation expected the trainees were shown the TED talk by Sunni Brown about doodling (Brown, S. 2011). Sunni Brown is an expert in the use of visual thinking to support organizational and group success (Brown, Gray & Macanufo 2010).

Trainees' presentations and views on teaching

The Trainees divided themselves into five groups. The first group considered the place of avatars in virtual lives. The presentation began by indicating the extent to which most people's lives already involve a substantial amount of digital information stored in a variety of databases and that for an increasing number this information is deliberately made available to be seen by 'invited' others. The presentation noted that a smaller but significant amount of people are involved in taking part in additional lives by means of avatars operating in virtual worlds – through on line gaming and so called second life They then posed the question that if a person had an avatar how might it be used to help them in their 'real' as opposed to a virtual world – in the workplace, in education, in parenting? They then considered the consequences of competition between the physical and virtual worlds; something described by Susan Greenfield. They used the Young Foresight device to consider the pros and cons of such a situation. They noted that whilst it might enable the breakdown of stereotypes and support equal opportunities the virtual identity might become so strong that people preferred to live the virtual life and neglected their physical life. This they argued could lead to a decline in physical activity and poor health and the breakdown of social endeavours and communities.

The second group considered Nintendo games and asked the question 'Does the Nintendo 3DS offer a positive contribution to the advancement of technological and human evolution?' The presentation began with a time line of the development of Nintendo games starting at 1989 with the first gameboy and finishing with Nintendo3DS. They used the Young Foresight device to identify important aspects of the Nintendo 3DS as follows:

Technology - hand held interactive gaming device with 3D capability and augmented reality
People - any gender, ethnicity, culture and age
Society - start of gaming revolution, change in communication, interaction and play
Market - equal market share across North America , Japan and rest of world

They used the winners and losers tool and indicated that there appeared to be many more winner groups than loser groups but a significant loser group was the family.

The third group considered food manufacture using Pringles as a main example. The presentation gave information about the rationale for producing Pringles – stackable, fresh, crisp, unbroken from the tubular container and linked the developers, Proctor and Gamble, to McDonalds which processes un-served French fries so that the resulting material can be used as Pringles feedstock. In using the Young Foresight device to comment on Pringles they noted the effectiveness of the manufacturing process (showing a YouTube video); the appeal of the product to a wide range of consumers; the marketing via a 'once you pop you can't stop' slogan and the acceptance by society of the product – wide availability in supermarkets. In their winners and losers analysis they noted the consequences of automated manufacture, the destination of the packaging in landfill and the problems caused by overindulgence of such highly processes foods. To some extent these features would have been better included in the Young Foresight analysis, as they don't explicitly identify particular winners and losers.

The fourth group considered MP3 players and 'portable' music. The presentation gave a history of music playing devices - wax cylinder, shellac discs, vinyl discs, walkman cassettes, personal CD players, MP3 players including ipods and iphones. They noted that the latest developments had resulted from a convergence of the following technological improvements: better, smaller batteries; increased memory capacity and data compression. They saw the MP3 player as a great leap forward for portable music – small, light, easy to carry, can be used anywhere, instant access and highly reliable, with social benefits – cheaper access to music, democratization of music and reduced environmental impact through digital manufacture and distribution. They saw the winners as the consumer, the distributor, independent labels and the environment. They identified the drawbacks as isolation from surroundings and people, ear damage, piracy, short life span, data loss, poor quality control and the impossibility of personal repair. They saw losers as the consumer (health risk and poor quality sound), the distributor (piracy and loss of control) and large labels (piracy again). They speculated about the future of portable music noting that MP3 players will cease to exist as storage devices as entire libraries will be accessible wirelessly from the cloud. This they saw as a disruptive technology leading musicians being able to operate in niche markets yet still reach a wide audiences on line. They wondered whether this increased availability of on line music with its inherent limitations might give rise to resurgence in live music.

The fifth group considered the use of zebra fish biology to cure heart disease. They started with the recent campaign concerning research into the zebra fish which can repair damaged heart tissue. Their winners and losers analysis of research that leads to medical treatments for heart disease noted the development of commercial brands to deal with anti-ageing and raised some of the social and economic problems associated with a society in which there is a larger proportion of older people. They noted that the research involving zebra fish was more humane than other possible approaches. Investigation on embryos could be carried out on eggs outside the female zebra fish unlike investigations on mouse embryos which develop inside the female and have to be removed from the female mouse resulting in the death of the female mouse. Finally they asked where cell regeneration technology would be applied identifying the following possibilities: cloning, growing organs for transplants, anti ageing products and cosmetic surgery.

Feedback from the trainees on the extent to which they would wish to teach pupils in secondary school about the nature of technology was positive in all cases. They had mixed views on exactly when such teaching should take place. Some advocated starting in primary schools with pupils aged 10 years, others thought it should be part of the curriculum for pupils aged 11 – 14 years whilst others though it best to delay such work until pupils were at least 14 years old.

Discussion

The trainees were asked to identify a technology that they thought young people might find intriguing and/or need to understand. The technologies they chose would in all cases meet these criteria. They were provided with four different approaches to choosing their examples. Only one group appeared to make use of any of these strategies. The group considering MP3 players considered developments in the new and emerging technologies of battery design, increasing memory capacity and data compression. It is perhaps not surprising that a member of this group was a trainee with a degree in electronic engineering The group which considered the use of zebra fish biology to cure heart disease chose this topic as a member of the group had a relative who had recently survived a heart attack and had become involved in supporting a charity that raised funds for research into ways to combat heart disease. The group that considered food manufacture had two members whose specialist area was food technology. Some of the group which chose Nintendo games were mature students whose own children played these games. The group who chose avatars and their place in virtual lives were the only group to explicitly relate their chosen technology to the ideas of writers presented in the introduction. The reasons for choosing a particular technology vary from group to groups but personal experience and area of subject expertise seem to play a major part. Three of the groups explicitly used the Young Foresight approach to considering their chosen technology whereas all groups used the winners and losers approach indicating to some extent that both these techniques might be useful in developing approaches to critique.

In England the National Curriculum is undergoing revision. The Minister for Education, Michael Gove, has commissioned an Expert Panel to make recommendations. At the time of writing the Panel has recommended that design & technology become a basic subject (DfE 2011). This means that both primary and secondary schools will be required to teach the subject offering courses for older children that will lead to qualifications in public examinations but that there will be no statutory programme of study or attainment targets. Schools will decide on content according to local conditions and public examination specifications. The Panel's main reason for this is given on page 24 and footnote 57 of the response and indicates that the Panel views design & technology as having weaker epistemological roots than those subjects granted National Curriculum core or foundation subject status. Of course this is incorrect. Technology which is the subject underpinning design & technology has epistemological roots going back much further than, for example, science and a well established canon with regard to both the philosophy of technology (Dusek 2006), which has a strong and interesting relationship to the philosophy of science, and a role in putting science education under a scrutiny which widens pupils' perceptions of the usefulness of science (Layton 1995). The minister has still to pronounce on these recommendations and the Design & Technology Association is campaigning for design & technology to be reclassified as a subject that has a statutory programme of study. A situation in which design & technology has no statutory programme of study will leave many schools lacking guidance and it will be essential that teachers have some understanding of the nature of technology and the way it interacts with society if this is to be part of a design & technology curriculum. Even if the subject is given a statutory programme of study and attainment targets it can be argued that it is still highly desirable for trainee teachers of design & technology to consider the nature of technology. At the moment there is no requirement in initial teacher education for this to be addressed.

It is important to ask whether the approach used in this case study provides a transferrable means of engaging trainee teachers from other institutions in England and other countries with the nature of technology. Is an introduction which considers a range of ideas from contemporary writers in the field appropriate? Are the writers and the ideas in this study the most suitable? Are the classroom tools for engaging with critique the most apt? Are the ways of choosing a technology to consider useful or necessary? Are the 'crunch questions' the most suitable for stimulating discussion? Does the presentation task lead to the most appropriate learning outcomes? The author would welcome discussions with colleagues who are interested in the place of the nature of technology in initial teacher education for technology teachers so that an acceptable general approach may be developed and studies of its use and effectiveness be carried out in different countries.

Conclusion

Clearly caution must be exercised in drawing firm conclusions from such a small study but the findings may be taken as indicative of the wider picture and help with regard to considering how those training to be technology teachers may be introduced to the nature of technology and the relationship between technology and society. There is no doubt that the trainees were engaged by the workshop and responded positively to the idea that they might teach pupils in schools about the nature of technology and the interaction between technology and society. As the only input into their initial training such a workshop would be inadequate to equip them to tackle a significant amount of such teaching but it does serve to whet their appetites. It is hoped that this small study could provide a starting point for developments that lead to collaboration in considering the nature of technology in initial teacher education for technology teachers.

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Making by printing – disruption inside and outside school?

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Abstract
This paper considers the possible impacts of additive layer manufacturing (3D printing) on current global socio technical systems concerned with the manufacture and distribution of goods and how the introduction of this technology might disrupt the secondary school technology curriculum.

Introduction
This paper explores the possible consequences of making available to students in secondary school a technology as it is beginning to be disruptive in the world outside school. The technology under consideration is additive layer manufacture sometimes known as 3D printing. This paper is in five main parts. First it will describe the nature of additive layer manufacture. Second it will consider the nature of disruption in the context of technology. Third it will consider the extent to which additive layer manufacture has the potential to be significantly disruptive of prevailing socio technical systems. Fourth it will consider how this technology might disrupt current practice in secondary school technology education. Fifth it will consider arguments for and against introducing this technology into the secondary school curriculum.

Additive layer manufacture
The Centre for Additive Layer Manufacturing (CALM) at Exeter University defines additive layer manufacturing (ALM) as:

> A modern fabrication process that can use a wide range of materials to create products ranging from medical implants to parts of an aircraft wing. Three-dimensional parts are built up in two-dimensional layers as little as 0.05 mm thick; this way of building parts offers great flexibility and opportunities for creating new products at low cost, whilst reducing the carbon footprint associated with manufacturing. (http://emps.exeter.ac.uk/engineering/research/calm/)

Digital files describing products can be sent anywhere in the world where there are customers with 3D printers. The manufacture of those products at those sites, as opposed to manufacturing in bulk in one place and then transporting to customers in different places, reduces transportation costs and hence impact on the environment. The data used to define the layers to be deposited starts in the form of a digital description of the item to be produced and is then converted very quickly by software into an STL (Standard Tessellation Language) file, which software in the 3D printer turns into a precisely described set of layers. These layers are then printed, one on top of the other. CALM provides a brief history of ALM on their website at http://emps.exeter.ac.uk/engineering/research/calm/whatis/history/

The technology has grown from it's inception in the late 1980s, when it was considered to be a means of rapid prototyping using thermosetting plastics, to the present day where the process can deal with a much wider range of polymers and metals to produce finished products. Significantly, the technology is now seen as a means of manufacture as opposed to simply prototyping. Current work is preparing the supply chain for potential demand for products using these processes.

What is a disruptive technology?

According to Christensen (2012) 'disruptive technology' is a widely used and generally accepted term but a more accurate term is 'disruptive innovation' because market disruption has been found to be a function usually not of technology but rather its changing application. A ubiquitous example is the automobile. While a revolutionary technological innovation, it was not, at its inception, a disruptive innovation because early automobiles were expensive luxury items that did not disrupt the market for horse drawn vehicles. The market for transportation essentially remained intact until the debut of the lower priced Ford Model T in 1908. Henry Ford (1922) indicated his intention to be disruptive as follows:

> I will build a car for the great multitude. It will be large enough for the family, but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one – and enjoy with his family the blessing of hours of pleasure in God's great open spaces. (p 73)

The *mass-produced* automobile was a disruptive innovation, because it changed the transportation market. The automobile, by itself, was not. It is in the situation of changing application that additive layer manufacturing finds itself and which might lead to it becoming disruptive.

Will additive layer manufacturing be a disruptive innovation?

In England the Technologies and Travel Project (http://www.lancs.ac.uk/tnt/) funded by the Economic and Social Research Council (ESRC) and undertaken by Lancaster University, and the University of the West of England, Bristol (UWE) hosted a one-day scenario building workshop around the future effects of computer-aided design and additive manufacturing and their possible consequences for global patterns of both freight transport and consumer travel. The workshop presented four possible scenarios described below, each dependent on the extent to which there was either high or low engagement with 3D printing and either high or low corporatization of 3D printing. These scenarios are shown diagrammatically in Figure 1.

Scenario 1 Desktop factories at home

The technical possibilities of fabrication in the home using desktop 3D printers significantly disrupted global systems of production, distribution and retailing. Many factories in the global south closed or downsized. Yet many supply chain and distribution networks remained intact and have even been consolidated due to rapid growth in demand for powders and other feedstocks for 'printers'.

Scenario 2 Localized manufacture
There has been a blossoming of high-street retail bureaus or 'print shops' to cater for the trend in use of online networks of 3D designs organized through large scale corporate databases developed by suppliers such as Google or Amazon. Global manufacturing and distribution has grown from these new business opportunities with emerging supply chains of material feedstocks due to localized manufacturing on a vast scale. Much manufacturing 'returned' to the global north and this has reduced the large-scale transport of objects from the global south.

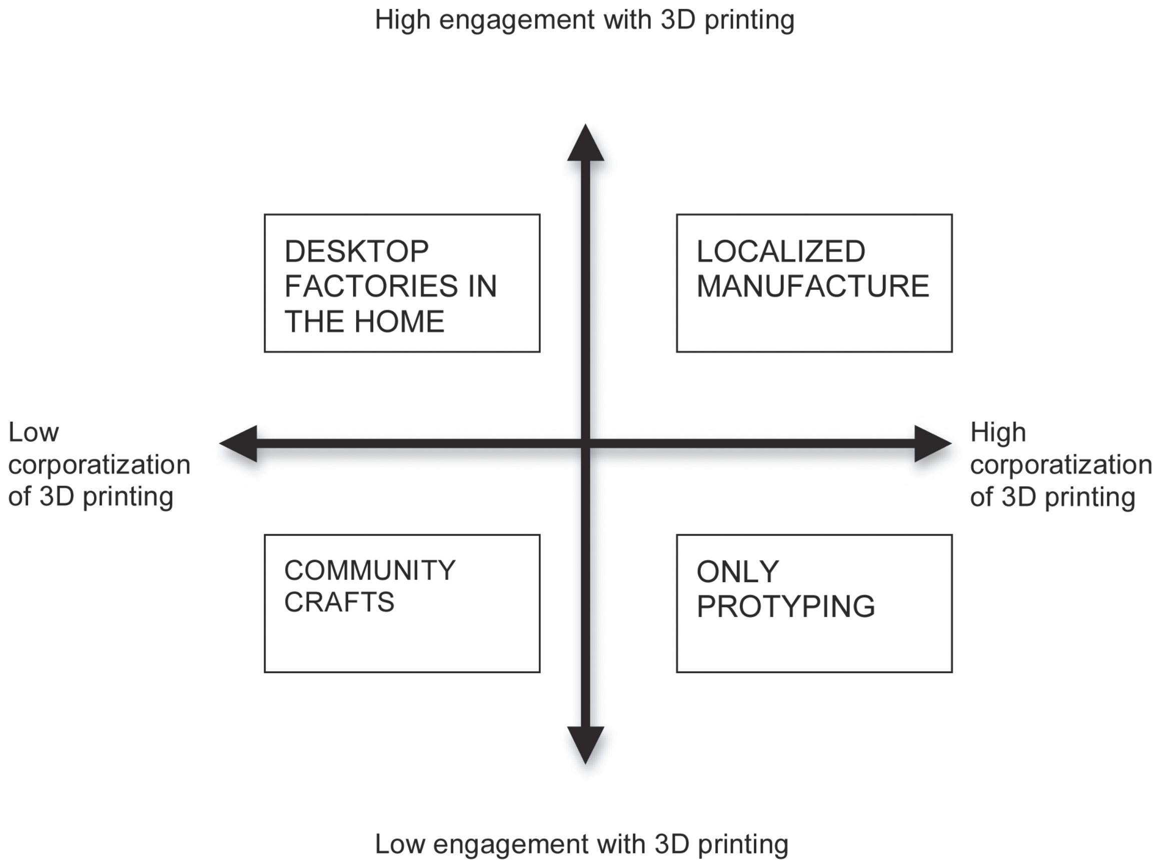

Figure 1. Scenario building for 3D printing

Scenario 3 Community craft
Growing up in a knowledge economy with easy access to new technology has meant that community groups championing 3D printing innovated and experimented through informal networks based around local innovation. Most people continue to procure consumer items in the traditional way either through online purchasing and delivery from distant manufacturing centres or through retail high-street stores.

Scenario 4 Only prototyping
Although many types of 3D printers were developed, hardly any made a successful market entry, with the products being of too low-quality or too expensive. As a result, most people continued to depend upon online and traditional retailers for the purchases of goods that were manufactured in 'factories' often very distant from these consumers. Rapid prototyping remained the main use of 3D printing technologies and this had little impact upon transport or travel patterns.

Scenarios 1 and 2 have the potential for significant disruption to the prevailing socio-technical system of manufacture and distribution. In scenarios 3 and 4 the current system in which the majority of goods are produced in the global south and transported to the global north is maintained. Some have already indicated their scepticism with regard to scenarios in which there is disruption. Dean (2012) Editor-in-Chief of *Develop 3D* describes how he used an inexpensive 3D printer (£1500.00) to manufacture a bracket for his weather station – the original had been broken by windy conditions. A highly successful experience for Dean but he was not persuaded of the viability of scenario 1. He writes, "I'm still not convinced that there truly is a mainstream market for 3D printers – people just don't, in the majority of cases, want to get involved in making their own stuff."(p. 66). Welch (2012) has suggested that all kinds of people make all kinds of stuff – cakes, rock gardens, quilts, shelves for the garage, model aircraft etc and that Dean misjudges peoples' 'makerliness' although whether 3D printing would appeal to the hands on making described by Welch is debatable. One argument against this is that 2D printing used to be a specialist occupation but with the advent of home computers many people are quite comfortable with designing and printing fully illustrated documents as well as high-quality photographs. The pervasive nature of home printing is also indicated by most on-line businesses offering printable versions of relevant documentation. Is it possible to that 3D printing will grow in the same way as 2D printing? Maly (2012) argues that typography in the early 1900's typography was a heavy industry involving the forging of fonts yet in less than 100 years homes and small businesses are quite comfortable carrying out their own printing. Given that 3D printing is in its infancy, only 30 years old, Maly argues that it still has plenty of time to mature and become pervasive as did 2D printing.

Scenario 2, localised manufacture, is gaining credence. Whilst the use of additive layer manufacturing has been used for rapid prototyping as a means to reduce lead-time prior to manufacture it is now being used for production. Twenty percent of 3D printing is now thought to be of final products rather than the printing of prototypes (Kross, 2011). General Electric has announced that it will intensify its focus on additive manufacturing to develop a variety of products, from aircraft engine components to parts for ultrasound machines (Cox, 2011). Markillee (2012), writing in *The Economist* in an article entitled "The third industrial revolution", asserts that the geography of supply chains will change. Markillie cites the Boston Consulting Group, who speculate that in areas such as transport, computers, fabricated metals and machinery 10–30 percent of the goods that America now imports from China could be made at home by 2020, boosting American output by $20–55 billion a year (Markillie, 2012).

Hence scenario 2 has appeal to those who wish to see a revival of manufacturing in the global north. This scenario also has appeal to those who wish to solve the global problems of resource depletion and climate change by moving towards a circular economy (Ellen MacArthur Foundation, 2012). The transport of goods from centres of mass manufacture by means of containerisation in extremely large cargo ships contributes to the amount of carbon dioxide in the atmosphere. If goods were produced at or near the site of consumption the amount of carbon dioxide released through transportation would be reduced although this begs the question of the transport of the material required to print the items. Once printed items had reached the end of their useful life it would not be difficult to return them to the technical nutrient stream to be reused in printing other items. If this could be carried out without significant loss then resource depletion would be reduced. Some however are sceptical. Mims (2012) considers that the notion that 3-D printing will on any reasonable time scale become a "mature" technology that can reproduce all the goods on which we rely is to engage in a complete denial of the complexities of modern manufacturing. He argues that 3D printing will have the biggest impact within traditional factories. Mueller (2006) has foreseen this position and considers that 3D printing will be used to develop multiple design possibilities for parts and enable limited numbers of products to reach market whilst tooling up for conventional manufacture to take place.

Disruption of current practice in secondary school technology education

Williams (2007) takes the position that one of the purposes of technology education is to prepare school students to engage in a participatory democracy and that Web 2.0 provides some interesting possibilities because it provides services which students readily access and become familiar with and (citing O'Reilly 2006) are characterised by open communication, decentralization of authority, freedom to share and reuse, user's ownership of data and an effectiveness that develops as people use them. Steeg (2008), building on Williams' advocacy for Web 2.0, argues that a possible future for technology education involves engagement with tools for personal fabrication linked to on line hacker/maker communities. Since 2008 a clearly identifiable on line 3D printing community has emerged and some members of this community are shown in Table 1.

Given the access to the Internet available to schools it is possible that students could use such organisations in two ways:

- Developing simple digital designs for products, which the organisation prints and then sends to them by post – the school and/or students would need to pay for this service;
- Developing simple digital designs for products which the organisation prints and sends by post to others who are prepared to pay for the design – the school and/or students would make money from this service.

In neither of these cases is it necessary for the schools to possess a 3D printer. The students would be involved in designing but not making, although it would be possible for them to acquire made versions of their designs. The making function would have been devolved to one of any number of on-line 3D print bureaus. If such a 'designed by me but made by somebody else, somewhere else' practice became widespread in, for example, England, it would be a major departure from prevailing practice where pupils are invariably required to make what they have designed. If it became well established it would be disruptive.

If a school possesses a single 3D printer then it is possible for students to develop digital designs and print them on-site but this is not without its problems. The size of the work bed in school-based 3D printers is small, making it impossible to print multiples of student work. Printing is also quite a slow process (the bracket printed by Al Dean took several hours). Hence it takes a long time for a class of students to each print what they have designed. Some models are not that reliable so there is a steep learning curve before the printers become simple to use. However, it may be possible to overcome these difficulties. Recently the company A1 Technologies has given this matter some thought and concluded that a different approach is needed. First, there needs to be a much more reliable 3D printer that is straight-forward to use in the low cost part of the market. Second, it would make sense for schools to buy several such 3D printers so that pupils would be able to parallel process their printing. To this end Martin Stevens, the CEO of A1 Technologies has designed such a 3D printer – the Maxit 3D kit printer made available in kit form which takes less than a day for a pupil (rather than a technician) to assemble, as opposed to a week for other 3D kit printers, and devised a modern manufacturing 'set' which consists of six Maxit 3D kit printers, six laser scanners, six haptic design packages, one Studiomill 5 axis milling machine, all necessary software plus cutting and printing material plus curriculum materials for students aged 11–18 for an overall price of some £23k (€28k).

Table 1 Some Members of the On Line 3D Printing Community

Name and address	Features – taken from website
Shapeways http://www.shapeways.com/	*Tutorials* *Printing* in up to 25 materials including metals, ceramics and glass *Uploading and ordering designs*
Ponoko http://www.ponoko.com Making outlets in five countries	*Choose and buy a product*. The designer will order the parts from Ponoko and send it to you direct. *Choose and buy a design* and download the files to your PC. You can then customize it if the Creative Commons copyright license allows. When you're ready to make it, upload the files to your My Ponoko account, select the materials, and get an instant price for us to make it and deliver it to your door. *Choose a design* and download the files to your PC for free. You can then customize it if the Creative Commons copyright license allows. When you're ready to make it, upload the files to your My Ponoko account, select the materials, and get an instant price for us to make it and deliver it to your door.
i.materialise http://i.materialise.com/ Headquarters in Leuven Belgium plus branches worldwide	*3D print your designs* Upload your 3D design and instantly see the price for your models. No login necessary Choose from a large selection of materials and colors Scale your model to the ideal size Order as many copies as you want *Sell your designs* Want to show off your design talent and make some money at the same time? Offer your designs for sale in our gallery and once a month, we will pay you a fee for every one of your items sold.
Thingiverse http://www.thingiverse.com	*Digital designs for a wide range of objects* Examples of a wide range of things made via 3D printing Examples of tools in the following categories: automated, clamping, crafting, cutting, electrical, hand, measuring and power
Creatity http://www.creatity.com Essentially a trading site for a variety of digital media – pictures, models, music and software	A suitable platform for trading of digitalized 3D objects

At the time of writing, this set has only just been made available. It remains to be seen as to whether schools will buy into this approach to making 3D printing available although there is a significant track record of A1 Technologies selling smaller volumes of their products into schools. Consider students aged 12 – 13 years, the age at which such students are taught computer assisted design and become familiar with the use of 3D modeling software to 'design on screen' (Winn in press). At the moment such students in most schools would not have access to the computer assisted manufacturing facilities that would enable them to make what they had designed on screen. If the school purchased a modern manufacturing 'set' a class of 24 such students would be able to work in groups of four with each group having their own 3D printer. The students could work both collaboratively and individually in developing designs to be printed. They would also be able to download free of charge open-source digital designs and either print as is or modify and then print. If such a 'designed by me and printed here' practice became widespread in, for example, England, it would be a major departure from prevailing practice where students are invariably required to make the products they have designed using hand and manually operated machine tools. If it became well established it would be disruptive. It would make assessment difficult. The collaborative nature of the on screen designing would give difficulties in assessing student's individual progress. The nature of the making taking place, being completely under the control of the 3D printer would also problematise the assessment of student's making skills. Note that there has been criticism of secondary schools in England that do not use modern technologies in their curriculum (Ofsted 2011, 2008).

Discussion

Crawford (2010) decries the closure of shop classes in the United States and celebrates the learning and self efficacy that come from the knowledge and skill that enables someone to understand and be able to repair their technical possessions. This has considerable resonance with the practical activity of designing and making that constitute the heart of many school technology programmes. If these programmes move to the point where the designing is done on screen so that the artefact can be made by additive manufacture the physical interaction between the hands, tools and materials and the hand eye coordination required to acquire mastery will to a large extent be lost. It is a question of breadth and balance. Introduction to and experience of modern manufacturing processes, such a 3D printing, should not be at the expense of denying students the experience of working with tools and materials. However it is important to realise that even if time and money can be found to introduce 3D printing into the technology curriculum without compromising or marginalising conventional designing and making activities the work carried out might be difficult to assess under current assessment requirements.

If 3D printing does become disruptive in the world outside school, then there is a further argument for including it in a technology curriculum. An important part of technology curriculum is the exploration of the relationship between technology and society through which students achieve an understanding of the socio-technical systems that operate in the world. The introduction of containerisation in the 1970s has resulted in a world container fleet of over 3000 vessels (Cudahy 2006). Recently Maersk announced plans to produce a new range of 'mega' triple-E container ship 20- storey high and as wide as an eight-lane motorway and taking four-five days to be unloaded (Vidal, 2011). The cargo container is part of a wider socio-technical system shaped by global production, consumption, provision, investment inequality, status and wealth (Birtchnell & Urry, in press). It is rare that a practical activity involving designing and making can be used to give insight into such large-scale socio-technical systems. There is the possibility that as students engage with a technology that disrupts their experience of school technology that same technology is also disrupting what happens in the world outside school.

At the time of writing Techfortrade a UK charity has announced an educational challenge with regard to 3D printing. Techfortrade has a mission to alleviate poverty through technology-enabled trade. Its aim is to act as a catalyst for new ideas; working with innovative projects that have the potential to scale and replicate. The 3D printing Challenge aims to find transformational uses for additive technology that deliver real social benefit in the developing world. During May 2012 there are workshops to support the challenge in New York, London, Johannesburg and Nairobi. The competition is aimed at identifying ideas worthy of further funding and taking them to market (Techfortrade, 2012). There is no reason why students could not be engaged with this challenge as part of their school technology curriculum. This would provide them with the opportunity not just to consider the disruption that is taking place in the world outside school but contribute towards such disruption. This indeed would be an interesting example of the participatory democracy through technology education advocated by Williams (2007). This has some resonance with the ideas of Facer (2011) who has argued that in the face of new and emerging technologies schools will need to redefine themselves as places in which communities debate and decide on the futures they wish to create for themselves.

The possible significance of 3D printing for both the world and technology education indicates that it will be worth carrying out empirical research into the impact this technology has on school technology education. The following research questions may be worthy of consideration:

To what extent is 3D printing being used in secondary schools?

What are the constituents of a 3D printing curriculum?

What impact does the introduction of 3D printing have on the rest of the technology curriculum?

What do stakeholders in the technology curriculum think about the introduction of 3D printing into the curriculum?

The author would welcome discussions with colleagues who are interested in pursuing these questions.

Conclusion

Despite some scepticism (Dean 2012, Mims 2012 and Mueller 2006) there is a groundswell of informed opinion that 3D printing will be a disruptive innovation that will have profound effects on global trading. Birtchnell and Urry (in press) imagine a future world of fabrication 'that is not something that would simply replace long supply chains and containerization. Rather the proliferation of 3D printing may change the overall ecology of machines and technologies'. This is of course speculative and uncertain but if their vision should become a reality there is the real possibility that students in secondary school may be able to use this technology in a future in which this technology contributes towards disruption of the socio technical systems of the wider world and the technology curriculum.

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Perceptions of STEM, within the context of teaching D&T in secondary schools: A phenomenographically inspired study

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Context

The teaching and learning of Science, Technology, Engineering and Mathematics (STEM) as an area is high on the educational agenda of governments both nationally and internationally. In the United Kingdom (UK) the supply of highly qualified scientists, technologists, engineers and mathematicians is perceived as vital in securing the future of the UK's economy (Roberts 2002).

Amidst the spending cuts across the English educational system, STEM thus far has escaped, as this Initial Teacher Training (ITT) related quotation illustrates:

> *"The Review recommends a major campaign to address the STEM issues in schools. This will raise the numbers of qualified STEM teachers by introducing…new sources of recruitment, financial incentives…and mentoring for newly qualified teachers."*
>
> Sainsbury (2007)

Worryingly however this investment has not been extended to include those aspiring to train to teach Design and Technology (D&T). Previously classified as a 'shortage subject' by the Teacher Development Agency (TDA:2010) the latest documentation (DfE 2011) presents a £9,000 bursary for those holding a first class honours degree (those holding a 2:1 classification will be awarded £5,000 and those with a 2:2 will receive no bursary) however for those holding a first in physics the bursary has been increased to £20,000 (DfE 2011).

D&T has much to offer the STEM agenda, however as Barlex (2008) notes, its' position in relation to STEM has *"oscillated between insignificance to [that of] valued contributor"'* for some time, and this perceived lowering of status, illustrated through the inequality of ITT bursary's is not the only cause for concern. These changes come at a time when the majority of schools are introducing the English Baccalaureate (Ebacc), which does not include D&T and as a comparatively expensive subject, which when coupled with this non compulsory status, presents a threat to its survival.

As a relatively new curriculum area, introduction as a result of the 1988 Education reform Act, the then Secretary of State for Education, Sir Kenneth Baker defined D&T as a subject:

> *'…in which pupils design and make useful objects or systems, thus developing their ability to solve practical problems"*

Baker was clear in his remit, defining a context for how this new subject would operate and highlighting the preferred curriculum allegiances:

> *"The working group should assume that pupils will draw on knowledge and skills from a range of subject areas, but always involving science or mathematics"*
>
> Department for Education and Schools,(DfES 1988)

When delivered effectively, D&T can help children better understand, through practical application, theoretical aspects of science and maths and it is upon these principles that the subject was first conceived. However the preoccupation with STEM has led some D&T teachers to express concern in relation to the potential loss of individual subject identity. This has created pockets of resistance, with some teachers reluctant to engage in the STEM agenda. This debate (Lewis et al, 2007, Barlex 2009; Pitt, 2009; Williams, 2011) about D&T's value and place within the curriculum provides the context for this study.

Methodology

At the outset of this study, the intended methodological approach was phenomenography.

As an approach, phenomenography seeks to identify multiple perspectives held by a particular group in relation to the same phenomenon, with the purpose being to highlight variation in the collective and in doing so present alternative views rather than focussing upon the individual experience (Åkerlind 2005). According to Åkerlind (2005) phenomenography emerged from an empirical background, as opposed to a theoretical or philosophical one, and may be defined as the study of ways in which various phenomena are experienced, conceptualised and understood (Marton 1994). '*Reality is a human construct*' (Wellington 2000) which presents itself as an interpretivist epistemology, and from this perspective there is no single view of the world, a real (objective) world 'out there' and a subjective (mental representation) one 'in here' (Marton and Booth 1997) which leads to a non dualistic ontological approach (Marton 2000).

It is through this approach that I sought to explore the lived experiences of D&T teachers in relation to their understanding of STEM. When using phenomenography as a tool to identify different perceptionial understandings, as originally intended in this study, it is vital that the researcher understands that people may experience the same 'thing' in different ways because what we experience is our reality, whilst our 'natural attitude' is however to assume that our world view is the same as experienced by others (Fazey and Marton 2002).

Critisim of phenomenography as a research approach (Sandbergh 1997, Webb 1997) focuses upon the researcher's inability to set aside their own preconceived ideas as data is sorted, which is vital in avoiding bias in order to prevent the misrepresentation or distortion of findings.

In this study, as a beginning researcher, whilst the data has been gathered using phenomenographic strategies, analysis of the data has not been analysed as it should, in order to produce the qualities and outcomes expected for a phenomenographic study. This paper therefore presents findings, derived from the 'raw data', which are influenced by phenomenography.

Ethics

Research has been conducted in accordance with the ethical guidance described by British Educational Research Association (BERA 2011). Informed consent was obtained and assurance given with respect to confidentiality, anonymity, and the rights of withdrawal.

Sample

In this study the sample size was nineteen (n=19). In line with phenomenographical selection criteria, participants were selected to encompass as much demographic variation as possible, and as such met the following criteria;

- All held Qualified Teacher Status (QTS)
- All were employed in mainstream secondary education in England
- All were teaching D&T (National Curriculum)

In relation to D&T; participants held expertise in; catering, hospitality, food, child development, product design, resistant materials, electronics, systems and control, textiles (including art textiles and Textronics), graphics, engineering and motor vehicle maintenance.

Three participants taught only one area of D&T, whilst nine delivered four or more. Three taught areas considered to be 'outside' of the subject including; mathematics, science, Information Communication Technology (ICT), art, Personal Social and Health Education (PSHE), and Religious Education (RE). The group comprised of ten women and nine men. The cohort age ranged between twenty-eight and sixty-two years old. Years in service ranged from one to thirty-nine. All participants were working within their respective institutions on a full time basis and had spent between one and thirty-one years working within their current school.

With regard to Teaching and Learning Responsibility (TLR), management or other allowances held, one was second in department, four were heads of department and one was an assistant head teacher. A further four held allowances for pastoral positions, one was an Advanced Skills Teacher (AST), one was head of PHSE and another was the schools Special Education Needs Co-ordinator (SENCo). One was a STEM co-ordinator and two ran post school STEM clubs.

Geographically participants worked within six local authorities across the North West of England, with one teaching outside of England, but following the English National Curriculum. Six schools were designated as technology or engineering colleges, one was classified by Ofsted as being in '*special measures*' and another had been served with *'notice to improve'*.

Research design

Semi-structured interviews designed to gather 'the lived experiences of participants' were undertaken using phenomenographical procedures advocated by Kvale (1996) and Bowden and Green (2005). The same 'initial' question was posed, with supplemental questions asked if the natural flow of conversation began to cease. Participants were asked to talk about their favourite D&T project, and as the conversation developed participants were encouraged to articulate the skills, knowledge and understandings embedded within the project. In order to elicit rich, detailed descriptions further questions sought to ask '*why?*' rather than '*what?*' (Åkerlind 2005). Participants were encouraged to discuss how the project linked to areas of the curriculum and only as conversation closed was a question about STEM posed. Depending upon the interviewee's response this either brought the interview to a close or enabled its continuance.

Interviews lasted between forty-five and sixty-five minutes, were transcribed verbatim (Ashworth and Lucas 2000), which involved participants verification of their accounts to ensure that perceptions had been accurately captured, following which all interviews were anonymised.

Analysis

Phenomenographic analysis strategies vary, Walsh (1994) advocates whole transcript analysis, whereas Svennson and Theman (1983) and Prosser (1993) prefer to explore segments and smaller section analysis. The approach taken in this study sought to consider the transcripts as a whole. A simple coding system was used to illuminate similarities and highlight differences. An iterative, analytical approach was adopted, which involved checking and continually sorting and comparing data. This is a phenomenographic technique through which analysis continues until no new data emerges. The data is then treated as a single transcript, with different perceptions being used to produce "*conceptions from a pool of meanings*" Åkerlind (2005).

Analysis then attempted to focus upon the identification of the qualitative differences in variation, with the 'space' in-between each being derived from the variation of importance. It is through this process that conceptions are aligned not to individuals, but to the group, giving rise to the formation of conceptions which can be organised to create a hierarchical set of understandings which are referred to as ‘outcome spaces’ or ‘categories of description’ (Marton 1994).

As a beginning researcher I applied the knowledge I had of phenomenography to generate the data set being considered and create a series of hierarchical outcome spaces. However, upon reflection, it is clear that having analysed the emergent data I have generated outcome spaces which in reality served to describe the participants understanding of the acronym ‘STEM’. This is in contrast to that which I know to be the desired realisation of “outcome spaces” that reflect participant’s lived experience (deep understanding) of the phenomena under consideration.

As shown below (fig.1.), initial attempts to analyse the data using phenomenographical techniques led to the creation of four hierarchically empirically grounded outcome spaces:

	Outcome Space
1	Demonstrates no awareness of STEM
2	Demonstrates an awareness of STEM; Maybe able to define the acronym, but is unable to link STEM to the work they undertake.
3	Demonstrates an understanding of STEM; Able to define STEM, and illustrates through examples how STEM can be delivered and links to their own teaching
4	Fully aware; Demonstrates a deep level of knowledge and understanding, is able to articulate citing fully and in-depth examples easily and confidently

Fig.1. – Initial outcome spaces derived from iterative DATA analysis.

However as the table illustrates (Fig.1.), the spaces are descriptive, illustrating only the participants ability to define STEM. Despite being driven by methods suitable to a phenomenographic methodology I have not been able to derive an outcome that strictly adheres to the principles of phenomenography. However, following analysis, the results I have arrived at have given rise to several findings which are of significance.

Raw Data; Presentation, Analysis and Discussion

Within the research sample, seven (7/19) participants held a food related background. During data collection two participants (2/19) described projects which integrated a significant number tasks which would be considered to be ‘STEM’ as this quotation illustrates;

> *“We teach a project on multi-cultural foods. Pupils are taught about cereals, cooking skills, presentation and packaging... it links to RE, PSHE and literacy... what? Does it link to STEM? No I don’t think so ... I don’t know what that is sorry”*

However both participants, whilst delivering exceptional lessons that clearly contribute to the STEM agenda, had no awareness of STEM, and consequently were therefore unaware that they are doing so. Of the participants (7/19) who described food related projects (all of which demonstrated clear links to STEM) two (2/7) had no awareness, three (3/7) demonstrated a limited awareness, and two (2/7) expressed confidently links in relation to the agenda they were effectively contributing to. Whilst it is some time ago (in England) that this area became known as Food Technology, much to the frustration of many, it is not uncommon to find previous titles, ‘domestic science’ and ‘home economics’ still in common use. This in itself creates an interesting paradox, as aspects of both previous titles make specific reference to STEM.

Seven participants (7/19) were able to demonstrate an awareness of STEM, but were not able to accurately define the acronym. Their language demonstrated a knowledge deficit in relation to an in-depth understanding, and they were not always fully aware that they were delivering aspects of STEM within their own practice.

The majority of teachers however (12/19) were easily and accurately able to define STEM. Their responses articulated how almost any task taught within design and technology can address aspects of STEM, however during analysis it became clear that whilst knowledge was not an issue, the participant's personal opinion of STEM and its place within the D&T curriculum was. In this study advocates sought to promote STEM which was in direct contrast to those 'opposing' STEM, who perceive the development of the agenda as being detrimental to D&T:

> *"Yes it links to STEM but no I don't make that explicit to the children....in my opinion D&T shouldn't be used as a vehicle for science and maths to realise their own curriculum"*

A further finding was the perception, cited by a significant number of participants (10/19) in relation to the difficulties they frequently faced in their attempts to deliver STEM. From the research group only one participant had a specific period of allocated time during their teaching day to deliver STEM. Where STEM was cultured in other settings, this was developed within the teachers own time with delivery taking place 'after school'. Lack of support or engagement from staff in STEM related subjects / departments and working in isolation were cited as barriers to effective delivery. In contrast some participants cited feelings of exclusion from the funding and organisational arrangements within their own institutions.

Conclusion

Whilst not phenomenographical as originally intended, this study brings to the fore several issues;

As findings from this study indicate, a number of participants express concern about STEM seeing it as a threat which could consume D&T as a subject within its own right. The latent 'power' of the teacher's personal perspective and their potential to either impact or sabotage the successfully embedment of STEM should not be underestimated.

Despite the argument for 'dispositions' (Hardy et al, 2008), currently within the English education system, STEM is not delivered as a single curriculum area. Frequently it is addressed through individual subject disciplines and STEM interrelated initiatives, such as science and engineering clubs (Mannion and Coldwell, 2008).

Findings presented here would suggest that in reality, despite the best efforts of those who have been tasked with implementing the STEM agenda in schools, as aspects of the STEM cohesion programme final report echo (DFE 2011), dissemination and equality of access in relation to STEM in schools is not as effective as it perhaps could be. There are a number of teachers (of D&T) who are unaware that they are delivering STEM, or who are unsure of the contributions that they can and do make.

Furthermore findings highlight tensions in relation to the actual delivery of STEM. With some (teachers of D&T) being unsure if it is within their remit and responsibility to engage, whilst others (with a desire to be involved) cite barriers which excluded them from doing so. Where participants believe themselves to be engaged in the delivery of STEM, the majority reported that they were doing so within their own time (after school) and / or in isolation of other STEM subject related colleagues.

It is intended that the data yielded from the interviews will be reanalysed using phenomenographical methods to produce outcome spaces which reflect 'the lived experiences of design and technology teachers' as this methodological approach originally intended in addition to the findings already arrived at through previous analysis of the data (Fig.1).

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The development of quality design and technology in English primary schools: issues and solutions

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Keywords: primary, design and technology, quality, nature of the subject, knowledge, value

Abstract
Design and Technology (D&T) education in our rapidly changing society has never been more important. The skills, knowledge and understanding that are at the centre of this subject prepare young people for their future lives in so many ways. However the foundations that need to be put in place in primary education are often ignored at this crucial stage of young people's development, either because of ignorance or lack of interest. Unless the building blocks are in place then future progress inevitably will suffer. This paper seeks to identify some of the key issues that can affect the development of the subject in primary settings and offers some possible solutions to the identified issues. Data was gathered from 5 groups of primary teachers (a total of 62 teachers) who were all studying towards an MA Ed through extended primary D&T courses. The teachers completed questionnaires before and after the course and all took part in semi structured interviews and group discussions throughout the course. Their responses were analysed and findings were also related to research. Implications for future activity are identified and suggested in order to help to address the issues raised from the research. Although the research is based in England it may prove a useful starting point for all those involved in primary D&T worldwide.

Research undertaken
Although D&T was introduced into the curriculum in England in 1990, evidence collected from teachers attending long award bearing primary D&T courses for more than six years indicated that the majority of these teachers were from schools where D&T is not well established. What then are the main issues that can be identified that are preventing good quality D&T? There has been no research that has focused specifically on this area (Harris and Wilson 2003), although studies have looked in general terms at issues that affect quality education provision in primary schools. If the quality of D&T is to be improved, then it is important that issues hindering its development are identified before they can be addressed.

For this research the description of quality D&T was discussed with the teachers. Their common understanding of the term included a school where there is:

- an understanding the nature of the subject
- confidence in subject knowledge
- planning across the whole school where the integrity of D&T is kept; there is breadth, balance and progression in relation to the content of the National Curriculum

- projects are authentic, there is a clear user/s and purpose, there is excitement about D&T
- a range of tools, materials and equipment that are sorted, easily accessible and well maintained.
- understanding of the value of the subject as part of the curriculum

From 2009-11, primary teachers on five long award bearing D&T courses (total of 62 teachers) agreed to take part in a small scale research project to try and identify issues that were undermining development, and then to draw out any common strategies that might provide a positive way forward to develop quality D&T. The teachers came from primary schools around England; over 95% were in charge/were subject leaders of D&T in their schools; over 97% had no formal qualification or none/almost no CPD in D&T; over 95% had held the position for less than 3 years; and over 96% were female. The age profile of the teachers was 37% 21-35 years; 43 % 35-45 years; 18% 45-55 years; 2% over 55 years. Ethnicity information was not gathered. Descriptive research was used (Best 1970) as it is concerned with 'practices that prevail ... how what is has influenced a present condition.' Some quantitative data was gathered to give an overview of answers to some questions; however qualitative research was the prime method used in order that discussion/comments could be gathered to gain more in depth reasons for the teachers' views. The teachers completed questionnaires before and after the course and all took part in semi structured interviews and group discussions throughout the course. It was felt that these data gathering methods would afford appropriate opportunities to gain insights into the teachers' feelings, opinions and reasoning for the stance that they took in relation to D&T development in their schools. Taping interviews would not have been practical in terms of the time it would take to transcribe for the size of this project; instead notes were taken during interviews and discussions – identifying the key points. Ethical considerations were taken into account (Robson 1993, Denscombe 2005). The teachers all agreed to take part in the research and understood the way in which the research would be conducted and findings disseminated and the anonymity of all personnel and schools connected with the study was ensured.

Analysis and discussion of findings

In the first instance, all data was studied, cross referenced and then key themes identified in relation to the teachers' own views regarding blocks that had prevented quality D&T from being identified in their schools. There were no significant differences in the way in which teachers gave their comments based on region, age, experience, and gender. In this paper the three key factors that teachers identified most often are discussed in detail, whilst the next 2 are identified, so that the length of the paper is acceptable for the conference.

Understanding the nature of the subject

From the initial questionnaires, discussions/interviews, it was very apparent that over 90% of the teachers had a limited understanding of the nature of D&T and this was supported by the work that was being undertaken in their schools. The idea that user and purpose were at the heart of a D&T project was not common practice in majority of the schools; children were taking part in craft activities, or 'appliance of science' activities such as making a torch without designing, or with a user or purpose in mind. After the course almost 100% of the teachers could see not only the true nature of D&T but how they could adapt practice in their school to ensure quality provision. Majority felt that this factor alone would make a huge impact on practice – it was the key factor.

Common quotes included 'we make but we don't design and really there isn't a user for the product'; 'we do skill activities and don't have an end product very often'; 'we have to fit the D&T with History so it ends up with the children making a Tudor house or a Roman sandal which I can see now is not D&T and not good History.'

It may seem unlikely that after 20 years that an understanding of the nature of the subject was missing. However the subject was new then in the primary curriculum and there has been little Continuing Professional Development (CPD) over the years on a regular and sustained basis. Unless the understanding is there, it is difficult to see how the subject can be planned for and implemented. Furthermore, data that was gathered from 2 major projects - one with Foundation Stage (3-5 years) practitioners (Benson, 2003, 2005, 2008) - and one with secondary teachers (11-18 years) (Benson, 2009) clearly indicated that there was still a lack of real understanding as to the nature of the subject with practitioners. A popular misconception among both groups of practitioners was that making was at the heart of the subject and that, for example, designing, exploration of materials, and evaluation was peripheral, if there at all. This finding was particularly surprising in the case of secondary teachers, most of whom had studied the subject to degree level and were teaching students to examination level in their schools. 'Key essentials' that should be included in D&T have been identified and published (www.data.org.uk) so that there is a consensus that can be used as a starting point and majority of the teachers identified these as being most helpful in developing their understanding of the subject.

I would argue that it is equally important that primary aged children have a clear notion of the subject. They need to understand its nature so they can engage in a more meaningful way with the activities. Little has been researched about primary aged children's perceptions of education and D&T in particular but more recently there has been a realisation of the importance of understanding, and taking into account, the children's viewpoint. (Rudduck and Flutter, 2004 McIntyre et al, 2005; Benson and Lunt, 2007). Over 90% of the teachers indicated they had not considered this notion but that they would address this when creating their D&T development plan.

Teachers' confidence in their subject knowledge

Almost all the teachers (98%) indicated that they felt that their lack of confidence in their own subject knowledge including practical skills and the use of tools and equipment was a major block to the development of quality D&T in their schools.

Quotes that exemplify their feelings include:

> "I have boxes and boxes of stuff and I don't know what to do with it. If I don't know how can I help others."
> "I don't have time to research the www for support for myself or for the staff'. Where do I start?"
> "I look at the catalogue and am not sure what to buy – do I buy bits and pieces or a class kit? If it is a class kit how do we get the creativity?"
> "What tools are essential? How do I get the knowledge to use them safely with the children?"

After the CPD this had diminished to 16% but over 90% felt that they would need to offer extended CPD to staff in their schools. Only 5% had studied D&T in any depth in their Initial Teacher Training (ITT) course and majority had had so little that they had difficulty recalling what they had done – even those who had recently graduated. It was evident that whilst the CPD may have enhanced their confidence and knowledge they had to have time on their return to school to support others. They felt that this was unlikely to be given even though D&T was in the development plan for over 70% of the schools. There were always other priorities such as an Inspection, Tests at 7 and 11 years or the high profile of literacy and numeracy.

From the time of the introduction of D&T into the English curriculum, there has been clear inspection evidence (Office for Standards in Education (OFSTED), 1998, 2002, 2003, 2007, 11) of the importance of teacher subject knowledge to enable the planning and delivery of appropriate activities. OFSTED has identified the lack of subject knowledge as a key factor in the poor delivery of the subject in primary schools. Practitioners need the knowledge and understanding to be confident in their teaching. This issue is not confined to England. In a recent report (OFSTED, 2011) the importance of teachers having appropriate knowledge and understanding was highlighted by other countries such as Australia, Finland and Singapore. To be able to teach effectively, practitioners need to feel confident that they are able to support in-depth learning, even in the Foundation Stage (3-5 years). There is a need to be able to take learning further – taking into account the different depths of learning at all ages and stages of development.

Planning the D&T curriculum

Planning for D&T was the third key issue identified. Over 88% of the teachers indicated that their schools were moving away from subject specific teaching and introducing theme or topic work or the creative curriculum. There are no definitive definitions for these curriculum planning tools but in general terms it meant that they were looking to plan a curriculum that made links across the curriculum – albeit inappropriate in many cases. A few schools (6%) were making links but if the link was not relevant then single subject teaching was planned for. The majority of teachers in this research project had to 'fit in D&T' to whatever topic or theme had been chose and this had led to inappropriate D&T activity, particularly when linked to History. The user and purpose were not identified and children were making history artefacts without understanding why they were doing it and the purpose for the activity. A significant minority of teachers (24% of the 88%) indicated that they understood that change was needed but that they felt there was little hope of making the changes on their return to school. When the initial planning had taken place, comments such as: "the children are making aren't they" and "D&T links well with History as it is about products in the past" had cemented the link and the teachers felt that more changes would not be welcomed.

At this time in England there is much debate about a new primary curriculum. The 'Rose Review' (2009) renewed the debate and many schools took from this that a thematic/topic approach was being favoured (McCulloch 2011). However, the review did indicate the importance of subjects and the knowledge of these. Certainly Robin Alexander's review (2010) of the primary curriculum is being looked at favourably. Specialists are advocated, subject expertise really matters, and the children's voice is used. In Alexander's review, the children identified their interest in pedagogy, their desire to have teachers who know their stuff, who explain things in advance so they know what a lesson is about, make sure the steps put in are not too large, and give the children records of what they have learnt. At the present time English schools await the final new curriculum that the Government is planning but how the curriculum will be delivered still appears to be in the hands of individual schools. It appears unlikely that those who have already spent several years planning a themed approach will change unless forced to and inappropriate links may remain. It should be remembered that there is much research identifying the inability of pupils to make links across the curriculum in terms of both knowledge and skills. (McCormick 2004).

The following two factors – Valuing the subject and attitudes were the next most commonly identified.

Valuing the subject

From the data, particularly at the end of course, analysis indicated that whilst much finance and time had been invested by the schools in course attendance over 60% of the teachers felt that they faced a struggle when they returned to school to disseminate the changes that they felt were necessary to improve D&T. Reasons for this were focused around the lack of commitment of the head to develop D&T, lack of opportunities such as staff meetings and CPD sessions to offer support, and a change in the school development plan. Teachers who thought that they would be able to bring about positive change all indicated that the head's support was an important factor in this.

During the course 5% of teachers had undertaken D&T activities in different ways with parents. They were all enthusiastic about the outcomes and felt that the parents were now much more supportive of D&T. In one school parents were invited to see a presentation of a Y1 (5-6 year olds) project on Playgrounds. Comments from parents included: "I would never have realised how much thinking took place while she was making her slide; I thought it was just a few pieces of card put together and painted brightly." "I didn't realise that he knew all those words about mechanisms and he could make something that worked so well. He really had to think".

Attitudes

The notion that it is important to foster certain attitudes in D&T grew during the course. Majority of the teachers had been involved in the initiative 'Social and Emotional Aspects of Learning – (SEAL)' (Humphrey et al 2008) and were integrating its principles into certain aspects of the school curriculum. However none had identified D&T as a subject in which SEAL was crucial to the way in which teaching and learning could be improved. It is vital that children feel able to take risks, to communicate and to share ideas in a supportive environment, particularly in D&T as there are no right answers. There are many solutions that can be considered the 'best' depending on the criteria against which they are being judged (Humphrey et al 2008; Benson and Lunt, 2009). In this supportive environment it is then possible for children to work together with others to share ideas and then to either continue on their own path or work together to a common solution. Previous research has shown the importance of SEAL in D&T (Benson and Lunt, 2009).

Addressing the issues

The following are some possible key actions that could be taken to address the issues raised. They are organised to indicate how actions need to be taken at different levels – it is not just the practice of the teacher in the classroom that would lead to the development of good practice in primary D&T. Funding will always be an issue but it is vital to have a vision and a game plan that can be gradually, successfully undertaken.

The teachers

They agreed that for example, more money and equipment would always be useful, more refined ways of assessing the pupils would help them to progress more rapidly, and more time allowance in the curriculum would enable more in depth projects to be undertaken. However, over 90% of the teachers felt that if the first three issues were addressed then improvements in D&T in their schools would be significant. Quality CPD was essential and it should be mainly face to face.

At a school level

Head teachers/principals need to understand and be supportive of the subject if it is to flourish in a school.

There needs to be a clear understanding of what has gone before and what comes after each stage/phase of education (Capel et al 2003; Hargreaves and Galton 2002). This can be achieved through liaison (face to face and electronically), visits to different schools, reviewing resources including websites and publications and auditing the children through a short activity or project as they move from phase to phase. Secondary teachers would have a role to play in supporting their primary schools in ways that are most appropriate for them. There needs to be a mechanism whereby all practitioners have a clear understanding of the subject, whole school planning can take place, expertise is shared, and practitioners can readily access support materials and resources during the planning and delivering of activities.

In the wider community

It should be remembered that many adults will not be familiar with the nature of the subject. Parents may not have studied D&T in their primary school; those in business and industry can be confused and think the subject is linked to computers, or manufacturing.

Parent workshops, leaflets, displays in local community buildings and shopping malls have all proved useful in helping understanding. Invitations to local businesses, industrialists, and retailers to support challenges, to attend D&T events may stimulate interest and action.

At a national level

There needs to be a real understanding of the nature of the subject, the realisation of its value and a commitment to producing documentation that is clear, relevant and is not in a state of constant change. There need to writers/consultants that have a good understanding and experience of primary education and teaching, and practitioners need to be involved.

There needs to be a national programme of CPD that all schools can access, some of which should be face to face and include practical skills development.

There needs to be an active National Association (or equivalent) that can update, provide support and act as a sounding board at a national level.

Inspectors need to have a clear understanding of the nature of the subject in order that they can provide accurate and supportive ways to take forward schools and provide a national picture of D&T education.

Final thoughts

It may seem as though achieving quality D&T in all schools is an impossible task but it is possible, with appropriate support and enthusiasm from practitioners and heads. Although this small scale research has shown some of the stumbling blocks teachers have identified, in the recent OFSTED report (2011) in England it was exciting to see the improvements in primary D&T where teaching in design and technology was good or outstanding in seventy two percent of the schools visited and in none of them was it less than satisfactory. A decade ago over half the teaching was deemed to be satisfactory, unsatisfactory or poor. Children's achievement was good or outstanding in three fifths of the schools visited. It is a tribute to the tenacity and resourcefulness of primary teachers that these improvements have been secured, often with very limited training opportunities and resources.

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Hands-on material in technology education: the first cycle of a learning study

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Abstract

The aim of this paper is to describe the first cycle of a learning study in technology education, using a hands-on material, in a Swedish preschool class, i.e. pupils at the age of six. The study was conducted by three teachers and two researchers during fall 2011. Within a learning study, the pupils' learning is in focus in order to find out the opportunities and obstacles in teaching. The teachers and researchers are working in close cooperation when planning, observing, analysing and revising a specific lesson in which a specific learning object is dealt with. The learning study described in this paper, was carried out with starting-point in the revised Swedish curricula, launched in fall 2011. The results show that the use of a hands-on material may obstruct the view of the learning object, if the pupils are not able to manage the material. The results also indicate that an unsupported practical oriented task could prevent the intended learning object to appear for the pupils.

Introduction

Current research shows that a learning study is a vehicle to enhance pupils' learning (Lo, 2009; Marton & Morris, 2002; Marton & Tsui, 2004). When conducting a learning study the focus on pupils' learning is of central importance. How does the teaching facilitate, or prevent, the possibilities to learn? Through conducting the learning study our intention was to 1) implement a learning goal in technology from the new syllabus implemented in Sweden during fall 2011 (Skolverket, 2011) and 2) improve teaching and thereby enhance the pupils' possibilities to learn a specific learning object. The indirect object of learning in this study was *the ability to use strength in own constructions* (bridges) and the indirect object of learning is *framed structures*.

Moreover, both pupils' and teachers' knowledge as well as the researchers knowledge about the teaching, learning and understanding of the chosen learning object were expected to improve during the learning process of working as a team in a learning study.

In this paper we aim to describe how the first cycle of a learning study was carried out in a pre-school class. This is the first learning study of three, to be conducted in three different age-groups, in order to study the progression of a learning object in the new syllabus for technology education implemented in fall 2011.

Learning studies

An overall purpose with the learning study approach is "to generate data that enable us to establish the relationship between teaching and learning" (Pang & Ling, 2011), i.e. "to help teachers to help students learn the object of learning" (Ling & Marton, 2012 p. 8). Lo (2009) gives an overview of the development of the learning study approach in Hong Kong as from the late 1990s, as the very first learning study was carried out in Hong Kong in 1999. The first ones were conducted in mathematics, Chinese language and English language, but cover most school-subjects today as well as various levels of the school curriculum. Those learning studies show the significance of the specific classroom research model, which can be summarized as follows:

The teacher learning takes place in their own practice, where the aim is to help the pupils to learn what is intended to learn and "the learning study always takes the object of learning as the point of departure" (Lo, 2009 p. 177)

Since the teachers work in close cooperation with researchers, and thereby work as researchers who generate knowledge about their own practice, "the theory-practice gap, which has led to the failure of many attempts to change classroom practice, disappears" (Lo, 2009 p. 177).

The learning studies have resulted in pupils' improved learning (Ling & Marton, 2012). The learning studies have also contributed to the teachers' professional development and the learning of researchers (ibid.). Like in Hong Kong, several learning studies in Sweden have focused on (the Swedish) language (Gustavsson, 2008) and mathematics (Kullberg, 2010; Runesson, 1999; Wernberg, 2009) in compulsory school, but also in biology (Vikström, 2005) and technology (Björkholm, 2011) in compulsory school and in economy in higher education (Rovio-Johansson, 1999). The results of these studies show the similar result as in Hong Kong, i.e. that the variation of the critical aspects plays a crucial part in whether the pupils learn what the teacher intended them to learn (Lo, 2009; Marton & Morris, 2002; Marton & Tsui, 2004).

The predominant studies concern mathematics and language, and thus the research overview points at a need of conducting more learning studies in other subjects, like for example technology in the Swedish compulsory school.

Method

In the light of the results from the body of current learning studies, there is an assumption that teaching will improve and the pupils' possibilities to learn thereby will enhance when carrying a learning study through. Therefore, our intention is not to examine if the teaching will be improved, but rather to examine in what way a learning study may be implemented in technology education, using a hands-on material. The hands-on material used in this study was *4DFrame*, a teaching material, which was invented in South-Korea about ten years ago (Hedkvist Manninen, 2010). The material contains of a variety of connectors and tubes, which are combined to polygons, or any other structures (see for example figure 1), and different kinds of models with moving parts, like cars, airplanes, windmills and waterwheels.

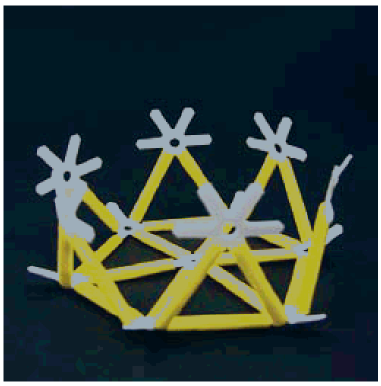


Figure 1 *4DFrame* structure

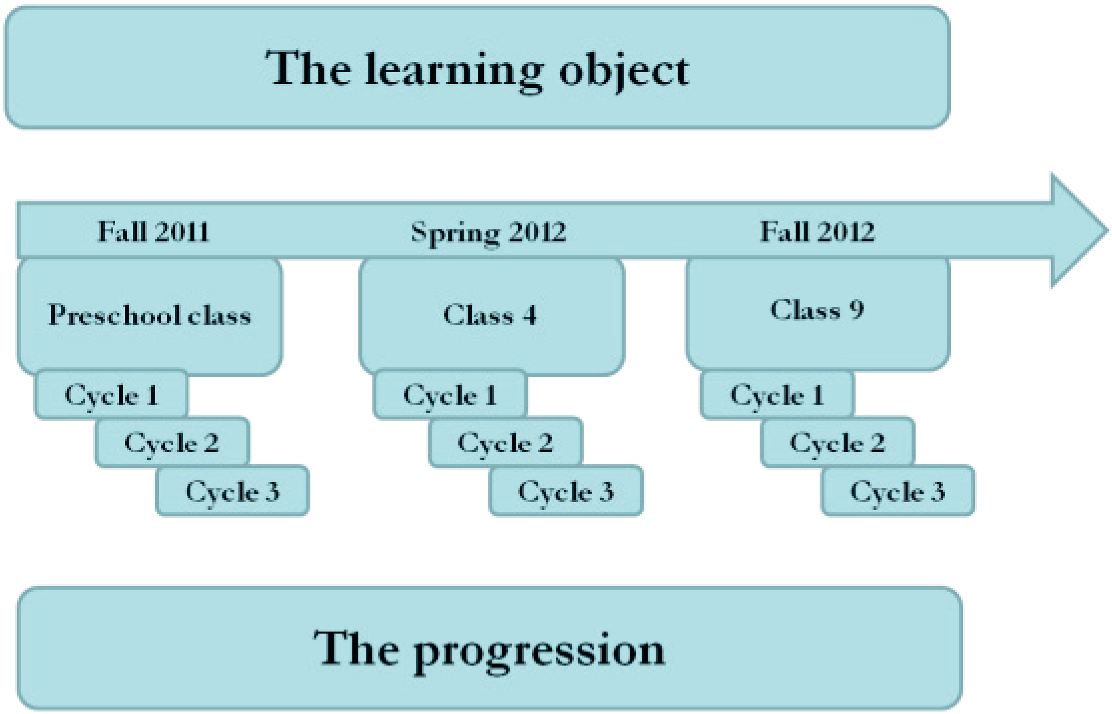
The teachers in this study have used *4DFrame* in their teaching for about two years and have both received training in the material and also themselves been in charge for in-service training.

Pang and Ling (2011) emphasize two important elements in the learning study approach. The first one is the distinct focus on the object of learning, i.e. to identify what the pupils should learn and the critical aspects that they must discern in order to understand the intended object of learning. The learning object has two aspects, the *direct* and the *indirect*. The *direct* object of learning is the content intended to learn and the *indirect* object of learning is a certain skill, value or capability that the pupils are supposed to develop.

The learning study approach follows the steps typical of an action research process (Pang & Ling, 2011). The different steps we have conducted are as follows:

- defining the learning object
- finding out the pupils' experiences of the learning object
- designing the research lesson(s) of the learning object
- teaching the research lesson(s)
- evaluating the research lesson(s) and identifying the pupils' learning problems
- adjusting the research lesson(s) based on the results (compare e.g. Marton & Ling, 2007).

These steps, i.e. the learning study cycle may be repeated in as many groups of pupils as necessary in order for the teachers to find out the necessary conditions for the pupils' discernment of the critical aspects of the learning object. In our project we are going to conduct three learning studies in three different classes (see figure 2) with the overall purpose to examine in what way learning studies may be implemented in technology education. In this paper *cycle 1* in the *preschool class* is described (see the arrow in figure 2). As figure 2 shows, each class is divided in three groups of pupils.



Figur 2 The timeline of the project

Data for this study was collected through a videotaped research lesson as well as pre- and post-tests. The pre- and post-test involved the pupils to build models of bridges of the hands-on material *4Frame,* sitting together in a classroom, followed by individual interviews. In our learning study we conducted three cycles, and in this paper one of them is accounted for, including seven pupils.

Results

The learning study followed the different steps described above and the following section describes the realization of the first learning study cycle.

The indirect object of learning in this study is *the ability to use strength in own constructions* (bridges) and the indirect object of learning is *framed structures*. The focus on these objects of learning was a result of the reading of the new steering document. The chosen objects of learning was also a result of the teachers' earlier experiences of pupils' difficulties in building solid constructions in general, but with *4Dframe* in particular. Since they are working a lot with fairytales in the preschool class, it was decided to frame the learning object within the story about *The Three Billy Goats Gruff*. The pre-test comprised to individually build a bridge of *4DFrame,* to the goats, and try the *strength* by hanging a weight on the bridge (see figure 2).

Before the pre-test the teacher read the story about *The Three Billy Goats Gruff* to the pupils and ended the story when the goats had walked over a bridge to graze on a meadow with green grass. She told them that there had been an accident, the bridge that the three goats had to walk over to come back to their home had broken, and invited the pupils to help the goats by, individually, build a bridge of the hands-on material *4DFrame*.

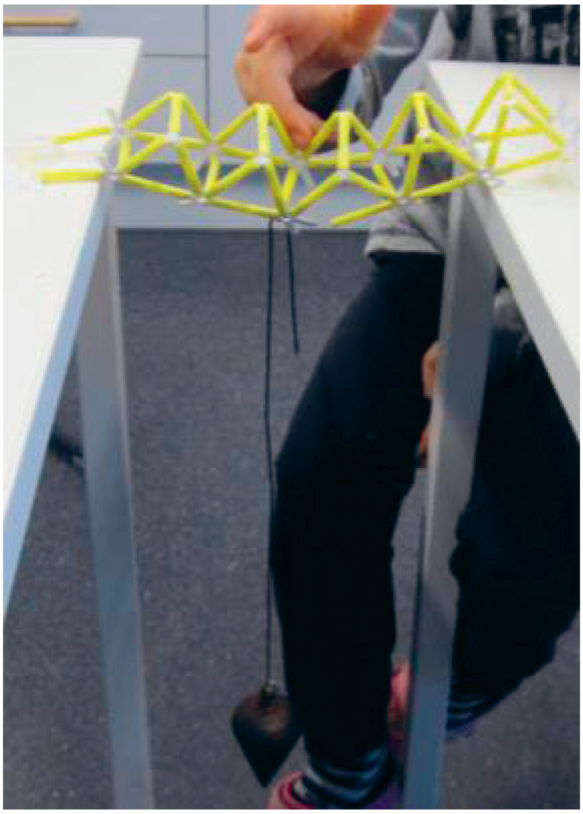


Figure 3 The solidity of the bridges were tested by a weight

When all pupils had finished their bridges, individual interviews about their constructions were conducted. These interviews constituted the pre-test and aimed at revealing pupils' conceptions about the chosen learning object. Consequently, in the pre-test we asked the pupils questions about their use of geometrical objects and if they knew what framed structure is and they tested the solidity of the bridge with a weight (see figure 3).

When analyzing the interviews we found that the pupils had difficulties in discerning the geometrical objects as crucial for strength. Therefore, the difference between a triangle and a quadrilateral was chosen as a critical aspect to focus on in the research lesson, that was taught three weeks after the pre-test.

During the research lesson the teacher built a framed structure (triangle) and a square of *4DFrame* and contrasted the strength of the two geometrical objects in two different ways, by:

1) moving the tubes back and forth – the tubes at the framed structure hardly moved, but the tubes in the square did
2) hanging a weight that showed that the framed structure did not change shape, whereas the square did.

The teacher encouraged the pupils to stand on the floor with the legs wide open, so a framed structure was formed of the legs and the floor, and the arms at their hips so there became two more framed structures:

> *Let us pretend that the wind blows.* (They blow with their mouths.) *And now you try to keep your balance and that is working great when you are standing like this. Maybe we are in a boat, and the boat is rolling back and forth, but we are able to keep the balance.*

Then the teacher contrasted the framed structure with a linear form, by asking the pupils to put their legs together:

> *If we are standing like this* (she put her legs together) *and letting the arms hang downward, and then the wind blows and the boat is rolling.* (The teacher and the pupils tipped over, some of the pupils even fell on the floor.)

Directly, after the research lesson the pupils were asked to build a new bridge followed by an interview. One of the pupils was absent at this occasion, so there were six pupils. When looking at the bridges it is obvious that the pupils rather made variants of their first bridges (see figure 4), than applied the experiences from the research lesson about framed structure. Notwithstanding, their first bridges were not simultaneously available until they had finished their second one.

Figure 4 Colored bridges from pre-test and white bridges from the post-test.

The pupils explained their thoughts about their second bridge as follows:

> *I built such a bridge last time too, I built in a similar way.* (Pupil 2, P2)

> *I wanted to build like last time.* (P4)

Those excerpts show that the pupils had their first bridge in mind, when they built the second one. There were also examples of ad hoc constructions, as the following excerpts show:

> *I just took some connecters.* (P3)

> *I don't know why it became as it did.* (P5)

One of the pupils said that *I just thought, I wanted to build like this* (P1) and another one explained that the new bridge had sides and a roof, since *it* [the bridge] *becomes more solid of the side and the roof* (P6).

When analyzing the research lesson and the post-test, we noticed that how the pupils had connected the *4DFrame* material often was more important in the test, than what geometrical objects they had used. Sometimes an expected stable construction broke, because they had not put the pieces together properly.

Discussion and conclusions

The analyses of the data material and the discussions we have had in the team have contributed to a great extent when it comes to examine our own teaching. The pupils' results in the post-test showed that there were no obvious connections between the lesson and the building task for the pupils, which supports the idea of repeating the learning study cycle in order to "helping teachers to help students learn the object of learning" (Ling & Marton, 2012 p. 8).

The teaching in the Swedish preschool classes follows the national curriculum, but the aims for the pupils to reach are not stated before class 1. This means that the pupils in this study are not used to be taught in this goal oriented way as in this learning study, which may have influenced the results. Nevertheless, there are mentionable findings from the first cycle. An important knowledge, obtained from the first cycle, is that the hands-on material, used in this study, added a dimension that prevented the understanding of framed structure, since the pupils needed to be able to handle the material properly first. Furthermore, since the results from the post-test from the first cycle were depending on how the pupils had connected the building material, than on what shapes they used, we saw that it was not possible for them to reach understanding of the intended object of learning before they could handle the material. Thus, our conclusion is that when using hands-on material in teaching, time is needed to be able to manage the material, before focusing on the intended object of learning. The handling of the hands-on material will otherwise obstruct the view of the learning object.

Furthermore, our study also indicates that the practical oriented task obstructs the view of a specific learning object, since the pupils rather made variants of their first bridges, than applied the experiences from the research lesson about framed structure. Does this mean that an unsupported practical oriented task could prevent the intended learning object to appear for the pupils?

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Exploring the capability of evaluating technical solutions: A collaborative study focusing on teaching and learning in the primary technology classroom

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Key words: Technology education, Technical solution, Fitness for purpose, Teaching, Learning, Variation theory

Abstract
The purpose of this study is to explore the capability of evaluating technical solutions in terms of fitness for purpose in the primary technology classroom. In the study we conceptualize pupils' ways of experiencing technical solutions in terms of what critical aspects are discerned. The analyzed data is drawn from a classroom study of technology education in a Swedish primary school. In this presentation we make an analysis of two technology lessons about technical solutions in grade 2 (pupils are 8-9 years old). We then analyze interactions between teacher-pupils, pupils and materials and tools. The results include pupils' different qualitative understandings of the specific content in terms of critical features discerned as well as how interactions in the classroom contribute to the collective development of technological knowledge.

Introduction
The capability to evaluate technical solutions is highlighted by several authors as an important educational outcome within technology education (Barlex, 2011; Coles & Norman, 2005). It is considered essential as an analytical tool within design decision-making capabilities and for interpreting existing technological objects and systems. The importance of developing the capability concerned is well advocated in technology curriculum documents across the world. In the Swedish technology curriculum of 2011 (National Agency for Education, Sweden, 2011) the knowledge area named technological solutions is about making technology of everyday life transparent and comprehensible to pupils. Teaching in technology should give pupils the possibility to develop their ability to identify and analyze technological solutions based on their function, i.e. what they do, and fitness for purpose; in other words, how effective they support their intended functions. Another example is the New Zealand technology curriculum, which highlights evaluating technical solutions in terms of fitness for purpose that includes the physical nature, i.e. its physical realisation such as shape, size and structure etc., and function (Ministry of Education, New Zealand, 2007).

The limited amount of empirical research done on this area of technology education (Frederik, Sonneveld & de Vries, 2011) indicates that pupils have difficulties in evaluating technical solutions in terms of fitness for purpose (Compton & Compton, 2011). So, how can this type of knowing be described and what does it take to know it? This conference paper is based on a collaborative interventionist teacher-researcher study in primary education focusing on this specific capability. The aim of the study is to contribute to the understanding of what it means to be able to evaluate technical solutions in terms of fitness for purpose. Through an iterative classroom based study, we explore what is critical for pupils' learning and how it can be enhanced by the teaching methods used.

Background

Phenomenography is a qualitative research approach (Marton, 1981) grounded in a non-dualistic ontological position, depicting experience as an internal relationship between the individual and the world. A basic assumption is that people perceive, understand or experience a particular phenomenon in the world in a limited number of qualitatively different ways. These qualitatively different ways of experiencing are logically related to each other and usually formed as a hierarchical structure with rising complexity, since the basic idea is that certain ways of experiencing something are more powerful than others.

From describing different ways of experiencing something, phenomenography has evolved and qualitatively shifted focus to questions concerning the nature of the different ways of experiencing (Pang, 2003). These different ways of experiencing mainly arise because critical aspects of the phenomenon are discerned. According to variation theory, learning is seen as a change in the learners' ability to discern critical aspects (Marton, Runesson & Tsui, 2004). From this it follows that, in order to make learning possible, these critical aspects must be made possible to discern. To do so, the critical aspects must be experienced as dimensions of variation. Variation thus enables the pupils to experience aspects that are critical for a particular learning and the development of certain capabilities.

> The critical features have, at least in part, to be found empirically – for instance through interviews with learners and through the analysis of what is happening in the classroom – and they also have to be found for every object of learning specifically, because the critical features are critical features of specific objects of learning (Marton et al., 2004, p. 24).

The critical features (or aspects) are thus related to the specific content and linked to the pupils' experiences of the object of learning. The critical aspects are not the same as pupils' difficulties with the content taught; instead it is what pupils must be able to discern to experience the object of learning in a certain way. One can thus identify critical aspects from the difficulties pupils exhibit by analysing the differences between ways of experiencing a phenomenon in terms of critical aspects discerned. When the critical aspects have been identified, the teaching must be planned to make it possible for pupils to experience patterns of variation that highlight the critical aspects of the object of learning.

Evaluating technical solutions

Technical functions are closely linked to human intentions and activities. In the user context, it is mainly the object's function in relation to the realization of the goal or purpose that is important, whereas the physical nature of the object is of minor importance. From an engineering perspective, however, the function of a technical object is mainly related to its physical nature, since it realizes or performs the function (de Vries, 2005; Kroes, 2002). A main task of engineer's is to design, develop and produce physical objects or systems that can achieve specific functions. These functions are often described in terms of criteria that the designed object must meet. The results in terms of technical solutions can be varied and some fulfill the function better than others. In the same way, some materials are better suited than others for use in a particular object in order to fulfill the function. Knowledge of functions as well as knowledge of the relationship between function and physical nature thus have evaluative elements, since knowledge of functions of objects is not about what they do, but rather what they ought to do (Jones, Buntting & de Vries, 2011).

Although there is limited access to research on pupils' understanding of technical solutions (Frederik, Sonneveld & de Vries, 2011), results indicate that pupils in both primary and secondary education have difficulties in understanding the link between physical nature and function, as well as the fitness for purpose (Compton & Compton, 2011). Oboho & Bolton (1991) studied how pupils in the 11-16 age range judged whether an artifact designed was a "good" or "bad" design. The younger pupils tended to respond more in terms of function than physical structure, stating what they could do with artifacts in a concrete operational way. The thinking appeared to go on towards structural terms with increasing pupil age, implicating that structure possibly is an understanding of function in a more comprehensive manner. Cajas (2001) highlights the need of research on how young children learn about functional properties of materials and states that young children have problems in distinguishing the properties of the object from the properties of the material from which the object is made. A contribution to the field is a study by Chatoney (2008), observing pupils, aged 6-7, and their development of knowledge about materials during activities comprising designing and making a toy. The analysis was based on the relationships between material and object, and teacher-pupil interactions. Results show that knowledge about materials has a central position in this kind of activity. The knowledge is introduced in the beginning of the activity, as soon as the functions are defined, and it is viable throughout the entire process.

In summary, research on this specific content within technology education indicates that it involves certain difficulties for pupils. Linking function and physical aspects seems to be hard for pupils as well as evaluating technical solutions' fitness for purpose in general. What one has to know in order to be able to evaluate the fitness for purpose of technical solutions' is, however, not self-evident. This study explores the meaning of this specific knowing by investigating what is critical for pupils' learning. By designing teaching activities that make it possible to discern these critical aspects, systematic teaching-learning strategies can be developed.

Method

The study was carried out as a learning study (Marton & Pang, 2006; Pang & Ling, 2011), which could be considered as a further development of the Japanese lesson study (Fernandez, Cannon & Chokshi, 2003; Lewis, 2000) or a hybrid of a design experiment (Brown, 1992) and a lesson study (Marton & Pang, 2006). The rationale for using this model is its focus on a specific object of learning, i.e. what the pupils are supposed to learn, and on the related teaching-learning process as it is practiced in the classroom. The model has a collaborative approach, in which teachers' professional knowledge is crucial in identifying pupils' learning difficulties and what it takes to know something. What is critical for learning something specific is explored through a systematic and iterative process (Marton & Ling, 2007).

Teaching context

The study was conducted with four teachers in primary school during a period of six months. Two classes in grade 1 and 2 (pupils aged 7-8 years) participated in the study. There were 23 pupils (grade 1) and 26 pupils (grade 2) in the participating classes. Based on teachers' experiences regarding pupils' difficulties in problem solving, the researcher and teachers agreed to choose the object of learning "to evaluate technical solutions in terms of fitness for purpose". In order to further set the limits of the object of learning, an opening-closing function was selected.

The design, implementation and preliminary analysis of the pre-test have been presented briefly (Björkholm, 2011). The analysis of the pre-test resulted in four qualitatively different categories, describing pupils' experiencing of the phenomenon, technical solutions' fitness for purpose. These were "effective for me in a specific situation", "effective for others in different contexts", "technical efficiency", and "relevant technical standard solution".

Based on the qualitative differences between these categories, dimensions were discovered and analyzed resulting in the following identified critical aspects:

a/ user and context
b/ material, form and components
c/ key component interaction

These critical aspects formed the starting point when planning the lessons. Variation theory was used as a tool when planning, opening up dimensions of variation, in order to make the intended learning possible. All lessons included a classroom discussion and a problem solving task given to pupil pairs. In order to focus the structure's significance for fulfilling the function, different kinds of solutions with an opening/closing function, like zippers, hinges, screw caps, were compared and examined. Different types of materials, such as plastic, metal etc., their areas of use and properties were emphasized in the first two lessons. Materials were chosen since it was the primary aspect mentioned by pupils' when talking about the physical nature in the pre-test. The two categories indicating the least complex understandings of the phenomenon focused on the user dimension. In order to open up dimensions focusing on the design context, materials could thus be considered as an appropriate link between user and design contexts.

Study design

The teachers-researcher group planned the first lesson based on the critical aspects identified in the pre-test. After the lesson had been conducted, it was analyzed by the researcher. At the subsequent teachers-researcher meeting the analysis was discussed and based on these results, changes in lesson design were proposed. Thereafter, a further three cycles with lesson planning, teaching and revising the lesson, were conducted.

Data was generated by audio recording the six teacher-researcher sessions, each of which was approximately two hours long. Each of the four lessons was video recorded and lasted for approximately 60 minutes. Texts, drawings and models produced by pupils during lessons were collected or documented by photo.

Analysis

All generated data was transcribed verbatim. The lessons were analyzed using variation theory as an analytical tool. Pupils' understanding of the object of learning during the lessons in terms of linguistic and bodily expressions was analyzed focusing on identifying difficulties in pupils' learning. These difficulties were then analyzed in order to understand and identify aspects of the object of learning not discerned by the pupils concerned. Since discerning these dimensions could be seen as essential for making the specific learning possible, they were identified as critical aspects. The preliminary results concerning critical aspects were discussed with the participating teachers using selected video sequences, and possible ways of understanding pupils' learning difficulties were discussed.

Results

This article investigates what it means to be able to evaluate technical solutions concerning `opening-closing´ in terms of fitness for purpose, based on the critical aspects identified during the research process in relation to pupils' difficulties in learning this specific content in the technology classroom. The analyses of the lessons suggest the following additional critical aspects:

- Materials separated from objects
- Main function and secondary functions related to key components

Materials separated from objects

When discussing different types of materials and their uses, some pupils had difficulties in distinguishing between the material and the object made of the material. In the following example, the material cardboard is discussed.

> *Teacher: /../ Cardboard, what can you use it for then? Erika?*
> *Erika: If you want to send big things to someone, you can pack it, so it won't break*
> *Teacher: Smart. Jens, what do you think?*
> *Jens: Pizza, pizza boxes*
> *Teacher: Oh yes, to put the pizza in, when bringing it home*
> *Ralf: You mean packages*
> *Teacher: Packages, you think. Yes, yes. Måns?*
> *Måns: Shoe boxes, all kinds of boxes*
> *Ralf: Then it is still packages*
> *Teacher: Yeah, right. Olle?*
> *Olle: You can have boxes, boxes, simply. Moving boxes, they are usually made of cardboard. If they are made of wood, then they are very difficult to handle and they can be prickly and hard and a lot heavier than cardboard, but cardboard is anyway quite strong to put heavy things in*
> *Teacher: It is good to use cardboard, a different material, you think*
> *Nina: There are boxes in here*
> *Teacher: Oh well, have you seen any?*
> *Nina: Over there (pointing)*
> *Teacher: Yes, we use a lot of cardboard boxes over there. Yeah, you know, talking about boxes /../*

Discerning the material as separated from objects made of the material, can be considered critical for the understanding of materials' significance for realizing the function. As seen in the above example some pupils just discern the object, when talking about cardboard. Without discerning the specific material, these pupils will not be able to evaluate this aspect of the technical solution. Thus, this aspect is identified as a critical aspect.

When the critical aspect is raised in the classroom discussion, the teacher gives the pupils opportunity to discern a variation of possible meanings of cardboard. The comments by the pupil Ralf give pupils opportunities to experience varying appearances of "package". Olle also contributes to the collective knowledge production in the class through his comment on the appropriateness of different materials from the user's view based on the properties of the materials, when comparing boxes made of wood and cardboard.

Main function and secondary functions related to key components

During lessons, some of the pupils had difficulties in distinguishing the main function opening-closing from the secondary function unlocking-locking. This problem is illustrated in the following example, when talking about a glass jar and its opening and closing function.

> *Teacher: What is it that makes this possible to open and close (opens and closes a jar with a hinged lid)? Is it this thing (the locking mechanism)? Or is it (opens it with the hinge)? What do you say, Molly? You don't know?*
> *Molly: It is perhaps this thing that fits into the hole (pointing to the rubber ring)*
> *Ellen: But it is just to, to prevent the glass, if you happen to drop it*
> *Markus: Or to make it tight*
> *Teacher: Aha*
> *Marcus: It is a weird hinge*
> *Rickard: Yes, exactly /../*
> *Teacher: It is some kind of hinge, some of you think*

August: Hooks!
Teacher: That doesn't look like anything we have seen before
August: Hooks, hooks, they are hooks
Teacher: Like hooks, see? Exactly, and this, what does it do, then (shows the locking mechanism)?
Molly: It closes the jar
Markus: Locks
Teacher: It perhaps locks the jar. It opens and closes like this (shows how the lid opens and closes with the hinge). And this one locks (shows the locking device). Ok

Different parts of the jar and their functions are examined through the collective discussion. To separate the locking from the closing function, the teacher focuses on the parts linked to the different functions. The pupil Markus is distinguishing between the closing and locking function, the teacher responds by showing the different parts and their corresponding functions. The pupils have thus possibilities to simultaneously discern the closing and locking function linked to different parts of the jar. In the discussion additional parts of the jar are examined and more secondary functions come up. Alternative functions of the rubber ring around the jar opening, as protection and tightening is mentioned. A further dimension of the physical nature linked to opening and closing function is highlighted in the example. The pupils talk about weird hinges looking like hooks. The pupils are given the opportunity to discern a hinge, a standard technical solution used for opening and closing, and compare it to other hinges they have seen before. They may in this way get the opportunity to experience an additional variation of types of hinges.

Discussion

In this study some critical aspects of the object of learning to evaluate technical solutions in terms of fitness for purpose, were identified during the learning study process. These critical aspects could be considered as further dimensions necessary to discern in order to develop this specific knowing. When a critical aspect is raised in the lessons, the teacher and pupils together construct the space of learning and what is possible to experience during lessons. A variation of answers and examples mentioned by the teacher and pupils, could lead to a deeper and more complex understanding of what it is to be learned. However, even if a critical aspect is made possible to experience in a lesson, it does not imply that all pupils learn.

The critical aspect concerning the distinction between the material and the object could be understood in relation to earlier research (Cajas, 2001) indicating that young children have problems in distinguishing properties of the objects from the properties of the material. During the learning process, discussion and design decision making seem to be vital in making 7-8 year-old pupils aware of concepts of materials and functions and how to evaluate technical solutions. Giving pupils opportunities experiencing the critical aspects through discussion, design decision making and involvement in the task, allow them to explore technical solutions in terms of material, components, main and secondary functions from the engineering view as well as from the user perspective. The importance of these factors for knowledge production in primary technology education is well highlighted by Chatoney (2008). Compton & Compton (2011) suggest the content needs to be introduced across more than one level and broken down into smaller ideas, in order to enable pupils' learning of technical solutions' fitness for purpose. An alternative way of interpreting pupils' difficulties and how to enable learning is in terms of critical aspects necessary to discern and to design teaching that give pupils opportunities to experience variation through classroom discussions and design activities that are linked to pupils' real problems and needs.

The question of how results from a learning study can be of use for other teachers and contribute to the collective knowledge base of the teaching profession has been discussed lately (Carlgren, 2010). A study by Kullberg (2010) indicates that it is possible to communicate the findings, in terms of critical aspects, from one learning study to other teachers and that the findings concerning pupils' learning may be valid even for other pupils and for different contexts. Learning study aims to have implications for teachers and teaching, what Nuthall (2004) refers to as pragmatic validity. Larsson (2009) suggests a variant of generalization in qualitative research, based on the perspective of the user of the research. Communicated patterns produced by research can be recognized in new cases and in that way the user of research get tools for identifying patterns in the everyday world. This kind of reasoning could hopefully be applied in the field of learning study. The findings from this study may be used by teachers in their own teaching context, looking for the critical aspects identified and using them for structuring the content of teaching in order to support pupils in experiencing technical solutions in more complex ways.

In a recent article reviewing the development of technology education over the last two decades, Jones et al. (2011) call for an increasing focus on classroom-based research in order to develop understanding of how pupils learn in technology and how teaching can enhance pupils learning. They state that such work can make great contributions in terms of methodologies that are theoretically and empirically based. The involvement of teachers as research partners is well highlighted as a way to break down some barriers between the academic field and practice. The findings of this study will hopefully contribute to the understanding of pupils' learning in technology and how teaching can enhance learning, as well as in terms of an empirically and theoretically based methodology that takes its starting point in the classroom and benefits of teachers' professional knowledge.

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Technology & design as contexts for science and mathematics? An empirical study of the realisation of curriculum intentions in Norwegian schools

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Abstract

The research presented in this paper investigates how conceptual knowledge from mathematics and science is addressed in four extensive cross-curricular teaching projects in different Norwegian schools (year 3-10). Classroom sessions related to the project were videotaped with two cameras recording selected groups of students and one recording the classroom as a whole. Recordings cover a total of ca 250 hours. Selected parts of the material were analysed with regards to communication between teacher and students and within student groups. Results indicate that conceptual knowledge from science is rarely addressed by teachers and students. With some interesting exceptions, this also applies to mathematics. Knowledge discussed by teachers and students was for the most part technological in nature and did to a low degree draw on or motivate for conceptual knowledge from science and mathematics.

We interpret this finding as an effect of two matters: Firstly, technological tasks mainly require technological knowledge rather than science and mathematics in its pure form. Secondly, the conceptual knowledge that is of relevance is not brought to stage due to the strong focus students as well as teachers have on the practical aspects of the student project. From the study we conclude that technology in the Norwegian curriculum should be strengthened as a knowledge domain in itself, and not considered as merely contexts for the learning of conceptual knowledge from other subjects. Links between technology and science/mathematics need to be conceptualised in other ways.

Introduction: Design and Technology in the Norwegian curriculum

The research presented in this paper investigates the relationships of technological knowledge and conceptual knowledge from science and mathematics as it comes to expression in the classroom. This is done by means of six of four extensive cross-curricular teaching projects in different Norwegian schools (year 3-10). In our analysis of the teaching projects, we focus on conceptual knowledge, in the meaning of declarative, generic knowledge comprising concepts, relationships and principles that may have significance for action (see McCormick, 1997).

In the Norwegian curriculum for compulsory school, implemented in 2006, design and technology is positioned as a cross-curricular topic involving the three subjects Arts and crafts, Science and Mathematics (Utdanningsdirektoratet, 2006). This curriculum arrangement was partly based on the vision that practical, technological projects for pupils would serve as constructive and motivating contexts for learning science and mathematics (see Bungum, 2004, 2006). The curriculum document underlines the link to science in particular by stating: "The interaction between natural science and technology is a key part of this main subject area. Natural science principles constitute the basis for understanding technological activities" (Utdanningsdirektoratet, 2006).

The curriculum of the three subjects involved is, however, not very well coordinated. In Arts and crafts, design is represented as a main subject area. In lower secondary school it includes the design and making of products, tools and techniques for this process and also perspectives on consumerism and sustainability. In the mathematics curriculum, the subject area is represented mainly by aims about enabling students to apply skills from algebra and geometry in contexts such as design and technology. In Science, design and technology is described as a specific main subject area, combining aims that are technological in nature with aims that focus on applying science knowledge in practical contexts.

There is little systematic evidence of how the subject area technology and design is realised in schools, but a small survey indicates that many schools do not pay particular attention to the cross-curricular nature of the subject area (Dundas, 2011).

Epistemic perspectives on science, technology and their relationship in schools

The positioning of technology in the Norwegian curriculum actualizes various perspectives on the nature of technological knowledge. In the philosophy of technology it is commonly accepted that technology represents a domain of knowledge in its own right, and should not be regarded as straight-forward applications of generic knowledge from science and other academic disciplines (see e.g. Staudenmaier, 1985). The different purposes of science and technology are often used to make a demarcation between the two areas of activity. In addition, technology is highly situated in the practical context, and involves knowledge that cannot be understood simply by means of discerning the relevant scientific laws (Boon, 2006). To be useful, this knowledge needs to be reconstructed, combined with other forms of knowledge and adjusted to the situation at hand (Layton, 1991). Other forms of knowledge may be knowledge of operational principles (Vincenti, 1990) where pure theoretical knowledge may explain working principles of each component, but not how they operate together on a systemic level.

The focus on technology as independent of science may, however, become too one-sided (Tala, 2009), as science and technology are in their modern form highly interrelated, described as a "seamless web" (Hughes, 1986), post-academic science (Ziman, 1984) or technoscience (Bencze, 2001; Tala, 2009). Many have pointed to that this close relationship should also be represented in the schools' curricula, in teaching and in how students engage with science and technology in their general education (Barlex & Pitt, 2000; Bencze, 2001; Hadjilouca, Constantinou, & Papadouris, 2011; Petrina, 1998; Sidawi, 2007).

The way technology is framed in the Norwegian curriculum provides opportunities to explore the potential for the teaching of science and other subjects in a context of design and technology, and to investigate how students may make use of knowledge from these subjects in creating technological artefacts and systems.

Research methods

The empirical study presented in this paper investigates how conceptual knowledge from mathematics and science is addressed in four extensive cross-curricular teaching projects in different Norwegian schools (year 3-10). Four teaching projects were developed by the research group in cooperation with the local teachers, but fully taught by the teachers in six different schools. In the development, we attempted to create cross-curricular projects with a good potential for incorporating science and mathematics, but also that the projects should be realistic to run in schools with regards to materials as well as teacher knowledge and skills. With one exception, which was a one day event, each project lasted ca 30 hours, and the schools involved ran only one project.

Classroom sessions related to the project were videotaped with two cameras recording selected groups of students and one recording the classroom as a whole. Recordings cover a total of ca 250 hours.

From the video material, we have analysed approximately 100 situations of communication, where either students or teacher made contact in order to discuss aspects related to the project. The analysis focuses on dialogues between teacher and groups of students, since the use of language constitute an essential aspect of learning (Mortimer & Scott, 2003). This means that we have not considered the value of mere practical experiences for future learning and motivation in science and mathematics.

Selected parts of the material were analysed with regards to science and mathematics content in the communication between teacher and students and within student groups. The first step in the analysis was to choose situations where either the students or the teachers made contact in order to discuss aspects related to the project. Thereafter the communication in each situation was classified based on whether concepts related to science or mathematics was discussed or not. The need for science and mathematical knowledge in order to solve the technological challenge given was also evaluated.

In order to secure data validity, observer triangulation (see Robson, 2002) was conducted between members of the research group in interpreting and coding the video data.

The student projects

The four student projects were:

1. Models of buildings

In this project students used the software Google Scetchup to design a building on the computer, and to make templates of the individual parts with correct measures. The conceptual knowledge involved is the scales students work with in order for the measures to be accurate. With help from the templates students then built the model in cardboard and other materials. This project was put into practice at three schools. At one school students in grades 3-7 designed a simple open shelter to be used for outdoor activities in the local community. The fact that such a shelter was to be built, and that the students' models would be used to generate ideas for its design, added an aspect of authenticity to the project. In another school, students in grade 9 designed the house they wanted to have in the future. And at the last school students at grade 8 designed constructions for a playing ground, also a project that was to be realised in full size by the local authorities.

2. Model of town with lights

The project involved building a model of the students' home town Hammerfest, with streets and buildings, and surrounding landscapes including mountains and the fjord with an island. The project was undertaken in a class of grade 10, where students worked in groups performing various parts of a joint model. Students themselves were to decide on what scales to use and what parts of the city and the landscapes that were to be represented in the model. The model was to be enlightened by electric light, making a link to the fact that Hammerfest was the first town in Norway with electric street lights. The project has potential for working with conceptual knowledge in terms of scales in mathematics and principles of electrical circuits in science.

3. Model of oil platform and drilling system
The activity was undertaken in grade 8 and formed part of a larger project about oil exploration. Students used Lego Robotics to construct the drill, and were allowed to use various materials for making the platform. The main challenge for the students was to design a motor system that allowed the drill to rotate and simultaneously make a vertical movement. The project potentially involve concepts and principles from mechanics, such as force and transformation of movement.

4. Model of the solar system
In this project students in grade 5 created a model of the solar system with correct scaled-down dimensions. They made models of the sun and the planets in various materials with appropriate colours and relative sizes calculated by using scales and information about real planet sizes. The model of the sun was placed at the school, and students used a GPS system to find the correct position of the planets in the landscape surrounding the school. This way the project aimed at facilitating students' skills in working with scales in general, and dimensions in space in particular.

Results

Results indicate that conceptual knowledge from science and mathematics is rarely addressed by teachers and students. Knowledge discussed in the dialogues was for the most part technological in nature. Clear evidence of increased motivation among students can be found, but this motivation seemed to be directed towards the project as such and not towards specific school subjects.

In none of the situations analysed students or the teacher discussed any concepts or principles from science. With some interesting exceptions, this also applies to mathematics in project 1-3. When mathematics was brought into the discussions, the initiative came from the teacher and was not really necessary for solving the task. In project 4, however, mathematical calculations of measures were crucial for finding the distances in the model of the solar system. Mathematics thus formed part of the initial work in the project.

The lack of science and mathematics content in project 1-3 can be illustrated through three situations that appeared to have a good potential for incorporating concepts and principles from science and mathematics. In the first situation, grade 10 students in project 2 (model of town) are working with scales between a map and the decided size of their model. Buildings were supposed to also have a correct scale relating to the landscape. The task of calculating with scales soon became very complex, due to the irregularity of the shapes. Some of the students then figured out they could make use of an overhead projector in transferring the map to the size of their model. In this tool, the transfer of measures to a different scale is "inbuilt". Students made use of their creativity and understanding of how a projector can assist in fulfilling their task. This illustrates how technological work is dynamic and draws on combinations of knowledge and ideas. Understanding of scales formed part of the students' solution, even if they didn't succeed with calculations. They did, however, succeed in finding an effective solution for an optimal result, and thus did not need to conduct the complex calculations that would be needed if a polygon should be scaled up.

The second situation is drawn from the same student project, and relates to electricity. Since electric light chains (for Christmas decorations etc) are cheap and easily available, neither students nor teachers found it worthwhile wiring their own circuits with bulbs. This could have given opportunities to learn about differences between ways of connecting (series / parallel), and relations between voltage, current and energy use. However, from a technological point of view, the class chose the optimal solution with regards to stability in the circuit and their use of time and effort, which solved the problem without time consuming activity that were doomed to give suboptimal results.

In the third situation, students in project 3 were working with construction of a model of a drilling rig. The task of making a system that allows for rotation and vertical movement simultaneously can be interpreted as involving mechanics in terms of forces, transformation of movement and energy transfer. Yet they have some relevance, concepts and principles from physics were not of any use in solving the task itself. The task rather required experience with and understanding of technological principles in a less abstract form and adjusted to the actual context as described by Layton (1991).

Conclusion and implications

The results of the study shows that conceptual knowledge from science and mathematics to a little degree formed part of the cross-curricular projects on design and technology, neither as tools to solve the tasks nor as a learning outcome. This deviates somewhat from the curriculum intentions and some of the arguments put forward to introduce design and technology as a cross-curricular topic in Norwegian schools.

We interpret this finding as an effect of two matters: Firstly, technological tasks often require mainly technological knowledge rather than science and mathematics in its pure form. Secondly, the conceptual knowledge from science and mathematics that is of relevance is not brought to stage due to the strong focus students as well as teachers have on the practical aspects of the student project. Project 4 about the solar system works as an exception here, showing that mathematics may form a constructive part of a technology project, given that the mathematics knowledge is an absolute prerequisite for solving the task. In the other projects it was not.

From the study we suggest that technology projects *may* provide useful practical contexts for conceptual knowledge from mathematics and science, but if it does not form a necessary tool this knowledge should be addressed in separate sessions in the subjects. Rather than viewing technology and design as contexts for the learning of science and mathematics, effort should be put into identifying and conceptualising the genuine technological knowledge to be represented in the curriculum.

This does not mean that links to science and mathematics are absent from the technology projects we have studied. The links do, however, go beyond the learning and application of pure conceptual knowledge. Firstly, the projects provide opportunities for experiences that facilitate a deeper understanding of specific topics in science and mathematics. For example, in project 4, gave students a bodily experience of the relative dimensions in the solar system, an experience that is hard to get from textbooks and classroom teaching. Secondly, the projects involve aspects of systematic experimentation that resembles how professionals educated in a range of disciplines, including science and mathematics, work with problem solving in authentic projects in technological contexts. In order to have any effect on students' motivation and understanding, these links must be made explicit to students.

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Applying STEM Instructional Strategies to Design and Technology Curriculum

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Abstract
Proponents for STEM education argue it has potential to contribute to student learning, their lives, and global economies. STEM's promise is viewed with enough credibility that some nations have begun to adopt its principles through mandates and funding. If STEM is seen as a practical solution for future learning, then it is necessary for design and technology instructors to consider how to incorporate STEM strategies into their curriculum. The purpose of this paper is to illustrate three approaches that can be used in STEM education (*Silo, Embedded, and Integration*) and apply them within the context of a technology education course.

Introduction
As a growing trend in the academic world, STEM education is used to address real-world situations through a design-based problem-solving process, much like those used by engineers or scientists (Williams, 2011). STEM advocates argue approaching education through these strategies enables students to recognize their education as applicable and essential (Banks, 2009).

This is significant for technology education as it is presented with an opportunity to increase its validity (Kelley, 2010). Although technology education programs continue to enhance students' school experiences, they must dispute a stigma of irrelevance for those learners who desire to pursue an academic course of study (Wendy Fox-Turnbull, personal communication, October 20, 2011). To offset this vocational image, technology education instructors can increase the presence of academic content into their curriculum through including STEM, design-based learning strategies.

Three approaches for teaching STEM education are currently being practiced. The distinction between each of these methods lies in the degree of STEM content used. They include *silo*, *embedded*, and *integrated* approaches. Following a discussion of each of these strategies, the researchers provide an example lesson, *Infection Detection*, where each approach is applied.

The Silo Approach

The s*ilo* approach to STEM education refers to isolated instruction within each individual STEM subject (Dugger, 2010). Emphasis is placed on "knowledge" acquisition as opposed to technical ability (Morrison, 2006). Concentrated study of each individual subject allows the student to gain a greater depth of understanding of course content. This focused instruction stirs appreciation for the beauty of the content itself (Jenny Chiu, personal communication, September 27, 2011). This is how science, technology and engineering, and mathematics education been approached in curriculum design and teaching.

Silo STEM instruction is characterized by a teacher-driven classroom. Students are provided little opportunity to "learn by doing", rather they are taught what to know (Morrison, 2006). Morrison (2006) suggests the prevailing belief behind s*ilo* STEM instruction is to increase knowledge which generates judgment. An instructor operating within the confines of their discipline can produce quality instruction for students which must not be overlooked. It is propelled by mandates for students to learn content and pass tests. Figure 1 depicts the s*ilo* approach.

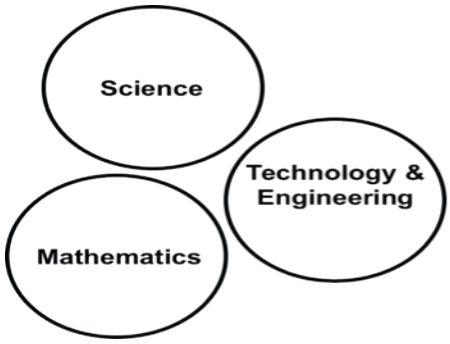

Figure 1. Silo approach to STEM education. Each circle represents a STEM discipline. The disciplines are taught separately which keeps the domain knowledge within the confines of each discipline.

There are potential shortcomings associated with a purely *silo* method to STEM instruction. First, Dickstein (2010) suggests s*ilo* instruction has the propensity to isolate prospective STEM contributors to the field. It has been observed females are less likely to participate in courses containing the word "engineering" within the title, e.g. Civil, Mechanical, and Electrical Engineering. The lack of female participation limits valuable perspectives which could enhance STEM related fields (Bour, Bursuc, & Konstantinidis, 2011).

Secondly, it is possible *silo* instruction may encourage students to maintain a segregated perception of content courses. Without practice students may fail to understand the integration which naturally occurs between STEM subjects in the real-world (Breiner, Harkness, Johnson, & Koehler, 2012).

Finally, the *silo* approach can unintentionally inhibit students' academic growth. It may tempt teachers to rely on a lecture-based methodology rather than a hands-on approach, which research indicates is more desirable for student learning (Dickstein, 2010; Deslauriers, Schelew, & Wieman, 2011). While an instructor may choose to implement a variety of teaching strategies, in a *silo* classroom, the content would likely remain the focus of study. This may limit the amount of cross-curricular stimulation and student understanding of the application of what they must learn.

The Embedded Approach

Embedded STEM instruction may be broadly defined as an approach to education in which domain knowledge is acquired through an emphasis on real-world situations and problem-solving techniques within social, cultural, and functional contexts (Chen, 2001). In practice, e*mbedded* teaching is effective instruction because it seeks to reinforce and complement materials that students learn in other classes (ITEEA, 2007). A technology education teacher uses embedding to strengthen a lesson which benefits the learner through understanding and application.

In a STEM *embedded* approach, the technology education content is emphasized (just as it would be if taught in the *silo* approach), thereby maintaining the integrity of the subject matter. Yet, *embedding* differs from the *silo* approach in that it promotes the learning through a variety of contexts (Rossouw, Hacker, & de Vries, 2010). However, the *embedded* material is not designed to be evaluated or assessed (Chen, 2002). Figure 2 depicts the *embedded* approach to STEM education.

Figure 2. Embedded approach to STEM education. Each circle represents a STEM discipline. Domain knowledge from at least one discipline is placed within the context of another. The embedded components are not usually evaluated or assessed.

Although *embedding* can be a valuable instructional strategy, there are challenges that must be considered. For example, the *embedded* approach may lead to fragmented learning (Hmelo & Narayanan, 1995). If a student cannot associate the *embedded* content to the context of the lesson, the student risks learning only portions of the lesson rather than benefiting from the lesson as a whole. Additionally, it is essential to ensure the *embedded* components are something the student has prior learning and are grade level appropriate. If the instructor has to stop and teach or remediate a student on the *embedded* knowledge, the students' learning may be disrupted (Novack, 2002).

The Integrated Approach

An *integrated* approach to STEM education envisions removing the walls between each of the STEM content areas and teaching them as one subject (Breiner et al., 2012; Morrison & Bartlett, 2009). *Integration* is distinct from *embedding* in that it evaluates and assesses specified standards or objectives from each curriculum area that has been incorporated within the lesson (Sanders, 2009).

Ideally, integration enables a student to gain mastery of competencies needed to resolve a task (Harden, 2000). Training students in this way is perceived beneficial as it is a multidisciplinary world reliant on STEM concepts, which students must use to solve real-world problems (Wang, Moore, Roehrig, & Park, 2011). Additionally, instructing through *integration* produces the expectation of increased interest in STEM content areas, especially if it is begun when students are young (Barlex, 2009; Laboy-Rush, 2010). Two common approaches to integrative instruction are *multidisciplinary* and *interdisciplinary integration* (Wang et al., 2011).

Multidisciplinary integration asks students to connect content from various subjects taught in different classrooms at different times. It relies on corroboration between faculty members to ensure content connections are made (Wang et al., 2011).

Wang et al. (2011) explain *interdisciplinary integration* begins with a real-world problem. It incorporates cross-curricular content with critical thinking, problem-solving skills, and knowledge in order to reach a conclusion. *Multidisciplinary integration* asks students to link content from specific subjects, but *interdisciplinary integration* focuses students' attention on a problem and incorporates content and skills from a variety of fields. Figure 3 depicts the *integrated* approach.

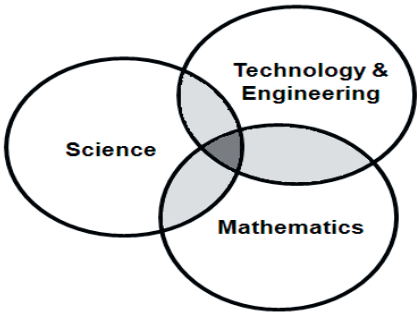

Figure 3. Integration approach to STEM education. The STEM content areas are taught as though they were one subject. Integration can be done with a minimum of two disciplines but is not limited to two disciplines. The lines indicate the various options in which integration could be achieved.

Proponents of STEM education may suggest integration is the best approach for STEM instruction (Laboy-Rush, 2011; Wang et al., 2011). However, it is important to remember individual STEM disciplines "are based on different epistemological assumptions" and integration of the STEM subjects may detract from the integrity of any individual STEM subject (Williams, 2011, p. 30). In other words, as Harden (2000) explains, "subjects and disciplines give up a large measure of their own autonomy" when working within the confines of integration (p. 555). Therefore, instructors must consider how these potential effects can inhibit the integrity of their content and decide if integration is the most beneficial method of instruction.

Additionally, instructing through integrative approaches requires pedagogical training. Teachers often struggle to instruct through integration (Williams, 2011). This may hinder students' understanding due to a lack of general structure within the lesson, a phenomenon referred to as the potpourri effect (Jacobs, 1989). In the potpourri effect, teachers incorporate material from each discipline, but they fail to create one common objective.

Perhaps even more detrimental than the potpourri effect is the polarity effect. Teachers may become territorial over specific subject matter limiting the incorporation of other content. This may lead to a lack of understanding by students (Jacobs, 1989). Careful consideration must be made when choosing the appropriate method of instruction. Each method discussed offers strengths and challenges which must be addressed when implemented.

Infection Detection Activity

This activity was designed using the International Technology and Engineering Educators Association's (2007) *Standards for Technological Literacy*. Standard 14, Medical Technologies, stipulates students will develop an understanding of and be able to select and use medical technologies. A technology education teacher would use this standard while teaching their appropriate grade level content.

In this lesson, students are told to assume the role of an immunologist and investigate a new virus which is making people ill in a remote Amazon village. They are tasked with designing a vaccine to alleviate the spread of this virus. Each team creates a portfolio containing the components listed in Table 1.

A technology and engineering laboratory using the *silo* approach emphasizes the activities centered on developing the virus model, vaccine administration devices, or the packaging. Through an *embedded* approach a technology education teacher can *embed* domain knowledge from science by exposing students to microscopic images of diseases, vaccines, and viruses or they can *embed* mathematics when students use measurement to determine the amount of vaccine to be administered, a dosage schedule for vaccine administration, or the design of a box for delivering the vaccines.

Finally, this lesson (Table 1) can become an example of the *interdisciplinary* approach if all components are taught by the technology education teacher. However, if technology education teachers were instructing through a *multidisciplinary integrative* approach, each teacher (the technology educator, science, and/or mathematics teacher) would address the same lesson through their specific course content during their instructional time period on the same day. They would evaluate and assess those learning requirements associated with their learning objectives. Table 2 illustrates the learning outcomes for the *Infection Detection* activity by grade level.

Table 1. Operation Infection Detection

	Operation Infection Detection – ITEEA Standard 14 – Medical Technologies			
	K-2	**3-5**	**6-8**	**9-12**
	Vaccinations	*Vaccines & Medicine*	*Immunology*	*Telemedicene*
	Students will create a portfolio containing the following:			
Science	Collage of items needed to care for infected people and belongings	Virus symptom card detailing virus name and symptoms	Medical disease webpage with virus name, pictures, symptoms, plan of action, vaccine information, and how to prevent additional spread	Medical disease webpage with virus name, pictures, symptoms, plan of action, vaccine information, and how to prevent additional spread
Technology and Engineering	Create a three-dimensional model of the virus within these constraints: Free standing, 6"x12" Create a prototype of a vaccine administration device	Create a three-dimensional model of the virus within these constraints: Free standing, 6"x12" Create a prototype of a vaccine administration device	Create a prototype of the virus within these constraints: free standing, 12"x12", and placed on a structure that can be rotated so that all angles of the virus may be seen Create a prototype of a vaccine administration device	Computerized, prototype of the virus; image must rotate so that all angles of the virus can be seen, and it must be in various colors Create a prototype of a vaccine administration device Packaging for an air drop of vaccine. Limited to a box size of 2'x4'. Included in this box must be the device for vaccine administration
Mathematics	A way to measure amount of vaccine administered Three-dimensional model measurement	A way to measure amount of vaccine administered Three-dimensional model measurement	A Chart/Rubric for vaccine effectiveness Three-dimensional model measurement A way to measure amount of vaccine administered	A Chart/Rubric for vaccine effectiveness Dosage schedule A way to measure amount of vaccine administered

Note: This table summarizes a STEM activity for students in grade levels K-12 that utilized ITEEA (2007) Technology Standard 14 – Medical Technologies. It is entitled *Operation Infection Detection*. It is strongly recommended by the authors that the activity be read prior to reading through the strategies. The full detailed activity can be found by visiting the following website: www.operationinfectiondetection.yolasite.com

Table 2. Learning Outcomes for Infection Detection by Grade Levels

	K-5	*6-8*	*9-12*
		Students will be able to:	
Science	• Identify scientific characteristics of viruses • Explain how a virus infects its host	• Identify scientific characteristics of a virus to help prevent additional spread • Diagram a virus • Explain how a virus infects its host	• Identify scientific characteristics of a virus to help prevent additional spread • Diagram a virus • Explain how a virus infects its host
Technology & Engineering	• Define characteristics of Immunology • Demonstrate understanding of vaccination usage and administration tools	• Define Immunology • Demonstrate understanding of vaccination usage and administration tools • Demonstrate understanding of products and systems used to provide information about viruses	• Define Immunology • Demonstrate understanding of vaccination usage and administration tools • Demonstrate understanding of products and systems used to provide information about viruses • Define Telemedicine • Construct a plan for delivering and administering vaccines by airdrop through telemedicine
Mathematics	• Measure prototype size • Demonstrate dosage amount estimations	• Measure prototype size • Measure dosage amount	• Measure prototype size • Measure dosage amount • Create a viable dosage schedule • Apply constraint size and weight to configuration of vaccine box

Note: This table illustrates learning outcomes for the *Infection Detection* activity. Each discipline has learning requirements which can be effectively taught through any of the three approaches. Depending on the subject and approach, the appropriate grade level standards that align with the learning requirements would be identified and used in the lesson.

Conclusion

As society seeks a technologically literate and STEM proficient student, it is important to evaluate and pursue methods for delivering technology education instruction. This paper was written with the intent to provide technology education teachers with an improved understanding of STEM including three distinct STEM instructional approaches (*silo*, *embedded*, and *integration*) that can be used to enrich and differentiate the content that is being delivered. Each approach was defined, strengths and shortcomings were described, and ideas for implementing the STEM approaches were presented through the *Infection Detection* activity. Teaching any of these strategies requires technology education teachers to evaluate their content and determine how best to serve students through each approach. Although interests are forming about the significance of STEM and technology education, and steps have been made through instructional practices, additional work is necessary. The researchers suggest further studies in STEM curriculum mapping, pre-service STEM teacher education, creation of professional development activities to enhance the use of STEM instructional approaches, and the development of assessments to determine the effectiveness of STEM instructional approaches on student learning. We must proceed to enhance the potential of technology education as a primary through secondary school subject.

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Democratic Consensus on Student Defined Assessment Criteria as a Catalyst for Learning in Technology Teacher Education

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Keywords: Values, Democratic Assessment, Technology Education, Capability

Identifying the contemporary values and goals that underpin a new conception of technological education are important when contributing to the education of undergraduate initial technology teacher education students. Motivating students to explore and establish what is of value in their subject domain is a significant challenge facing academics and practitioners alike. Williams (2009) presents design based technology education as being embedded in the personal and social context of the student, where the value of what is being learned is as important as the content itself.

Design based tasks have the potential to encourage students to establish and make explicit their views and beliefs. Requiring students to establish their own assessment criteria introduces uncertainty, risk, and confusion into the process of learning. Establishing what is of value now becomes the primary concern for the learner in a quest to demonstrate their capability within a personal view of the subject domain.

This study implemented a constructivist approach to learning in a design based task focused on the development of design, craft and processing skills. The method employed a peer assessment strategy through the use of an Adaptive Comparative Judgement (ACJ) model of assessment that required students to democratically assess the work of their peers. Assessment criteria were not made explicit, as students were encouraged to present their own conception of capability developed throughout the learning activity.

The significance of the study was highlighted by the reaction of the students to their dual role as learner and assessor and how this affected their learning. The empirical evidence collected highlights the importance of empathy as a mediator when developing critical reflective practise. The study outlines the cultural impact of democratic peer assessment on initial teacher education students while establishing what to value within their subject domain.

Rationale for the study

With its origins in vocational and craft training, technology education is challenged to reinvent its value and objectives within a broader conception of schooling. Grappling with the epistemic cultural complexities, the definition of technological education needs careful consideration. In response to a contemporary design activity, this study focuses on the capacity of Initial Technology Teacher Education students to present, identify and value what constitutes capability within the technology domain.

Complexities of Technology education

Williams (2009) describes how technology education is struggling for relevance and definition in the post modern era of globalization. Rasinen (2003) identifies two distinct forms, the *lehrplan type* which provides very specific details of the domain content and how it should be taught with the *Standards type* concentrating on the curriculum goals to be met within the subject domain. A shift toward the standards type approach to curriculum is identified with the onus being placed on personal development of students' capabilities and thinking skills (Rasinen, 2003). To achieve the contemporary goals of technology education Williams (2009) proposes that "a personal relevance type of curriculum design may be the most appropriate". This is based on humanistic educational theory with its emphasis being on personal growth, integrity, autonomy and uniqueness.

The challenge is to ensure that teachers are not only competent in their subject domain but also that their value system aligns with the new subject philosophy. This poses a challenge to Initial Teacher Education (ITE) providers to implement programmes of study that allow students to personally explore and define the role and value of technology education. Shifting from solely the provision of technical skills to a broader education agenda supports the global consensus that values personal development. Defining technology based education is made difficult by the contextual setting and needs of individual curricula. It is recognised that the post modern technology subject has the potential to develop and deliver outcomes of autonomy, creativity, problem solving, self-actualization, critical reflection/appraisal and communication skills (Kimbell and Perry 2001, Barlex 2007, Williams 2009). Learners' values are central to the appraisal of personal, social, economic and environmental implications of their actions (Kimbell and Perry 2001).

Objectives of Technology Teacher Education

Much debate is generated on what constitutes the modern day technology subject but where there is consensus, is that the hegemonic practices, methodologies and values grounded in the vocational approach still dominate the classroom learning environment (Dow 2006). Owen-Jackson (2000) and Banks and Barlex (2002) comment on how traditional pedagogic practices based on the transfer of knowledge are generally imposed on a new domain. These pedagogical practices are grounded on passive conformity rather than encouraging creativity and critique (McGarr, 2010). Breaking the hegemonic behaviourist cycle (Drakers, 2005) and implementing change is becoming increasingly important as Drakers argues that:

> *... learning in this narrow model is linear and instrumental and to all intents and purposes, not meaningful learning at all. It is more concerned with the assimilation of the young into an already established value system which has more to do with control than it has to do with liberation.* (p.113)

Dow (2006) identifies the areas of pedagogy and assessment as being fundamental to successfully implementing change. She comments on how the implicit beliefs held by the teacher can act as a barrier to implementing change and places emphasis on the important role ITE programmes play in the development of such implicit beliefs.

Assessment – the tail that wags the curriculum dog

The measure beyond the artefact or finished product is critical to ensuring the sustainable value of the post modern view of technological competencies. Measuring a complex iterative process requires a flexible model of assessment that can value evidence of learning in response to individual heuristics while supporting diversity and measuring capability. Kimbell (2010) highlights the conflicting philosophical approaches to assessment in technology education and highlights how the empiricists, rationalists and Social culturalists presents logical emphasis and yet "do not comfortably acknowledge each other" (pg 20).

A general principle of assessment is that it rewards students for the quality of their effort. Identifying this quality and assigning it value are the key challenges for the assessor. Kimbell (2007) outlines the difficult nature of judging student work against abstract criteria, but when compared with an exemplar of capability the task becomes much more meaningful. Project e-scape (Kimbell et al. 2005, 2007, 2009 and 2012) outlined a new and innovative approach to the assessment of performance portfolios. The approach, based on the comparison of students work, relies on a holistic judgement where overarching criteria are used to guide the assessor to make a professional judgement. This requires the judge to have an understanding of what is better or worse in terms of the required capability while eliminating the varying standards that may exist across a group of assessors. This approach has particular significance when introducing a group of student teachers to the field of assessment as they can focus on evidence of capability without the worry of levels of attainment. This study evaluates the impact of students personally establishing their own criteria for assessment. The value of engaging students in this type of peer assessment has the potential to increase thinking, learning and confidence, helping the student to establish the role and purpose of assessment (McDowell and Sambell, 1999).

Method/Approach

This paper focuses on the findings from the initial phase of a three year longitudinal study. The aim of the study was to facilitate ITE students' in the development of a personal construct of capability in technology education. The learning activity centred on a thematic design brief, where students were required to produce decorative artefacts (Flower and Scene – the rationale for the design of the task is beyond the scope of this paper and details can be found in Seery et al 2012) that demonstrated a synergy of design solution. The openness of the brief facilitates diversity of interpretation which is housed in the context of a post modernist view of technology education and ultimately enables the personalisation of approach. For the purposes of assessment students constructed an electronic portfolio to present their definition and evidence of capability.

Coupled with this approach to learning the study employed an assessment strategy that exercised the students' personal construct of capability, by assigning value to the design task outcomes. This was achieved through the use of an Adaptive Comparative Judgement model of assessment (Kimbell 2009) where the students democratically ranked the quality of their peers work. The objective of the study was not to provide students with explicit assessment criteria but rather to facilitate them in establishing their own criteria for assessment based on what they valued. This necessitated an approach to assessment that provides over-arching criteria or goals for learning and assessment that students consult with when developing a personal construct of domain capability. The over-arching criteria used in this study are based on the findings of Kimbell (2004) that identified indicators of innovative and creative solutions to design tasks as Having, Growing and Proving of ideas.

Findings

This study focused on the implementation of ACJ as an assessment tool to evaluate student performance in the design task. The ACJ session ran for 16 estimation rounds generating a rank order of student portfolios based on the democratic consensus of the judging group. A Cronbach Alpha reliability coefficient of 0.955 was recorded for the judging session which is considered as very highly reliable (Cohen et al. 2007 p. 506). The graph in Figure 1 shows a high level of consensus on the portfolios across the rank after 16 estimation rounds of judging.

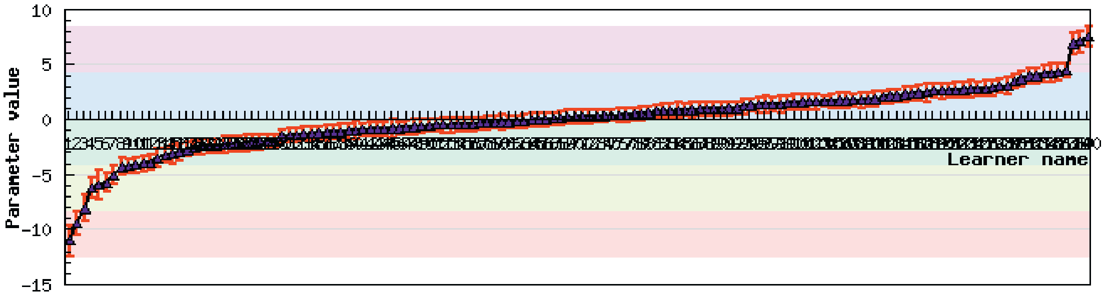

Figure 1 - Rank Parameter Value Error Plot (Round 16)

One of the strengths of the ACJ assessment process is the statistical data that is gathered on both the students' portfolios and the judges as the process evolves. Portfolio statistics were analysed and 7 portfolios were observed to be outside the fit criterion for the rank orders (Seery et al. 2012). Kimbell (2009) presents a similar level of misfit observed with a group of professional teachers assessing portfolios in a design and technology based activity. By comparison this low level of misfit is impressive for the group of novice assessors. The significance for this study is that this high level of consensus was achieved using individually constructed criteria based on the students' individual construct of capability within the domain.

On analysis of the judgement history of the misfit portfolios it was noted that technical problems with the portfolio were cited as reasons why some portfolios lost to a portfolio of a lower parameter value. Judging comments:

"portfolio B would have won only for the text being in computer language"

"could not load portfolio A??????"

The level of disagreement between judges overall was very low with the portfolio statistics indicating that where there was disagreement it tended to be concentrated on a number of individual portfolios.

Capacity of Students to make professional judgements

The judging statistics present the high level of consensus within the group with only 3.89% of the judgements being outside of the judging fit criterion. This indicates that the student judges had a high level of agreement on what they perceived to be of quality in the work that they assessed. An analysis the judging data identifies two judges from the student judging group that were outside of the judge fit criteria for the rank. It should be noted that one of the misfit judges only made one judgement while all other judges averaged 20 judgements each. The second judge was outside the misfit parameter by only 0.01. This judge's average judgement time was 2 minutes 27 seconds, approximately half that of the group average, which may indicate that this judge may not have analysed the portfolios for capability to the same level as others within the judging group.

Overall the low level of misfit for the novice assessors indicates that their individual interpretation of capability converged on qualities that were observed and valued by the group through the democratic ACJ assessment process. The significance of the high level of consensus lies in the fact that the judges were not given explicit assessment criteria to identify these qualities or make their judgements. The consensus was reached on the basis of the epistemological understanding developed by each individual student as a result of their engagement in the design task. The consensus was achieved despite students producing their own '*unique*' and diverse interpretations of the task.

Discussion

Having confidence that your effort will be rewarded is a central issue for any student engaged in an activity where innovation and creativity are key outcomes. Jeffrey and Woods (1997) outline the need for trust in a creative classroom where the student needs a climate that offers personal confidence and security.

The ACJ model of assessment was presented and demonstrated to the student body as the means by which they would be assessed. Students were informed that they had to personally construct their own criteria for assessment and that they would generate the rank order of capability using the ACJ approach. The reaction of the students was positive. An average of 70% of the students agreed that they were confident that the model of assessment would value what they presented as capability. The consensus of the group was that generating their own assessment criteria through their engagement in the task had a positive effect on their learning. They also agreed that this had a positive impact on them determining what was of value in the subject domain. The removal of explicit criteria and the introduction of democratic peer assessment were the catalysts for the natural propagation of a social-constructivist approach to learning. The evolution of collegiality among the class group was in contrast to the prescribed traditionally focused approach used in previous years to this study. One hypothesis for the students' supportiveness is that no student felt as if they were trying to compete on predefined criteria, as their interpretation and engagement in the task was uniquely personal. What was observed was that students engaged in dialogue with peers and teaching staff in an effort to establish the value of their actions among their community. This sharing of ideas and experiences give confidence to students who were trying to navigate their way through the development of a personal construct of capability and ultimately the definition of criteria for assessment. Over 60% of the students reflected that being peer assessed encouraged them to interact more with their peers during the learning activity. The consensus amongst the group was that the purpose of these discussions related to more conceptual issues of clarifying their thinking or problem solving than with sourcing information and getting help with procedural aspects of manufacture. An average of 52% of students agreed and 36% strongly agreeing that discussions with peers were mutually beneficial. This indicated that students found benefit in discussing other students work and that their learning did not always happen in the context of their own project. A further indication of the level of peer support that developed in the classroom is indicated by 88% of the students' initiated communication to help peers with their work. The peer to peer collaboration was clearly a means for the students to externalise and validate their thoughts and ideas in relation to the task. This is a critical feature of the constructivist approach. Therefore, finding out what your peer was doing was not the only focus; finding out why they were doing it was now becoming important, as making meaning within the subject domain and establishing a common frame of reference for capability was essential for learning.

Overall the latent integration of the assessment into the learning activity had a positive impact on the students' experience. The removal of explicit criteria did not stifle students' progression but rather promoted dialogue and interaction that was valued more than the normative comparison that would ultimately decide on quality.

Conclusion

Although, this paper did not consider the validity of the rank that the student's produced, it was addressed in the parent study. The research presented in this paper highlights the capacity of the students to democratically reach consensus on what was of value in response to a thematic design brief.

When considering Initial Technology Teacher Education the capacity of future educators to define domain specific qualities and competencies as they evolve is a powerful paradigm for change. This research highlights the value of moving from a deterministic approach to assessment and allowing learners develop the meaning that underpins capability.

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Reading Technological Artifacts: Does technology education help?

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Key Words: Technological Artifacts, Technological Literacy, Physical and Functional Nature, Critical Interpretation

Abstract
Reading technological artifacts is recognised internationally as an important aspect in developing technological literacy. To be read – or critically interpreted, these artifacts are required to be understood as much more than an 'entity as such'. Instead, they must be seen as the embodiment of design and purpose and located in the complex socio-cultural milieu of their inception, development and use.

Philosophical attempts to guide critical interpretations have been supported by focusing on the interrelated dual (physical and functional) nature of technological artifacts (Kroes & Meijers, 2000; de Vries, 2005; Vaesen, 2008). This aspect of the philosophy of technology is the basis of the New Zealand curriculum achievement objectives related to the Nature of Technology strand component known as 'Characteristics of Technological Outcomes' (Ministry of Education, 2007). In this component significant emphasis is placed on students developing understanding of the interrelated physical and functional nature of technological outcomes (or artifacts) and how these outcomes are understood as embedded in their social and historical context.

Exploration into students' ability to read technological artifacts has been a part of a number of research projects undertaken in New Zealand over the last eight years. This focus has been continued in our latest research– the *Technological Literacy: Implications for teaching and learning* (*TL: Imps*) project. In this paper, we share our early findings related to reading technological artifacts and discuss these in terms of previous national and international research findings.

Introduction
Technology as a form of human endeavor involves both the development and production of outcomes which exist in the 'made' world and as such intervene in ways both intended and unintended in the made, natural and social world we both create and/or inhabit. Technology education programmes designed to support the development of technological literacy will therefore require students to be provided with opportunities to understand both the processes of development and the nature of the resulting outcomes. In this paper we are focusing specifically on aspects of learning related to the later of these – the nature of technological outcomes or as they are more commonly known - technological artifacts. Technological artifacts are understood to be products and

systems that result from technological practice to address a need or opportunity. Reading technological artifacts is recognised internationally as an important aspect in developing a philosophical understanding of technology as part of an overall technological literacy (de Vries, 2005; Vaesen, 2008; Frederik, Sonneveld, & de Vries, 2011).

When this technological literacy is framed as 'broad, deep and critical' (Compton, Compton & Patterson, 2011; Compton & France, 2007a), further caveats are placed upon technology education programmes. That is, when students are expected to read or critically interpret such artifacts they are required to understand these artifacts as much more than 'entities as such'. Instead, they must be seen as the embodiment of design, purpose and knowledge and located in the complex socio-cultural milieu of their inception, development, use and disposal. Philosophical attempts to guide critical interpretations have been supported by focusing on the interrelated dual (physical and functional) nature of technological artifacts (Kroes & Meijers, 2000; de Vries, 2005; Frederik, Sonneveld, & de Vries, 2011). This focus is clearly captured in the philosophical strand (known as the Nature of Technology) within the New Zealand curriculum (Compton and Compton, 2011). This strand is comprised of two components. The first being the Characteristics of Technology (CoT) which is focused on the development processes and their surrounds. The second is the Characteristics of Technological Outcomes (CoTO) which is focused on technological artifacts (Ministry of Education, 2007). In the second component significant emphasis is placed on students developing understanding of the interrelated physical and functional nature of technological outcomes (or artifacts) and how these outcomes are understood as embedded in their social and historical context. Developing understanding of knowledge underpinning the development and use of technological artifacts is also important to the ability to read artifacts – particularly that associated with understanding the materials used. This focus is captured in the Technological Products (TP) component of the technological knowledge strand (Ministry of Education, 2007).

Exploration into the ability of students to read technological artifacts has been a part of a number of research projects undertaken in New Zealand over the last eight years. This focus has been continued in our latest research project – *Technological Literacy: Implications for teaching and learning* (*TL: Imps*). In this paper, we present initial findings from a series of interviews undertaken to gather data on how students read technological artifacts. We discuss the initial findings from this project with those from earlier research, both in New Zealand (Compton & France, 2007b) and elsewhere (Frederik, Sonneveld, & de Vries, 2011).

Research Overview

As explained elsewhere (Compton, Compton & Patterson, 2011) the *TL: Imps* project is a national research project funded by the New Zealand Ministry of Education. The project began in July 2010 and is scheduled to run through to June 2013. The aim of the *TL: Imps* research is to explore student technological literacy and document how it can be supported through programmes based on the integration of the three strands of the technology learning area in the NZC (Ministry of Education, 2007). Of particular interest in this research is the way the components work together at different levels of student learning to ensure students progress in each component individually and in such a way as to best support an increasingly sophisticated and holistic technological literacy.

This project provides an opportunity to evaluate the success or otherwise of the latest phase of technology curriculum development in New Zealand in terms of supporting a transformation of students into increasingly technologically literate beings. As part of this project, students ranging from age 5 years to 13 will be interviewed about technological artifacts, both known and unknown. This data will be used to identify the ability of students to read technological artifacts as indicated by their ability to *judge* a known artifact's fitness for purpose, and their ability to *determine* what an unknown artifact might be.

A series of three interviews will be conducted over a two year time period. Round 1 interviews focused on collecting baseline data and were undertaken between March and April 2011. Round 2 interviews focused on collecting data after the completion of the first year of a known technology programme. These interviews were undertaken between October and December 2011 (see Appendix A for interview details). A third round of interviews will be undertaken after the completion of the second year of the technology programme. These are scheduled to occur between October and December 2012. When ever possible, the same students will be interviewed in each round. The participant makeup and interview structure of the interviews to date is provided below.

Interview Participants and Codings:

The 19 schools involved in the research are geographically located throughout New Zealand and include nine primary (year 1- 8), seven secondary (year 9-13) and three composite schools (year 1-13). The schools are a mix of urban and rural and include students from a range of socio-economic and ethnic backgrounds. Ninety two teachers and 1428 students have been involved the project to date. Almost one third of these students (432 or 30%) have been interviewed in Round 1 and/or Round 2. More female (258 or 59.3%) than male students (174 or 40.3%) have been interviewed as reflective of the overall cohort of students involved (748 or 55.8% female and 593 or 44.2% male).

During Round 1 a total of 392 students were interviewed. The majority (290) of these students were interviewed again as part of Round 2. Some of the original students will not be interviewed again until Round 3 as the school they attend was severely damaged in the Christchurch earthquake. Other students have either left their respective school, or were not available on the day of the interview. An additional 43 students were interviewed in Round 2 to replace students who had left. Therefore the number of students in the Round 2 cohort overall was be 333.

The distribution of students interviewed in Round 1 and/or Round 2 by year group is shown in Table 1.

Table 1: Participants by Year Group

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
#	33	31	32	34	33	25	36	32	69	49	26	21	11
%	7.6	7.2	7.4	7.9	7.6	5.8	8.3	7.4	16	11.3	6	4.9	2.5

The artifacts used and questions asked are provided in Appendix A. The student answers to the questions were used to code students as reflective of their ability to judge fitness for purpose of a known artifact and their ability to determine what an unknown artifact was. Students were coded using a 0-4 scale for ability to judge fitness for purpose whereby:

- 0 = Unable to make a judgement. Never heard the term fit for purpose and/or has no idea what it means
- 1 = Makes a judgement on incorrect understanding of term. May or may not have heard term before but considers it refers to a product being 'healthy'
- 2 = Makes a simplistic judgement. Heard term before/never heard term but worked it out – holds a simplistic understanding whereby fitness for purpose means it is able to 'do its job' where the job is its 'technical' function
- 3 = Makes a reasoned judgement. Uses given example to explain how the judgment is based on the artifact in relation to specifications. Links specifications to technical and social considerations such as user-friendliness, user or environmental impact
- 4 = Makes a well-reasoned judgement with a sophisticated explanation. Often linked to more than given example, showing a bigger picture view that includes reference to such things as ease of use/not malfunctioning/environmental impact and/or marketing factors alongside working as intended and often discusses need for evidence before a judgment can be made (e.g. I can't say till I've tested it/evidence from others - prototyping).

Students were coded using a 0-6 scale for ability to correctly determine what an unknown artifact is whereby:

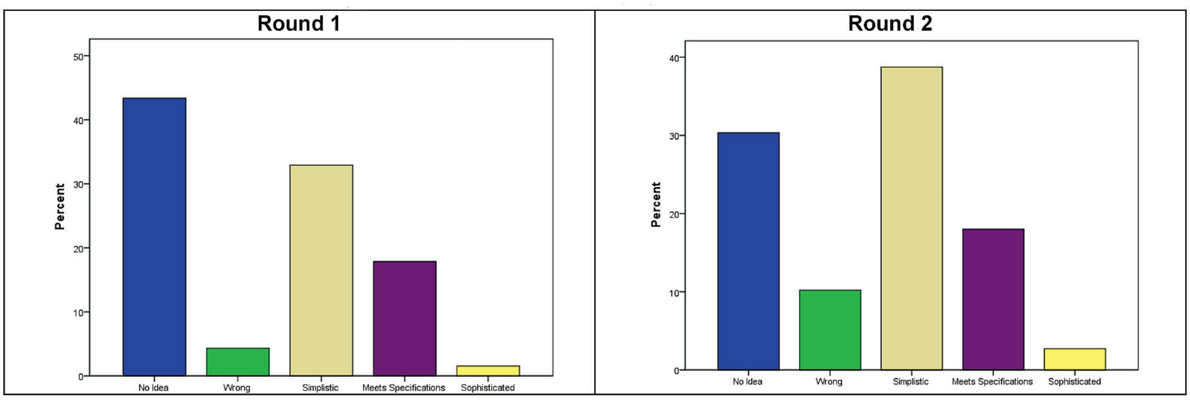
0 = No idea
1 = Suggests an idea – (wrong) unsupported by observation or reasoning
2 = Suggests an idea – (wrong) supported by observation and/or reasoning
3 = Suggests an idea – (wrong) challenged by observation and reasoning – changes idea in keeping with this but still wrong
4 = Suggests an idea – (wrong) challenged by observation and reasoning – changes idea in keeping with this and works out what it is
5 = Suggests right idea - well reasoned
6 = States right – seen before.

Responses to the questions were also used to make a judgement about achievement level related to CoT, CoTO, and TP. The indicators of progression were used as a guide for this coding (Compton and Compton, 2011a; 2011b) where 0 = pre-level 1, 1=1 through to 8=8 for all components.

Findings

Reading an Artifact: Judging Fitness for Purpose
A total of 392 students were coded in terms of their ability to judge the fitness for purpose of the known artifact in Round 1 and 333 in Round 2. Figure 1 presents the results of this coding.

Figure 1: Fitness for Purpose of Known Artifact



Of the 392 students in Round 1, 170 (43.4%) had no idea what fit for purpose meant and therefore could not make a judgment on the juice carton. A further 17 (4.3%) held a wrong understanding and therefore their judgment of the juice carton was flawed. For example, if a product was fit for purpose it made you 'fit' or 'healthy'. One hundred and twenty nine students (32.9%) had heard the term before, or worked out the meaning from the words, and could use this to make a simplistic judgment on the juice carton as being able to 'do its job' or not. The majority of these students considered the product was fit for purpose as its 'job' was to provide someone with a drink of juice. Seventy students (17.9%) understood fitness for purpose in terms of the product meeting its specifications and could explain their judgment of the juice carton in terms of such things as convenience, size and ease of use. Six students (1.5%) provided a more sophisticated explanation of fitness for purpose and included the proviso that to make a judgment of the juice carton's fitness for purpose required evidence from its performance in situ.

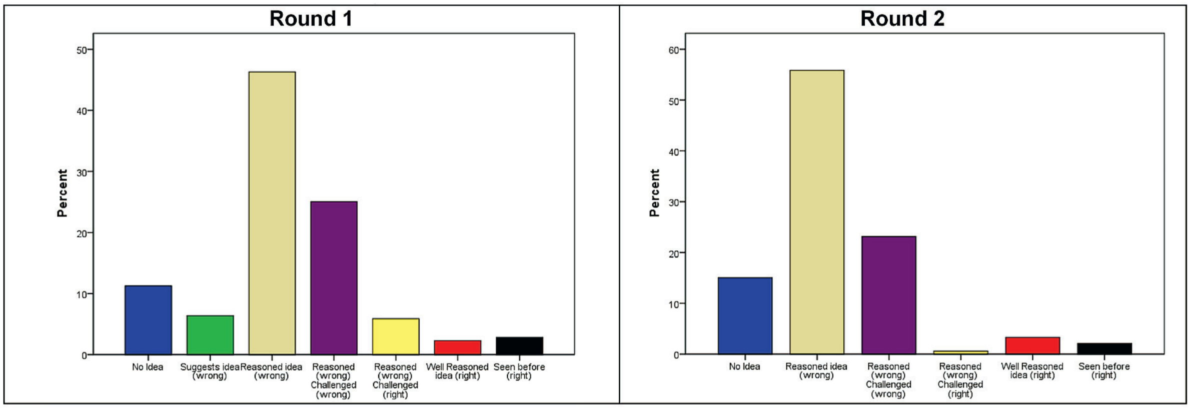
Of the 333 students in Round 2, 101 (30.3%) had no idea what fit for purpose meant and therefore could not make a judgment on the Bobble. A further 34 (10.2%) had a wrong understanding and therefore their judgment of the Bobble was flawed. One hundred and twenty nine students

(38.7%) had heard the term before, or worked out the meaning from the words, and could use this to make a simplistic judgment on the Bobble as being able to 'do its job' or not. The majority of these students considered the product was fit for purpose as its 'job' was to provide someone with a drink of water. Sixty students (18%) understood fitness for purpose in terms of the product meeting its specifications and could explain their judgment of the Bobble in terms of such things as convenience, shape, quality of water, environmentally friendly (reusable or recyclable). Nine students (2.7%) provided a more sophisticated explanation of fitness for purpose and included the proviso that to make a judgment of the Bobble's fitness for purpose required evidence, often scientifically based analysis of the water quality, from its performance in situ.

When this data was explored in terms of year groups there was an overall trending down of the 'no idea' and 'wrong' categories as the year group increased and a trending up of the remaining categories in both Round 1 and 2.

Reading an Artifact: Determining an Unknown Artifact

A total of 391 students were coded in terms of their ability to determine an unknown artifact in Round 1 and 333 in Round 2. Figure 2 presents the results of this coding.



Of the 391 students in Round 1, 44 (11.3%) had no idea what the item might be and did not make any suggestions at all. Twenty five (6.4%) students suggested (wrongly) what the item might be but provided no support for this idea. One hundred and eighty one students (46.3%) provided a reasoned suggestion (which was wrong) for what the item might be. The majority of these students focused on the physical nature of the item – making links to things they had seen before and did not self-challenge these ideas through observation and/or further explorations. For example, many stated it was a toy because it had wheels. Ninety eight students (25.1%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through a focus on the linked physical and functional nature of the item – using observation of materials, shape and exploration of function. All suggestions remained incorrect however. The majority of these students identified the 'chefn' branding and concluded the item must be a cooking utensil of some sort. Twenty three students (5.9%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through observation of materials, shape and exploration of function and coming up with the right answer. An additional 9 students (2.3%) came up with the right answer after undertaking a sophisticated reasoning exercise based on a combination of material properties, shape and exploration of function. Eleven students (2.8%) had seen the item before and therefore stated the right answer without any reasoning.

Of the 333 students in Round 2, 50 (15%) had no idea what the item might be and did not make any suggestions at all. No students made a suggestion as to what the item might be without providing support for their idea. One hundred and eighty six students (55.9%) provided a reasoned suggestion (which was wrong) for what the item might be. The majority of these students made links to the physical nature of the item – making links to things they had seen before and did not self-challenge these ideas through observation and/or further explorations. For example, many stated it was a muzzle for a dog because of its shape and the 'dog collar' part. Seventy seven students (23.1%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through a focus on the linked physical and functional nature of the item – making observations of materials, different fastenings, shape and exploration of how things worked together. All suggestions remained incorrect however. The majority of these students identified the item must be for use on a limb of some sort because of its adjustable fastenings. Only 2 students (0.6%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through observation of materials, shape and exploration of function to come up with the right answer. An additional 11 students (3.3%) came up with the right answer after undertaking a sophisticated reasoning exercise based on a combination of material properties, shape and exploration of function. Seven students (2.1%) had seen the item before and therefore stated the right answer without any reasoning.

When this data was explored in terms of year groups there was no obvious overall trending in either Round 1 or 2. When the data was re-cut across three categories based on the nature of the reasoning rather than the right answer, the level of reasoning showed some overall trending up as year group increased in Round 1, but this trend was not apparent in Round 2.

Analysis of results

In Round 1 almost half of the students (47.7%) could not make a judgment of the product's fitness for purpose. In Round 2 this figure had reduced to 40.5%. There was a corresponding increase (from 32.9% in Round 1 to 38.7% in Round 2) in the percentage of students who could make a simplistic judgment, and very slight increases in judgments based on specifications (from 17.9% to 18%) and more sophisticated judgment (1.5% to 2.7%).

In both Round 1 and 2, the majority of students could make a reasoned suggestion as to what an unknown artifact might be. Only 17.7% were unable or unwilling to do so in Round 1, and this figure reduced slightly to 15 % in Round 2. There was an increase (from 46.3% in Round 1 to 55.9% in Round 2) in the percentage of students who suggested a reasoned but wrong idea, and very slight reduction in challenging but incorrect ideas (from 25.1% to 23.1%) and a larger reduction in challenging resulting in a change to the correct idea (5.9% to 0.6%). There was a slight increase (from 2.3% to 3.3%) in the percentage of students correctly determining the artifact based on more sophisticated reasoning. Little change was seen in the percentage of students who had seen the item before (2.8% to 2.1%).

Based on these interim findings it would appear the technology programmes have not resulted in any significant impact on student ability to read technological artifacts. At best there may be some evidence of a slight shifting of students from being unable to judge a product as fit for purpose at all, to being able to make a simplistic judgment. There was no clear increase in student ability to determine an unknown artifact.

In contrast to this, student understanding related to Characteristics of Technology (CoT), Characteristics of Technological Outcomes (CoTO) and Technological Products (TP) showed a clear progression from Round 1 to Round 2. The greatest shifts overall were those related to CoT and TP. CoTO also showed good progress from pre-level 1 to level 1. The shifts between Round 1 and 2 are summarised in Table 2:

Table 2: Summary of Shifts between Round 1 and 2

	CoT	CoTO	TP
Pre-level 1	55.6% to 20.8% Decrease of 34.8%	52.6% to 21.4% Decrease of 31.2%	41.1% to 5.1% Decrease of 36%
Level 1	30.9% to 47% Increase of 16.1%	30.9% to 51.5% Increase of 20.6%	43.1% to 63% Increase of 19.9%
Level 2 or above	13.5% to 32.2% Increase of 18.7%	16.6% to 27.1% Increase of 10.5%	15.8% to 31.9% Increase of 16.1%

Discussion

At this early stage of the research it seems clear that the technology programmes of learning these students are currently participating in are providing opportunity for many students to increase their understanding of the components CoT, CoTO and TP. There was a greater percentage increase a level 2 and beyond related to CoT and TP than CoTO. In addition there is some evidence to suggest a small increase in student ability to read a known artifact (that is, judge its fitness for purpose), but no increase in reading an unknown artifact (that is, determine what it is).

As indicated earlier, for students to be able to read an artifact they must be able to make sense of that artifact as part of a wider sociocultural context drawing from the nature of technological artifacts and the knowledge of their material makeup. Being able to make a judgment of an artifact's fitness for purpose has a strong relationship to understanding CoT and TP - particularly at level 2 and above. Research undertaken in New Zealand during 2004-2006 found the majority of students found it very difficult to make normative judgments about technological outcomes and instead consistently used a personal like/dislike stance rather than using an understanding of materials used or the concept of fit for purpose as judgment factors (Compton & France, 2007b). This would indicate pre-level 1 understanding of CoT. Our initial findings would therefore appear to indicate that the movement in terms of student CoT and TP understanding may be related to the small improvement in reading a known artifact.

The findings associated with reading *unknown* artifacts are at this stage not particularly indicative of anything! While many students did seem to be developing a greater understanding of the physical and functional nature of artifacts, as indicated in the increased percentage of students working at level 1 CoTO, this does not appear to have translated into an ability to use such knowledge to 'decipher' the clues inherent in the artifact. These findings resonate with those reported in a small research pilot study in the Netherlands where it was found that "Both experienced and inexperienced teachers do not fully grasp the concepts related to the dual nature of technical artifacts" (Frederik, Sonneveld, & de Vries, 2011, pg 286). In addition, in both the Netherlands and earlier New Zealand research it was found that when teachers or students were attempting to work out what a 'mystery' object was, they tended to focus more on the physical nature without relating it to the functional nature. Understanding the relationship between the physical and functional nature is a key aspect of level 2 CoTO. The smaller percentage shift above level 1 in CoTO related understanding may help explain the lack of progress in determining what an unknown artifact is. Alternatively it may be that determining an unknown artifact requires a higher level of understanding than making a judgment as to a known artifacts fitness for purpose. These relationships require explored further exploration and will be a focused on again during school by school and the Round 3 analysis.

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Appendix A: Interview Props and Questions

Known Artifact		
Round 1 	**Round 2** 	Why has this product been developed? What materials have been used to make the packaging (Round 1)/the bottle (Round 2) Why do you think these materials were selected? How do you think this is made? How does the juice get inside the packaging? (Round 1) How do you think the filter works? (Round 2) Do you think this is a good form of packaging for a juice product? Why/why not? (Round 1) Do out think this is a good product? Why/why not? (Round 2) Have you heard the term fit for purpose before? *If student has come up with a useable definition of fit for purpose…* Do you think this a product is 'fit for purpose'? Why/why not

Unknown Artifact		
Round 1 	**Round 2** 	What do you think this is? Why do you think this? (prompt around materials, shape, parts etc) How do you think it might work? *If student has come up with a firmish idea of what it is and its use…* Who do you think it was designed for? Why do you think it was designed? Do you think it is a good design? Additional Questions for Round 2 What does something have to have for you to call it a 'good design'? *If student knows what fit for purpose means…* What do you think the relationship between fit for purpose and 'good design' might be?

Technological thinking in the kindergarten – training the teaching-team

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Keywords: Technological thinking, design, teacher training, preschoolers

This paper reports about the first stage of implementation of an innovative curriculum on technological thinking and doing in the kindergarten. The main goal in this first stage was to train the teaching teams, supporting their learning of the rationale, contents and pedagogical resources of the new curricular program. The program is the result of four years of research and development in an experimental project conducted in kindergartens in center Israel, and is currently being implemented in three kindergartens in north Israel in a cooperative effort between Tel-Aviv University and World ORT - a world non-governmental organization supporting technology education and vocational training in Israel and countries worldwide.

The challenge in this training effort is to foster the introduction of an innovative program influencing multiple aspects of the kindergartens' life: it is about technology (content), technological thinking (cognitive processes and skills), technology teaching in the kindergarten (pedagogy), and novel means and environments for young children's learning-by-doing technology (learning environment). Thus in this first stage of implementation, the main goals pursued were to ensure a progressive and natural adoption of the innovative program by the teaching teams, as well as its gradual and successful implementation in the kindergartens.

In this paper we report about the first stage of training and implementation of the program using data from structured teaching-teams questionnaires, observations, and documentation of actual activities in the kindergartens.

The context: Technological thinking in the kindergarten

Technology, and in particular design, are not part of the kindergarten's curriculum in Israel. In the Israeli educational system, kindergartens for the age-level we focus on (pre-school, age 5-6) are compulsory and mostly public - about 5500 kindergartens attended by about 170000 children. Typically kindergartens are independent and self-contained, managed by the teacher and aided by an assistant. Additional teaching resources are allocated for children with special needs in the kindergarten. Although some technology-related topics are often taught within the context of science topics, technological knowledge and relevant pedagogies are not part of most teachers' background or formal formation. Prospect for change (at least concerning selected topics) is expected when the new science and technology curriculum for this age level, currently under development, will be completed (Ministry of Education, in press). However, in our understanding a more comprehensive approach is required, encompassing goals, contents, pedagogical solutions and teacher formation efforts.

Technological contents for the kindergarten level have been integrated in curricula developed and implemented in different countries (e.g., in the UK, New Zealand, the U.S. or various countries in continental Europe - see Compton and France, 2007; ITEA, 2000; Turia, Endepohls-Ulpe & Chatoney, 2009). Although these efforts may differ in foci, emphases and conceptual approach, common sets of content categories and target skills can be identified, e.g., fostering technological awareness and literacy, acquaintance with the world of artifacts in which we live starting from the immediate and familiar environment (e.g., toys, tools and utensils at home), acquisition of materials manipulation skills and even design process skills.

In our proposal for technological thinking in the kindergarten, we put emphasis on the cognitive process involved and demanded for understanding, interacting with and designing the artificial world: the human-mind-made world. In our model we adopt a cognitive/epistemological perspective (Mioduser, 2009), claiming that we should teach/learn technology because the making of the artificial world has always been a defining characteristic of human beings' thinking and intellectual development. Thus, learning technology is learning about thinking, about learning, about the (outer) invented world vis-à-vis the (inner) inventors' world, and about the results of the co-evolution -both phylogenetic and ontogenetic- of the designed and the designers' worlds.

In the current implementation of our model the contents are organized in six main strands (Sx), running throughout the year along a developmentally-appropriate progression: S1 - the designed/artificial world (artifacts and their use/context); S2 - problem solving (from haphazard to budding systematicity in planning and implementing solutions), S3 - design and making (from free-form building to designed/reflective construction); S4 - notations (from conventional signs to computer programs); S5 - smart artifacts (from analyzing observed robot behaviours to the design of adaptive behaviours); S6 - the whole-kindergarten final project.

The teacher training process - procedure

The project is being implemented in three kindergartens differing in socio-economic status in Kiryat Yam, in the north of Israel. As part of the first stage of the implementation, the project was introduced to the different populations involved.

First, its goals and implementation processes were discussed with the local education authorities. Since the city is involved in intensive educational plans emphasizing science and technology learning, the projects is perceived as fitting these goals. The next relevant population are teachers - the introduction of the project with teachers is the theme of this paper and will be detailed later. A special activity was conducted with parents, in which the goals and components of the project were presented. Many activities refer to the technological environment both in the kindergarten and at home, and even involve members of the family in tasks conducted at home. The most relevant population are obviously the children. They experience gradually the activities and tasks as part of the regular life in the kindergarten, since these are integrated in the ongoing activities. Knowledge and skills are gradually constructed while children work in the different strands intertwined with the regular kindergarten activities.

The trainees are three kindergarten teachers and their teaching assistants - six participants. All six participants are very experienced (over 15 years of experience). However, this is the first time they deal with technology subjects.

The in-service training program implemented comprised: (a) 30 hours of group training in meetings held very other week in a different kindergarten; and (b) personal tutoring in each kindergarten for half a day every two weeks (about 30 hours per kindergarten). The whole process lasted about five months. Each group meeting comprised: (a) learning and discussing a new topic (focusing on either a conceptual issue, learning activity, or learning environment); and (b) sharing experiences, reflecting and elaborating about activities implemented in the kindergarten during the two weeks between the meetings.

The training program and schedule is summarized in Table 1.

Table 1: schedule and plan of the training

Meeting	subject
1	Conceptual framework and overview of the project. • The artificial word • Children's perceptions of the artificial world • Age-level developmental characteristics • Curricular strands
2	Problem solving as general process in daily life and technological problem solving
3	Construction tasks Sketching and representing for documentation and planning
4	Tracks and mazes - adaptive behavior design Notations
5	Robotics: building the robots
6	Robotics: the behaviour construction software
7	Robotics: Programming tasks

During the visits to the kindergartens the training tutor assists the teachers in integrating the theoretical concepts and practical ideas into the kindergarten's daily life. As well, all along the process the teachers are requested to document the experiences (digital pictures of children's work and performance, and actual products).

Data about the training and initial implementation processes are being collected using a structured questionnaire, observations, and products analyses. The questionnaire comprises 18 questions, and its foci relate to teachers': (a) understandings and perceptions of technology and technology-related concepts before and following the training program; (b) conceptions of the goals to be pursued in the implementation of technological thinking activities in the kindergarten; (c) thoughts, ideas and suggestions about curricular and pedagogical solutions for teaching technology in the kindergarten; (d) description of, and reflection about, the actual implementation of the technological thinking curriculum in the kindergartens; (e) perceived difficulties during the implementation process; (f) thoughts about the next stages of training and implementation.

Main insights from the training and early implementation stage

Due to the limited scope of this paper, in this section we present a brief and preliminary account of some of the data collected during the training sessions and implementation activities.

Teachers' perceptions as reflected in the questionnaires

Perception of Technology before and following the training

As could be expected, teachers' understandings at the beginning were related to the idea of a discipline closely related to science, which implies innovation and developments affecting all aspects of life, and fosters the generation of solutions satisfying human needs. Although after several training sessions teachers' first claimed that their understanding did not change much, the formulation of their answers indicated that they got "*improved understanding*", and that the process provided them with "*insights that helped sharpening*" their ideas about the nature of technology (italics stands for quotations of teachers answers).

They also indicated that they had no previous acquaintance with curricula related to technology in the kindergarten - the contents and approach are new for them.

Goals for technological thinking in the kindergarten

Teachers' answers revealed their perception of the importance and the potential contribution of the subject in the kindergarten: it supports "*a better understanding of reality, creativity, growth of thinking skills, and broadening of horizons*"; it stimulates "*motivation, curiosity, responsibility taking, and the development of problem solving, attention and communication skills*"; it fosters "*cognitive, motor, social and affective growth*".

Curricular/pedagogical issues

Teachers noted that before the training they did not think at all about the possibility to teach the subject in the kindergarten. Even for activities that were similar to some included in the innovative program (e.g., construction using different kits), they never approached these from the perspective of technological thinking. Now they are able to think about rich possibilities concerning a variety of pedagogical aspects, such as **types of tasks** (e.g., construction, disassembling artifacts, sketching), **contents** (e.g., focused mainly on technological topics or linked with other curricular topics), **generic skills** (e.g., problem solving, linking between the concrete and the abstract)

Asked about the main pedagogical aims to be pursued, the teachers formulated the above issues in the form of goals. As well they added goals related to technological contents, and to the role of doing in learning. One teacher noted that the approach adopted towards technology and technological thinking "*actually encompasses many of the goals demanded by the kindergartens core curriculum in its different subjects*" (e.g., notational literacy, numeracy, motor skills, social skills, contents in various subject areas).

Actual implementation in the kindergartens

Asked to supply examples of activities they now conduct in the kindergarten, their descriptions actually referred to the varied repertory addressed in the training sessions. In addition, they pointed that now it appears that "*everything they do in some way is technology*". This is consistent with the rationale of the program emphasizing thinking and cognitive processes, and with the linkage they now are able to recognize between these processes in the context of technology and in the context of other subject areas.

An interesting aspect of the implementation process relate to the teachers assistants. Traditionally the functions of the assistants are well defined and refer mainly to services and supporting functions. In our model they became integrated as partners in the training process, and then in the work with the children. Teacher responses are indicative of a change in their roles, in their partnership with the teacher, their understanding (and interest) of the processes undergoing in the kindergarten, and their sense of empowerment as partners in the implementation of the innovation.

Perceived difficulties in the implementation process

> Teachers pointed out difficulties or issues that ought to be addressed. They perceived as a challenge that the program is not formulated as a well structured, step-by-step linear program. We remind that the curricular model is introduced into the kindergarten's life as a sort of "pedagogical toolbox" comprising different strands, instruments and resources, and the teachers are allowed to compose activities and sequences according to their needs and the opportunities continuously evolving in the dynamic life of the kindergarten. This is certainly a challenging modality for teachers used to follow well structured curricula. They pointed up the additional load imposed by the new program, in aspects such as time allocation and management to deal with all curricular subjects, "division of labor" among the team members to deal at the same time with groups working on different tasks, or the

demand for regular documentation of the processes taking place and children's work (for further reflection, elaboration and learning).

They perceive also as demanding their role as "pedagogical companions" of the children in their work: instead of "teaching" in the traditional sense, now they have to be attentive to raising needs and questions and devise ad-hoc guidance and solutions in an ongoing fashion. In addition, individual differences lead to ample variance in needs, processes and even products, adding considerable complexity to the teachers' new role.

Other perceived difficulties relate to children's differential ability to master required skills, in tasks such as constructing with kits, or sketching and drawing. Interestingly and paradoxically, one difficulty mentioned relate to children's "over-enthusiasm or over-motivation" towards the activities, making the management of the ongoing work more demanding.

At another level, so far there is little involvement of the parents in the process. They mentioned that parents express interest when they see children's work and products. However at this point they were not exposed enough to the ideas, processes and activities being implemented, and they expect to generate more involvement in the future.

What next?

Teachers responses unanimously express their willingness and motivation to go deeper into the ideas and pedagogical components of the innovative program. They evaluate the first stage of the work as highly interesting and rewarding learning experience, and look forward for the new topics to come (e.g., the robotics chapters).

Three vignettes from kindergarten's life

A detailed description of the implementation of the whole program is beyond the scope of this paper. In the following we present three representative examples of the way the teachers interpret the materials from the training sessions and adapt these for the local implementation in their kindergartens.

Vignette 1: Paths and tracks - generating and representing behavior

Strand: representations and notations

Specific goals: Construction of physical paths for performing spatial behavior tasks
Creating representations for spatial behaviors

Description of the activity

The generic model of the activity comprises the design and building of physical paths (e.g., in maze-like configuration) which children traverse in a progression of tasks focused on different aspects. An example of a progression: first tasks emphasize spatial orientation (e.g., directionality, diagonals); then children create a physical 1:1 representation of the path using footprints and arrows, which are later reproduced on paper in a smaller scale; then they are requested to invent representations for the observed spatial navigation; the representations are then refined to become more formal notations (with agreed conventions) to serve as instructions to guide "novice navigators" of the maze.

In one kindergarten the localization of the generic model brought about the construction of an intersection of streets with traffic lights and crosswalks (Figure 1). Arrows were used to indicate directionality. Children navigated the space playing either the cars or the pedestrians roles - the whole system was controlled by children manipulating the lights. In the next stage the idea of discrete steps was introduced (as basis for further work on units, measurement and notations), when children navigated the space according to the steps indicated by a dice. Stations in the path required answering questions about road behaviour and security - conventions and rules.

Figure 1

Figure 2

Conclusion

This activity encompasses manifold aspects, knowledge and skills: e.g., spatial orientation and mobility, directionality, receiving and giving instructions, decision making, knowing and using conventions and conventional signs and notations (using representational means which are concrete, e.g., footprints, or symbolic, e.g., arrows, marks, numbers). This activity has been naturally linked to the topic "road safety" being treated at that time in the kindergarten. Thus, a generic activity from one strand of the technology program was localized by the teacher, and naturally integrated within the ongoing curriculum. The observations all along the process -planning, constructing, navigating the space, inventing representations, formalizing notations, formalizing the control rules- unveiled children's high level of motivation and enthusiasm as well as evident mastery of the complex set of skills involved in performing the task.

Vignette 2: Constructing, sketching and drawing

Strand: Design and making

Specific goals: Construction with modular building kits
Documenting the constructed form from different perspectives

Description of the activity

The generic model of the activity relates to the construction process of static and dynamic structures using modular building kits. The teacher's choice for localizing the activity was to emphasize observation and reflection about the constructed object using drawings as thinking aid. The children were encouraged to draw their object from different perspectives or projections - sides, upper and bottom views (Figure 2). She suggested to divide the drawing space in three parts with the titles of the projections.

Conclusion

The discussions conducted with the children focused on the properties of the different views, their nature as partial representations (what is missing?). The children were amazed with the way their object looked by the different views. The activity is demanding, however it allows reflection about the properties of the object (structure, form, dimensions, construction details) intertwining concrete and conceptual aspects, i.e., the drawing process and the drawings (reflecting by making) and the verbal elaboration (reflecting by conceptualizing).

Figure 3

Vignette 3: Representing problem-solving

Strand: Problem solving

Specific goals: Experiencing a problem solving process
Using concrete representations for the solution selection stage

Description of the activity
The generic model of the activity demands the repeated involvement in numerous problem solving processes fostering the development of systematic strategies and the acquisition of relevant skills. The problems to be solved are related not only to technology related topics, but to numerous situations from the kindergarten's life as well. After a few experiences triggered by the teacher, the problems then are normally raised by the children themselves within any possible context of their activities in the kindergarten. The structure of the problem solving process is gradually constructed and agreed fro conventional use. A critical stage is the one in which children raise alternative solutions supported by convincing arguments. Then the group is requested to define the chosen solution, by personal vote of the preferred option. In one kindergarten the teacher decided to elaborate with the children about the representation of the results of the vote, first by constructing a "human histogram" (Figure 3): every child in her/his turn made a choice and went to site in line in the appropriate "column". The teacher conducted a discussion about the dimension represented in the columns, the meaning of the unit used and their accumulation, and he configurations generated. Then they translated the representation into paper creating conventional graphic representations of the quantitative data.

Conclusion
The problem solving strand becomes powerful thinking and acting resource in the kindergartens' work on technological thinking. It encompasses many aspects that are gradually constructed by the children through repeated experience. The representational aspects are central to many stages in the process, including the consolidation of formal and conventional ways to express things. The focus chosen by the teacher, i.e., the graphic depiction of quantitative aspects, was implemented on the basis of the interplay between the concrete play and the symbolic representation - first as "concrete-symbolic" human-graph, then, once constructed and understood by experience, switching to only symbolic representation.

Concluding remarks

This paper presents only a very succinct glimpse into a very rich and complex process taking place in the kindergartens. We have witnessed a substantial transformation in teachers knowledge, perceptions and practices as well. More important, we do have evidences of teachers' appropriation of the components of the proposed model and their localization the generic ideas in correspondence with the idiosyncrasy and needs of each kindergarten and teaching team. The implementation of the model has already created important changes in the kindergartens' culture and life, and we expect to collect richer experiences as we move towards the advanced stages of the program.

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The growing necessity for graphical competency

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Keywords: Technology Education, Graphical Capability, Visual Culture

Abstract

This paper aims to explore the value of graphical competency within contemporary technology education and society. In an attempt to establish the key perspectives on the contemporary merit of achieving competencies associated with graphical education, a review of the literature from both national and international sources was undertaken.

Graphical education in Ireland, in the context of technology education, has its roots in vocational education. The traditional subject focused on developing knowledge and competencies primarily associated with craft based outcomes (Seery, Lynch, & Dunbar, 2010). This philosophy has shifted focus in recent times in reaction to the ever-changing needs of our global society. However, as McLaren (2008) discusses the recent changes in curriculum across many countries, as having left many educators questioning the role of communication graphics in today's educational milieu. With the availability of resources such as digital media and CAD systems in industry, many have questioned whether graphical education is a redundant subject area (McLaren, 2008).

Therefore, an analysis of the role of graphical competency in a broader technological context is required. Plane geometry, knowledge of projection systems, standards and conventions are core skills that were associated with an early conception of graphical education. Today however, a broader skills set is envisaged to comprise contemporary graphical capability within technological education. Elements of graphical education, such as spatial ability, are core cognitive aptitudes that have been identified as vital to many vocational fields (Steinhauer, 2011) most notably, but not exclusively, the technology and engineering subjects. However, they are also vital in everyday tasks such as communicating ideas and finding one's way in an environment (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002). Graphical education also lends itself to the development of further cognitive complexities such as modelling and ideation. As Baynes (2010) discusses, graphical competencies are directly related to practice and understanding in design.

Considering the visual nature of society, the requirement for graphical competencies becomes more urgent. Technology education offers a suitable arena for the development of these competencies and more specifically graphical education where the associated skills are taught explicitly.

Introduction

The principle goal of this paper is to examine the role of graphical education within a contemporary view of technology education. This research is concerned with investigating the purpose and value of graphical education and it is envisaged that the research presented in this paper will contribute to this investigation. Graphical education equips students with a number of core competencies, some of which will be discussed in this paper. Key perspectives on the importance of visual skills, as part of a broad skill set, are presented in the first section. The paper discusses the importance of visual literacy in contemporary society and within education. The paper addresses some of the contemporary views of graphical education within modern technological curricula.

The Visual Culture

Much of the available literature on modern visual literacy refers to the current culture of society as the visual culture (Duncum, 2001) or the digital media culture (Jonson, 2002). Regardless of the specific name there is no doubt that society, in general, has become more dependent on visuals to negotiate meaning in contemporary environments (Elkins, 2008). Mirzoeff (1999) distinguishes between two phases of human culture, modern which refers to the past and post-modern which refers to the present but reiterates that a concrete dividing line cannot be drawn between the two. He also highlights that it is in the postmodern era where the visual culture has become dominant over modern cultures (Ibid).

This shift that society has taken is evidence of a greatly altered environment where words and text alone are no longer the dominant mode of communication (Felten, 2008). As Duncum (1999) discusses, within contemporary society there is now a new amalgamation of technologies, economic relations and social formations where the pictorial plays the central role. Debord (1977) describes society as that of the 'spectacle' and discusses in depth the dominance of consumerism which is influenced predominantly by the visual. Authors such as, Lash and Urry (1994), claim that to look at the latest products that are available is to witness the seductiveness and power of the visual. Heywood and Sandywell (2012) claim that Debord's original allegory of the 'Society of the Spectacle' is no longer adequate and we should now consider the 'Universe of the Spectacle' as every branch of knowledge and contemporary social systems now rely on the creation of visual meaning.

Visual media is becoming the norm for communication in all facets of contemporary technological society (Bertoline, 1998). As outlined by Mirzoeff (1999), in everyday living, the internet and the television are the dominant modes of communication and there is always a visual message being described. With the ease of manipulation of visual media today, a renewed focus on visual skills is required and questions the role of education in equipping individuals to participate effectively in the visual culture.

Visual Literacy

The role of the visual within postmodern culture and the need for a renewed focus on visual skills are becoming more apparent. This section of the paper attempts to address some of the skills required to participate effectively in this contemporary visual culture. Brumberger (2011) provides an overview of a number of attempts to define visual literacy which are not all completely in agreement. Although there is disagreement as to an encompassing definition of visual literacy, most theories share common concepts (Avgerinou, 2011). A general definition as Bleed (2005 p.5) describes it as the ability to 'understand and produce visual images'. Mirzoeff (1999) highlights that as the visual culture moves forward the skills required to participate in it change, this may be a factor that has prevented the establishment of a universal definition. Given the visual nature of modern society, visual literacy becomes even more necessary as part of a post-modern curriculum both in professional and everyday contexts.

The enGuage report (cited by Bleed 2005, p.7) lists visual literacy as one of the key skills for the future, which will 'advance thinking, decision making, communications and learning'. With the power of modern advertising, which relies heavily on the image, there is a need for citizens to become 'critical viewers' through the study of the visual (Mirzoeff, 1999). Stafford (2008) presents an urgent need to focus on visual studies within modern school curricula. One of the main reasons, as she discusses, to have an enhanced awareness of one's own visual strengths is due to the power of modern technology in completing some of the more basic neural connections of the mind:

> While growing neurons continuously establish transient connections with one another in a random fashion, these connections rapidly unravel unless some outside influx causes them to be utilized, amplified and thus stabilized
>
> (Stafford 2008, p.45)

These neural connections are essential during the learning process and with the access to visual technology that is available today such as computer aided design (CAD), animations and simulations, some may not be occurring to an extent that existed prior to the technological era. Onians, Anderson, and Berg (2012) describe in detail how an informed approach to studying the visual can be adapted from the field of neuroscience. Again, they discuss the critical links made by neurons during tasks and highlight that modern imaging can now graphically display dendrites being formed on the neurons during a task. These dendrites are generally formed as a part of experience, which today is predominantly visual (Bertoline, 1998). Eisner (2002) uses the example of a map as a visual tool which helps an individual to navigate an environment and reiterates that this is a powerful graphical tool that displays relationships in space. Therefore, if we have the ability to interpret and utilise such a tool, through the development of spatial abilities and visualisation skills, it allows us to 'understand a particular environment and our place in it' (ibid p. 11). Having a stronger awareness of one's own visual abilities can enhance performance in a number of contemporary settings.

Avgerinou and Ericson (1997) conducted an extensive review of literature in search for a definition of visual literacy and the associated educational benefits. Some of the benefits they cited were increased in all kinds of verbal skills, improved self-expression, increase in student motivation, catering for a wide variety of learning styles, improved image of self, confidence and independence (Ibid p.289). This work was further consolidated by the production of a framework, containing the core elements of visual literacy, which stemmed from the literature review (Avgerinou, 2011). This framework is illustrated in figure 1.

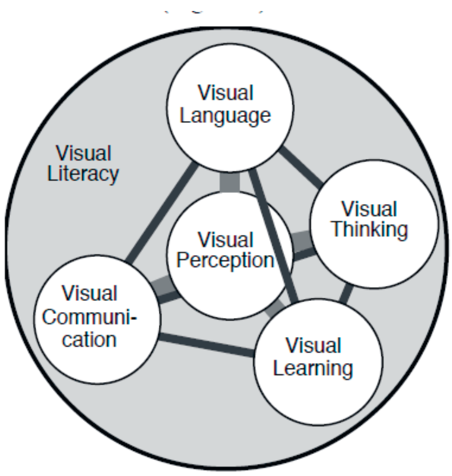

Figure 1: Components of Visual Literacy (Avgerinou 2011)

The Role of Graphical Education within Technological Curricula

Focusing on Irish education, graphical education began with its roots in two different areas; Art and Technical education. The focus of this paper is concerned with technical aspects of education and will therefore focus on graphical education where the skills taught were associated primarily with manufacturing based outcomes (Seery et al., 2010). Plane geometry, knowledge of projection systems, standards and conventions are core skills that were associated with an early conception of graphical education, and were primarily concerned with the effective communication of craft based outcomes (Seery et al., 2010) . While these skills may be still critical components of graphical competency, a broader conception is envisaged to comprise contemporary graphical capability within technological education.

Graphical education aims to address the development of a unique set of skills in students and encourage them to become 'problem definers and creative problem solvers' (NCCA, 2007). The philosophy of graphical education programmes varies slightly depending on the cultural context but a number of core areas associated with graphical education are commonly identified in the majority of the literature. These include problem solving abilities (NCCA, 2007) , creativity (Eisner, 2002), spatial cognition (Sorby & Gorska, 1998), geometrical knowledge (Olkun, 2003), drafting skills (McLaren, 2008), sketching abilities (Lane, Seery, & Gordon, 2009), visualisation , and ideation and modelling skills (Baynes, 2010)

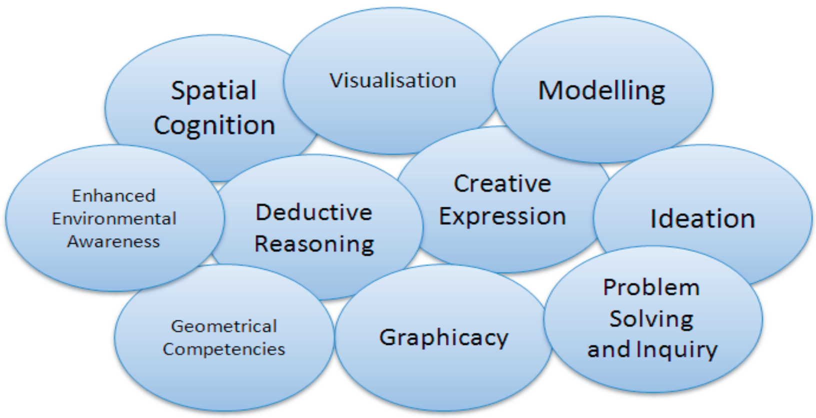

Figure 2: Some core aptitudes associated with graphical education

Figure 2 highlights some of the core competencies associated with a contemporary view of graphical education. Elements such as graphicacy which has been defined as means of visual communication (Danos & Norman, 2010) are critical within an contemporary technology curriculum. Communication by visual means has already been described as a critical element of modern culture earlier in the paper and is vital within technology education where students are often tasked with elaborating on and communicating design ideas. As Danos and Norman (2010) discuss, it is an area with great potential and can break through the conventional language barriers.

Elements of graphical education, such as spatial ability and visualisation, are core cognitive aptitudes that have been identified as vital to many career fields (Steinhauer, 2011) most notably, but not exclusively, the technology and engineering subjects. These skills, which are core elements of graphical education, are also essential for broader tasks such as finding one's way or place in an environment (Hegarty et al. 2002, Eisner 2002). The ability to visualise possible solutions to problems or issues is an essential skill within problem solving which is one of the core aptitudes technology education aims to address (NCCA 2007). Previous research by Sorby and Gorska (1998) and Sorby (2009) have shown that developing skills in sketching and drafting have significant positive effects on students spatial abilities and hence learning to use CAD.

Focusing on geometrical competencies within graphical education also facilitates the development of spatial abilities (Olkun, 2003). The development of geometrical knowledge and the ability to apply it to solving problems offers a significant basis for the development of advanced reasoning skills (Velichova, 2002). In the context of graphical education, geometry is a valuable analytical tool for solving problems of an abstract nature.

Modern graphical education promotes modelling and ideation which are core 'sense-making' activities (Kimbell, 2004). Modelling allows an individual to refine their cognitive process through various mediums and communicate aspects of the imagination which are not easily communicated through language or text (Baynes, 2010). Baynes (2009) illustrates the interchange between the mind and physical representation through modelling (see figure 3) which is critical for representing cognition in physical form. This interchange between internal and external modes of personal discourse is a very important skill refining a design or solution to an abstract problem. Lane and Seery (2011) has brought this concept even further in relation to supporting cognitive processing.

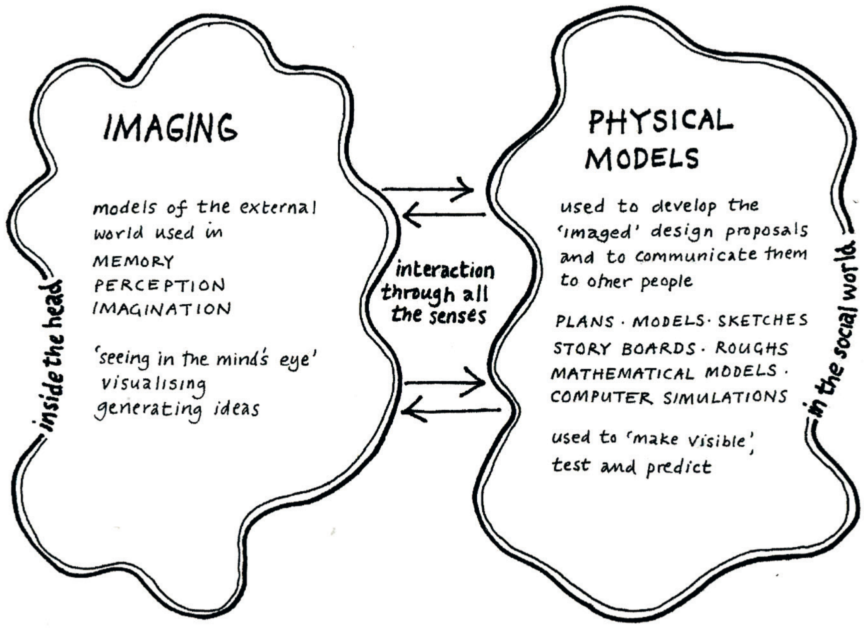

Figure 3: Diagram of interchange between imaging and modelling (Baynes 2009b)

Mechanical drafting of solutions still holds a place in the curriculum and as Field (2004) discusses, knowledge of technical drafting develops thinking in three dimensions and communication in two dimensional media. McLaren (2008) explores the value of teaching mechanical drawing in contemporary curricula and through an extensive analysis of literature establishes it as a universal graphical language which aids cognition and makes innovative problem solving explicit. Therefore, despite the dominance of CAD and digital media in most design contexts, tool independent graphical education still holds an essential role in developing robust competency.

Blurring the Subject Boundaries

Graphical education has been shown to develop a number of core competencies normally associated with design and engineering professions. This section attempts to explore the use of graphical competencies in broader educational contexts. Bedward, Wiebe, Madden, Minogue, and Carter (2009) explore the development of graphical literacy as a means of enhancing inquiry and problem solving skills in science education. The focus of their work linked elements of science, engineering and technology with a universal graphics tool during the problem solving process. The research provided robust evidence of the power of graphical representation in constructing meaning (Bedward et al., 2009) and has strong links to Baynes (2009a, 2009b, 2010) and Lane & Seery (2011) concept of refining cognitive processes through modelling although applied to a different context.

Sherwin (2008) provides a strong case for teaching visual literacy skills to law students discussing that the image when used in legal proceedings can often portray significant meaning not readily interpreted from linguistic mediums. Previous research by Danos and Norman (2010) has shown that visual skills are not just applicable to those subjects that explicitly teach it but to a wide range of different fields. The role of the visual has emerged as an urgent research topic according to Mitchell (2008) who explains that it is essential in all fields from human psychology and social behaviour to the structure of knowledge itself.

Petty (2009) provides an extensive review of the use of graphical tools in general teaching strategies which have been shown to produce an effect size (impact on student learning) of between 1.2 and 1.3. One of the primary reasons one should employ graphical representations of concepts is that it promotes whole brain learning and caters for a wide variety of learning styles (Petty 2009). Avgerinou and Ericson (1997) provide a brief overview of the pervasiveness of the visual across much of education generally which highlights the need for enhanced graphical competencies across all fields.

> In the middle years, we employ schemata and diagrams to simplify processes and procedures, e.g. The rain cycle. In secondary education, pupils are required to engage with an increasing range of visually presented information, e.g. conventional signs and maps. In chemistry, great reliance is placed upon the pupils' ability to understand three-dimensional molecular structures.
>
> (Avgerinou and Ericson 1997, p.289)

Conclusion

This paper considers some of the relevant viewpoints on the visual nature of modern culture. Graphical education has been discussed in relation to the role it has to play in developing a broad contemporary skill set. Expressing and constructing meaning through graphical means are methods that all young children engage with prior to formal schooling (Eisner 2002, Anning 1997). However as Eisner (2002) discusses, these skills are often overlooked in favour of more traditional elements of literacy during formal schooling. Felten (2008) states that the dominance of traditional literacy has ended and we have entered a new era of the visual. This is not to say that this paper advocates the discontinuance of traditional literacy but to place emphasis on a new concept of literacy that treats the visual as a core element including visualisation and visual thinking skills.

Visual thinking and expression are core elements of constructing meaning in a wide variety of learning contexts. Modelling and ideation, which are forms of visual expression, have been shown to be powerful problem solving and sense making tools (Baynes 2009a, 2009b, 2010, Anning 1997, Eisner 2002, Kimbell 2004). Graphical education promotes the development of these skills and more including, but not limited to, spatial cognition, analytical geometrical knowledge, which aims to develop deductive reasoning, and communication skills. Innovative thinkers and creative problem solvers are the types of graduates required in our multi-faceted, ever changing society (Robinson, 2001). With the role that visual communication plays in this modern society, providing students with the necessary graphical tools and the ability to put them in to action through graphical education can only enhance these desired qualities.

Graphical education is no longer rooted in a set of traditional values with a vocational focus. It has developed from a subject, which focused on the production of accurate mechanical drawings, to one which embraces a conceptual outlook. In order to develop these traits effectively, an enhanced vision of graphical capability must be established for future education. Lowther, Bassoppo-Moyo, and Morrison (1997) addressed a similar agenda when discussing the introduction of computers to education and stressed the need for educators to progress from literate to competent. In terms of graphical education, it is envisaged that this would mean moving from simply being able to use these graphical tools to constructing appropriate pedagogical resources and strategies to enhance the learning of them in the classroom. In other words, it means moving from being graphically literate to graphically capable.

Previous research by Brumberger (2011) has shown that simply being emerged in the visual culture of society does not guarantee the necessary cognitive skills required to become critical visual thinkers. The principle goal must be to establish a set of transferable cognitive skills that range across many subject boundaries and better equip the student with the necessary visual skills to participate effectively in post-modern technological culture. This brings into question the purpose of graphical education. Is it a subject that is purely concerned with representation or is it the arena to develop these enhanced cognitive aptitudes for transferable purposes? Education is the environment where these skills can be developed as a set of multi-modal literacies and capabilities. More specifically graphical education provides an opportunity to focus effectively and explicitly on transferable, life –long skill, especially within technology education.

If these graphical skills are to be facilitated through an educational milieu, further research must be undertaken to establish a framework of graphical capability. Does becoming a graphically capable entail simply mastering the core graphical competencies such as spatial cognition, ideation skills etc.? Alternatively, does it entail further development such as enhanced awareness of one's own metacognitive abilities in a graphical context? The research discussed in this paper supports the use of graphics as broader sense making tools and allows an individual to externalise their cognitive processes. This paper provides an initial rationale for developing graphical skills in contemporary education and establishes the basis for future research in the area of graphical capability.

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Challenging learning journeys in the classroom: Using mental model theory to inform how pupils think when they are generating solutions

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Key words: mental models, problem solving, Design and Technology, Mathematics

This paper presents a discussion about the interplay between Mental Model Theory and the generation of solutions to learning challenges in the primary classroom. It explores how pupils negotiate the problem solving spaces that can arise in the two learning areas of Mathematics and Design and Technology although the cross-curricula nature of learning in the primary classroom can conflate the two domains.

Learning challenges engage thinking. Teachers will think about, and subsequently design, challenging scenarios that will stimulate their pupils to generate a range of possible solutions. In turn, pupils will think about how they will meet the challenges. Mental Model Theory informs teachers' knowledge about thinking: it explains how mental models arise from the idiosyncratic methods of developing the dialogue and relationships necessary to guide thinking. Mental models are purposeful cognitive structures that have a process/product nature. They also have several functions that enable them to store data and enact strategies to generate outcomes. The theory explains how pupils engage in the thinking process to assimilate memory, new data and personalised strategies to find solutions to challenges. When faced with a novel challenge, pupils retrieve, restructure and/or create, and store useable mental models in accordance with their perceived relevance to generate an acceptable outcome.

This paper explores how a challenge, be it finding a solution to a mathematical conundrum or creating a response to a brief in Design and Technology, stimulates thinking processes. The discussion will consider how an understanding of the functions of mental models, through the use of the Mental Model Mode, can enhance constructive and inventive thinking in classrooms. It proposes implications for pedagogical practice and some key considerations for teachers as reflective practitioner – and designer of learning challenges.

1. Understanding mental model theory

The word "model" has lead to some vexation by researchers of cognitive theory because of peoples' certainty that they understand what the word means when used in the designation *mental model*. Everyone knows what a model is! To remove any ambiguity about the word, "model" here serves two grammatical purposes: a *noun* where it is "a representation in three dimensions of … a proposed structure", and as a *verb* "to form a thing in imitation of . . .[that is, to] devise a model of a phenomenon or system" (Moore, 1987, p. 900). Mental models, being "models" are bimodal (Edwards-Leis, 2010): as a *product* (Gentner & Stevens, 1983; Henderson & Tallman, 2006; Johnson-Laird, 1983; Newton, 1996) produced through cognition by individuals to create a representation or structure of a phenomenon or solution to a problem, and as a *process* (Carroll & Olson, 1988; Halford, 1993; Henderson & Tallman, 2006; Norman, 1983) where an action of retrieval, restructuring or creation occurs to form and reform these representations of the structure of a phenomenon or solution to a problem. Consequently, the term "mental modelling" can be used to explain the process that individuals undertake when they create, or retrieve, mental models in order to devise more useful or refined mental models to solve problems.

Confusion also exists in individuals' beliefs that a "model", in its purest form, may be a reproduction of the reality of a phenomenon in an environment. Mental models are not just reproductions: they have a dynamic existence that is separate to the reality they *model* once they have been produced by the individual (Edwards-Leis, 2010). When a mental model is seen as useful it is stored, by the individual, in long-term memory where it may be related or connected to many other mental models and cognitive structures such as schemes (Piaget, 1970), schema (Anderson, 1977), propositions (Kyllonen & Shute, 1989) and scripts (Preece, Rogers, Sharp, Benyon, Holland & Carey 1994). However, the mental model now exists within its own reality and no longer relies on the replication of its source phenomenon (Barker, 1999).

Novel problem situations are of interest to educators because they require learners to map knowledge and skills from known problems to new circumstances. Norman (1988) recognised that cognitive representations, such as schemata, could not explain what occurred when individuals encounter new or novel problems. Schema theory was seen to be inflexible due to schemata's reliance on static propositional representations (Johnson-Laird & Byrne, 1991) and it did not account for the negotiation of irregular everyday encounters with the environment (Halford, 1993; Norman, 1988). Mental models use both propositional representations *and* schema to predict outcomes (Kyllonen & Shute, 1989) and in doing so, assist the functionality of short-term memory (Henderson & Tallman, 2006). Solving complex problems can be limited by working memory because it cannot hold all the components, such as which particular knowledge and which application of skills is necessary to solve the problem (Merrill & Gilbert, 2008).

Halford (1993) argued that mental models reflect the structure of phenomenon in the environment whether it is a situation, task, concept or a problem with which an individual is faced. He hypothesised that if we can correctly, or incorrectly, understand the phenomena then we generate a respective correct, or incorrect, mental model. In other words, individuals can store mental models, that is, representations of phenomena which they correctly or incorrectly comprehend but for which they see some value in retaining. Norman (1983) also highlighted this inaccurate and incorrect nature of mental models thereby suggesting an explanation for and individual's retention of inaccurate information.

Senge (1992) suggested that mental models had a multifarious nature and explained that we "cannot carry all the complex details of our world in our mind" (p. 36). He argued that ". . . we do not have mental models . . . we are our mental models" as "they are inextricably woven into our personal life history and sense of who we are" (p. 37). The essence of mental model theory and its interest to teachers is its capacity to explain how pupils interact with the world. Gentner and Stevens (1983) and van der Veer and Peurta-Melguizo (2002) described this interaction by linking mapping with a mental model's function as a performance control mechanism. This mechanism enables us to predict, interpret, and communicate. Craik (1943), the grandfather of mental model theory, described them as "representations in the mind of real or imaginary situations" (p. 12) and used the theory to explain how individuals explain, understand and solve anticipated events.

In summary, mental models are cognitive structures that are based on new understandings, prior knowledge, existing ideas and past experiences that we use to interpret and explain events in our world (Moseley, Desjean-Perrotta & Utley, 2010). Williamson (1999) proposed that mental models are malleable and require some accommodation by the user or learner and that this may not always be easy to do, particularly if they are anchored by deeply held beliefs (Norman; 1983). Social and cultural relationships (Vosniado, 2002) that anchor a mental model may be very strong due to their being based on experiences, personal perceptions, and superstitions that may attach to certain emotions and/or experiences. Therefore the educational, social, and cultural relationships that exist to create mental models can, subsequently, make the mental model difficult to manipulate and alter if it is inaccurate. However, human experience can also serve to make learning richer and, therefore, remembered.

2. Methodology to discern mental model functions

The study that was undertaken to investigate mental model functions was an empirical qualitative study, based in an Australian Primary school commencing in February 2005 and ending in October 2006. The methodology was centred within information processing theory and linked with the introspection mediating process tracing paradigm. This approach presented a significant conceptual framework (Kail & Bisanz, 1992; Lohman, 2000) to provide the model to "look inside the minds of learners to explore what happens when learning occurs" (McInerney & McInerney, 2006, p. 96) and when students are carrying out tasks that involve problem solving (Henderson & Tallman, 2006). This focus was essential because a determination of the in-action mental models used by students when they were solving problems would determine the functions of mental models that guide the process.

The context for the study was robotics, which is an optional component of the Queensland Technology Syllabus (QSA, 2003). It provides a rich, multi-disciplinary environment in which to engage middle years students in designing, building, programming, and activating robots to complete set tasks. This study illuminated the dynamic nature of mental models through a longitudinal approach that incorporated a variety of investigative instruments. The study involved a binary focus both on the journey markers where data was collected through Likert Scale questionnaires, semi-structured interviews, stimulated recall interviews, teach back episodes, journals and focus group interviews, and on the intriguing glimpses of the human experiences afforded along the way.

The research examined how one teacher and her students' mental models can inform teaching, learning, and authentic assessment practices. There were twenty-four Year Six student participants and one teacher in the study. Four students were anonymously chosen to participate in the more in-depth aspects of the study including stimulated recall sessions and semi-structured interviews. All interview data were analysed using pattern coding (Miles & Huberman, 1994) in order to reduce data to workable units to enable both the determination of the mental models being studied and cross-participant analysis of common mental models. So while mental models are internal structures (Johnson-Laird, 1983; Norman, 1983) they can be exteriorised (Barker, van Schaik, Hudson, Meng Tan, 1998) when triggered by interaction with a domain system (Carroll & Olson, 1988; Norman, 1983) such as robotics. The resulting interactions, within the domain and with other participants, are physical (Jonassen, 1995) and those performances can be observed.

3. How the functions of mental models can assist problem-solving

Individuals construct idiosyncratic models (Norman, 1983) that may not be correct or useful to solve problems yet are retained because of their perception that they are functional. The uniqueness of a retained mental model retained arises from the way in which it reflects that individual's interactions with the environment (Halford, 1993). Mental models also contain reflections of problems, events, and stories that may be imaginary (Byrne, 1992). Such fanciful ruminations arise from our constant interaction with the world and reflect our individualistic ability to develop the relationships and dialogue necessary to guide understanding. The functions of mental models that enable problem environments to be explored have been established through longitudinal study (Edwards-Leis, 2010) and include how mental models help us:

- explain;
- predict;
- control action and thought;
- diagnose;

- communicate; and,
- remember.

The *explanatory* function enables understanding and selection of strategies because mental models "facilitate cognitive and physical interactions with the environment, with others, and with artefacts" (Henderson & Tallman, 2006, p. 25). Simply put, in order to understand their world by comprehending what causes, influence, controls or prevents phenomena, humans construct models of it (Johnson-Laird, 1983). But, not everything contained in a mental model is complete or accurate because, as Norman (1983) suggested, an individual's mental models are shaped by personal attributes such as their background experiences, expertise in different domains and, often, their unscientific or superstitious beliefs. Also, we forget thing, or store them poorly in long-term memory, and mental models that are not used regularly become stagnant (Norman, 1983), often needing re-evaluation and modification if they are to remain useful and functional as a means of explaining phenomena.

The *predictive* function enables problem solving in novel situations. This act is not always a straightforward, logical or tidy process due to mental models containing mental images, analogies, assertions, propositions, relations, abstractions, superstitious and beliefs (Norman, 1983), as well as the associated conceptual, declarative, and procedural knowledge (Johnson-Laird, 1983; Newton, 1996; Redish, 1994) for that situation. Mental models enable an individual to predict how a system will work or a problem will be solved (Johnson-Laird, 1983; Norman, 1983) and this function serves to differentiate mental models from other cognitive structures that do not account for novel situations that individuals encounter. If a mental model is accurate and complete then its predictive power should be greater and individuals can evaluate the plausibility of possible solutions. The search for solutions to classroom challenges usually requires pupils to concurrently run and link various mental models (Norman; 1983; Payne, 1991) as they predict possible outcomes.

The *control* function provides a platform from which to make decisions (Edwards-Leis, 2010) and control behaviour (Henderson & Tallman, 2006; Newton, 1996) because individuals consider options when faced with choice. Mental models are "what people really have in their heads and what guides their use of things" (Norman, 1983, p. 12). Individuals can be conscious of running mental models although they can also be run unconsciously or automatically (Henderson & Tallman, 2006). If a teacher is introducing a new idea that students are struggling to understand, they can retrieve and run mental models containing ideas, concepts, and/or strategies from past lessons that were successful. The teacher's retrieval of successful experiences (Henderson & Tallman, 2006) indicates that mental models can be controlled to adapt the environmental phenomena and subsequently enable successful mapping of the new knowledge to existing mental models.

The running of mental models enables even poor performances to be controlled because opposed to other cognitive structures such as schemata and scripts mental models have the capacity to deal with novel situations. The classroom experiences, documented by Henderson and Tallman's (2006) research, were found to be either "liberating or stultifying" (p. 25) for the teacher and pupil. The difference is due to control: either the individual controls their mental modelling by retrieving and/or adapting them when they are diagnosed to be ineffectual to facilitate an effective solution or the individual is controlled by an unadaptable mental model and cannot make progress to a solution.

The *diagnostic* function of mental models enables students to develop metacognitive awareness. The term "perturbation" (Ritchie, Tobin and Hook, 1997) was used to explain the contradictions felt by learners when new knowledge was needed to link with prior knowledge to create a remodified mental model. The customised mental model would incorporate the new experiences and concepts in order to overcome the perturbed state. Some guidance may be necessary for the learner to move through perturbation into a state of equilibrium (Piaget, 1970) and this need for guidance reflects Vygotsky's (1978) Zone of Proximal Development where it is important to take students "a little beyond" (p. 8) what they know or feel comfortable doing alone. The diagnostic function of mental models for pupils, therefore, relies on an understanding, or metacognitive awareness, that they may be working with a mental model that does not allow them to assimilate new concepts (Royer, Cisero & Carlo, 1993) without this guided assistance.

The *communication* function enables others to see and understand the externalisation of an individual's mental models. Mental models facilitate the communication processes of writing, reading, talking, and listening while thinking through problem-solving situations (Barker, van Schaik & Hudson, 1998). When students share or communicate their mental models to others in class it involves oral discourse (Craik, 1943) that requires discussion where the social negotiation of a transitory mental model that can jointly be held by the participants occurs. This sharing often necessitates a "collaborative critiquing of one's own and others' mental models" (Henderson & Tallman, 2006, p. 47). Mental models are communicated through a language and other individual and cultural nuances such as facial expression, body posture, and vocal shades which all need to be 'translated' so that communication is successful. Written discourse can be complex as well and involves some form of writing where text or symbolic script is used to express what is known (Barker, van Schaik & Hudson, 1998).

Mental models have a *memory function*. They are transient and permanent because of their existence in both working memory and long-term memory (Gentner & Stevens, 1983; Henderson & Tallman, 2006). However, it would seem that multiple mental models or parts of mental models could be run simultaneously (Norman, 1983; Payne, 1991). How an individual links the related parts of the mental models that are run depends on the network of related understandings (Henderson & Tallman, 2006) that they instantiate when the mental model is created and stored. Subsequently, how well an individual accesses or retrieves the required mental model, or part thereof, will depend on the efficacy of the storage process and the relevance of relationships perceived. Mental modelling can be influenced by many factors, including a student's meta-ability and their ability to effectively use their working memory (Newton, 1996; Power & Wykes, 1996).

4. The Mental Model Mode: a diagram of functionality

While mental models are internal representations they are externalised through some action. When pupils undertake problem solving in primary classrooms they are required to perform certain behaviours necessary to create or find a solution. While the learning areas, within which the students are operating, might differ the mental modelling required to complete the task should show similarities. The diagram (Figure 1) is the Mental Model Mode (MMM) that has been designed to explain the mental modelling that individuals undertake when they are addressing problem solving situations.

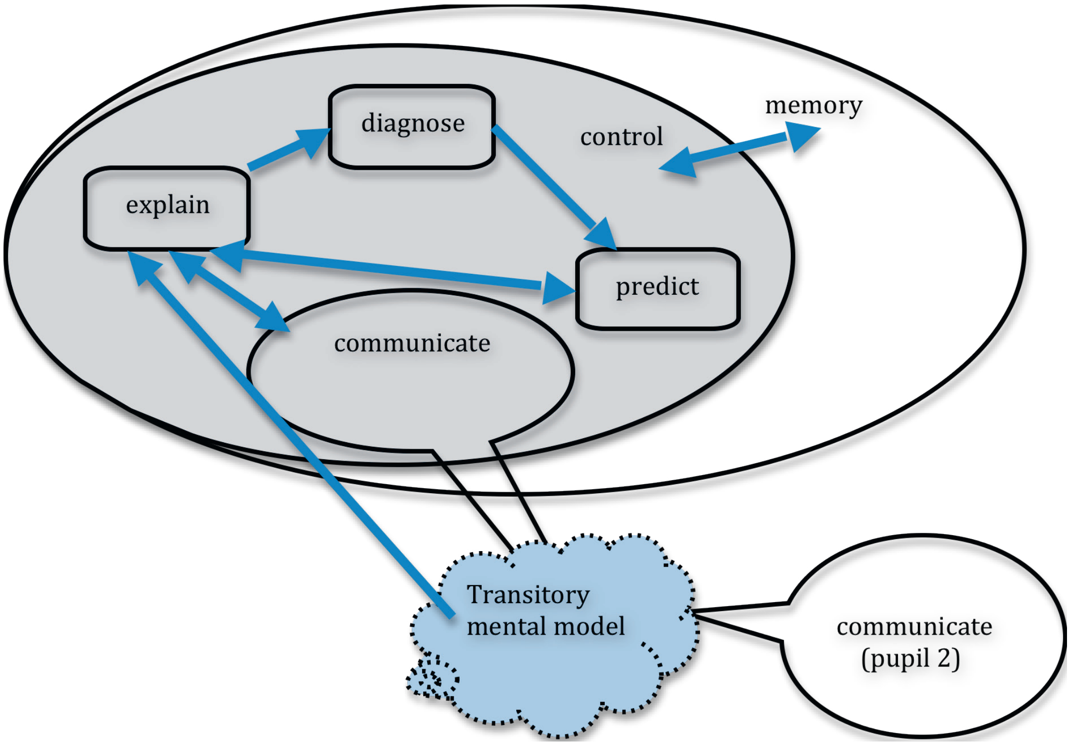

Figure 1. Mental Model Mode: diagram of functionality (Edwards-Leis, 2012)

The diagram accounts for the functions that mental models serve when an individual encounters a problem situation. The following discussion uses the domains of Design and Technology and Mathematics to illustrate the functions of mental modelling. It aims to establish the validity of the MMM to support teachers who are providing design or mathematical challenges for pupils in the primary.

One of the distinctions between problem solving in Design and Technology and Mathematics is the perception of complexity within the problem to be solved and the creativity afforded the pupil in seeking a solution. Design and Technology problems can be contextualised in most 'everyday' situations and while complex considerations need to be made the solutions available can be quite creative and unique. The solutions can be *new*. In mathematics, problems are most commonly used to introduce new mathematical knowledge (Jacobse & Harskamp, 2009) in order to contextualise the information and processes so that pupils can see how mathematics can be applied in 'everyday' situations. The solutions usually require some strategic processes, such as constructing a table to organise data or the comparison of features, and are most commonly *true*. This *new* versus *true* binary may not be mutually exclusive but offers and explanation for the delineation of the types of problems addressed in each of the learning areas.

Mental modelling using the MMM in Mathematics can involve a variety of processes to get to the same solution. Students encountering a problem to solve, such as how many pencil holders will be required for their Year Three classroom given x number of children, y number of tables, and z number of pencils, will need to retrieve the declarative knowledge about numerical values and operations from long-term memory necessary to explain what processes the problem involves. They will then diagnose their ability to solve the problem. This metacognitive process is essential because Johnson-Laird (2006) suggested that in most cases the inability to solve a problem is due to a lack of the knowledge required to do so. Once the pupil has established that they do have the necessary knowledge they make predictions or test solutions. If working with another pupil, they will share their transitory mental model predictions through oral, and perhaps written, communication (Figure 1). The pupil will decide whether, or not, to alter their chosen solution and adopt the transitory mental model or retain, and subsequently store, their own. They will need to be able to explain their solution and how it meets the criteria established in the problem and if it does – it is most likely *true*.

Design and Technology offers pupils opportunities to create novel solutions to everyday problems. Casakin (2011) discussed the access and retrieval process that students undertake when they design. This process, not dissimilar to that used by pupils to solve problems in Mathematics, engages the pupil in retrieving the conceptual, declarative and procedural knowledge required to transfer to a novel problem. The retrieval process depends on how a pupil explains the problem in light of their idiosyncratic ways of interacting with the world. If pupils, in the Year Three classroom above who established how many pencil holders were required, were subsequently given a brief to design and make them, then it is possible that a variety of ideals, values and intentions (Lawson, 2004) would inform the subsequent solutions. A teacher, who had exposed the students to a rich variety of materials, joining methods, and ethical design considerations, would anticipate disparate designs. The MMM (Figure 1) helps explain the processes that students undertake when designing where a constant cycle of explaining, diagnosing and predicting would occur as the pupil applied the design process to meet the requirement of the brief.

The MMM offers teachers a structure that explains the thinking processes that their pupils will use when meeting learning challenges. If pupils are encountering difficulties in negotiating a problem, then some part of the MMM may not operating effectively to advance learning. Newell and Simon (1972) explored the concept of problem space, which defined all possible sequences of the mental operations that pupils needed to address when solving a problem. An implication of this concept is that teachers need to consider this space and enact their own mental modelling, transacting the space to ensure that the all knowledge required for pupils to solve the problem is available.

Johnson-Laird (2006) suggests that "imagination helps us to reason and reasoning helps us to imagine" (p.351) and this has significance for teachers who are designing the challenges that will engage pupils in primary school classrooms. First, teachers should be creating the learning environments that expose pupils to rich problem states that enable them to mental model. Mental modelling, in Design and Technology or Mathematics should enable pupils to build upon the repertoire of skills, memories, strategies, and knowledge required to address novel problems. Problem states, regardless of learning areas, need to provoke robust mental modelling that engage both the *reasoning* that supports explaining, diagnosing and predicting functions necessary to problem solve and the *imagining* that promotes our idiosyncratic interactions with the world that create the relationships necessary to store mental models in our long term memory.

Providing significant opportunities to flex problem-solving strategies seems to be a key to success in learning to meet challenges. In addition to have the opportunity to problem solve, Joacobse and Harskamp (2009) recommend that pupils also be given some initiative for the approaches they will use thereby encouraging cognitive flexibility and adaptability. Mental model theory, through the MMM, enables the teacher to monitor the effectiveness of cognitive processes used by pupils when they are given such initiative. It can also help to explain why pupils repeat the same errors. Johnson-Laird (2006) reported that the most plausible explanation for a pupil's preference for an erroneous predicted solution lies in her inability to consider all alternative solutions and these processes may continue unless the pupil is helped to relinquish them. The Mental Model Mode provides a way to explain constructive and inventive thinking in classrooms and enables a clearer understanding of what really happens when we meet challenges.

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Technology and Gender in Early Childhood Education: How Girls and Boys Explore and Learn Technology in Free Play in Swedish Preschools

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The preschool is the first institutional context that Swedish children meet in their lives, and it therefore plays a very important role in the Swedish welfare state. As of 1998, preschools were part of the public school system and the first curriculum was then adopted. In the new curriculum for the preschool (2010) technology is emphasized as one of the most significant pedagogical areas to work with. In many countries the preschool age is seen as an important time for laying the foundations for interest in and knowledge about technology, since it is believed that the children's curiosity comes naturally. It is thus seen as a crucial age to get both boys and girls interested in technology. Although research on technology education in the preschool is lacking to a great extent, existing research largely confirms these views. The aim of this paper is to investigate how girls and boys explore and learn technology in free play in two Swedish preschools. The empirical study is inspired by an ethnographic approach and is based on qualitative data collected through observations and informal talk with children and teachers. Two preschools with children one to five years old were chosen for the study.

Today's society places high demands on the individual in terms of ability to acquire understanding of and knowledge about technology. One of the visions of the 2010 Governmental committee *Teknikdelegationen* was a Swedish society that provides all its citizens with the competence needed to understand, profit by and influence the development of an increasingly complex and technologically advanced society. Hence the committee emphasized that knowledge about technology must be disseminated early on, already in the preschool, and technology should be an important feature throughout the education system (Teknikdelegationen, 2010, p. 26-27). A clear majority of Swedish children now attend the preschool, although it is not mandatory. The preschool is consequently the first institutional context that Swedish children meet in their lives, and it therefore plays a very important role in the Swedish welfare state. As of 1998, preschools were part of the public school

system and the first curriculum was then adopted. In the new curriculum for the preschool (2010) technology is emphasized as one of the most significant pedagogical areas to work with.
In many countries the preschool age is seen as an important time for laying the foundations for knowledge about and interest in technology, since it is believed that the children's curiosity comes naturally (Axell, 2012). It is thus seen as a crucial age to get both boys and girls interested in technology. Although research on technology education in the preschool is lacking to a great extent, existing research largely confirms these views (see, for example, Parker-Rees, 1997).

The aim of this paper is to investigate how girls and boys explore and learn technology in free play in two Swedish preschools. The empirical study is inspired by an ethnographic approach and is based on qualitative data collected through observations and informal talk with children and teachers. Two preschools with children one to five years old were chosen for the study.

Previous research

There is a scarcity of technology education research concerning the early years, so here we present the few studies we have found that relate to our study, that is, primarily studies which connect play and gender to the learning of technology in early childhood. These studies concern both preschools and schools, since children aged three to six years can be either in the preschool or the school depending on country and school system.[1]

Fleer (2000) claims that there is little knowledge about how small children work when in technological learning contexts. In her article she presents a pilot study about the planning, making and appraising of technological activities by children three to five years old in a child care centre in the Australian Capital Territory. The study indicates that children as young as three years can engage in oral and visual planning when making things from materials, although it was difficult for most of them to use their plans for making constructions; the making did occur but the children often copied each other rather than following their designs (Fleer, 2000. Cf. Fleer, 1992; Hope, 2000). Milne (2012) is also of the view that children at the age of five can be taught some design capabilities, but that "it could be further enhanced by taking note of the focused but less structured practices of early childhood with a greater focus on child initiated play and fewer constraints posed by artificially posed tasks" (p. 11).

Tu (2006) investigated science environments in 20 preschool classrooms in the USA. He concludes that preschool teachers mostly organised activities that were unrelated to science but that around 13% of the activities were related either to formal or informal science education. According to Tu this low degree of science education in preschools both has to do with lack of science-related materials in the classrooms and teachers' unawareness of how to create science activities in daily preschool life.

Turja *et al* (2009) present an overview of an analysis of early childhood education curricula in six countries, and they conclude that the curricula do not offer much guidance for technology education in the early years. However, there are activities that can be utilized to boost technology education: "Play is highlighted as a fundamental way of learning seldom studied in the context of technology education" (Turja *et al*, 2009, p. 353). The authors take Mitcham (1994) as their starting point and assert that activities associated with technology might be transformed into roles that children can try out when playing – for instance, the roles of designer/inventor, manufacturer, mender, consumer/user etc. Turja *et al* (2009) also expound on various types of play, of which the best one for technology education seems to be the *functional play* where "children acquire knowledge of objects, materials and physical phenomena, and learn to master the use of tools and techniques through explorations and rehearsals" (p. 360). In short, it becomes possible for children to practice advanced technological activities and roles through creative play.

Furthermore, according to Turja *et al* gender stereotypes seem to be created as early as the age of three, which can be seen in the preschool when boys choose cars or typical male roles, and girls

1 For a recent, important overview of primary technology education, see Benson & Lunt, 2011.

pick dolls and typical female roles. It is therefore recommended, for instance, that boys and girls should, as far as possible, have equal access to activities and material, which should also be gender-neutral. Building and construction, either organised or in free play, should be made in social contexts that do not discourage boys or girls from participating (Turja *et al*, 2009, p. 363).

Mawson (2010) discusses the changing conception of the word ”technology” of seven children during their first six years in school (age five to ten) in New Zealand. There was only one child who could say anything about what technology is when he started school. When the interviewer asked “What does it (technology) mean?”, he answered ”You can make stuff”. As the other children experienced technology within the school context they also acquired a view of what technology is although it was poorly developed. Furthermore, Mawson shows that the girls found it more difficult to pin down what technology is compared to the boys. It is not clear why the girls were more uncertain in their understanding of the concept, but one explanation, according to Mawson, could be that the girls seemed to have a broader, more contextualized view of technology. They seemed to view technology in a wider context than the questions they had to deal with in the study. On the other hand, the girls had a more narrow conception in the sense that they did not see technology as planning to “develop new things” to the same extent as the boys, while both sexes ageed that “technology is making plans to solve problems” (Mawson, 2010, p. 3-8).

Mawson (2010) also shows that the children connected technological progress more to artifacts than to systems, which may be due to the heavy emphasis on designing and making products. Mawson relates the children’s answers to the question ”what does the word technology mean to you?” to their experiences of school technology (cf. Skogh, 2001), although this does not seem to have substantially developed their understanding of technology. This deficiency was due to a number of factors, for example, the lack of a planned progression for and teaching of the subject technology as well as the lack of understanding of the concept of technology among teachers. The children generally had a positive attitude towards technology, particularly the boys, but especially the girls were ambivalent regarding the value of technology for society (Mawson, 2010, p. 10; Cf. Mawson, 2007).

Theory and methodology

The study takes as one of its starting-points the framework of the sociology of childhood (James & Prout, 1990). One assumption in the sociology of childhood is that childhood is understood as a social construction. This means that childhood as a phenomenon varies over time and in different contexts. In this perspective it is also important that childhood cannot be separated from other variables like class, ethnicity and gender. It is also crucial to study children’s relations with each other and to study children’s living conditions in their own right (Prout & James, 1997).

This also means that even young children are to be taken seriously in technology education; children play an active role when engaging with science and technology and they do it in their own way(s). As a way of highlighting this in the analysis we use the term *childish science*, which was recently introduced as a conceptual tool for exploring the mutual relations between science, technology and children. Koch *et al* (2011) defines three strands of criticism toward traditional science education in which this term can be useful: 1. children’s life worlds are understood through their imaginaries of science, 2. children develop their own sense-making through specific cultures, social relations and rationalities, and 3. specific materials and technologies represent, communicate and translate knowledge in relation to children’s practices. Even though the concept applies to the school we believe that it is equally, perhaps even more, useful in a preschool setting of free play where the children’s own initiative dominate (Koch, Sørensen & Levidow, 2011).

In the interpretation and analysis of the empirical material we use a theoretical model for understanding technology and technological activity taken from Mitcham (1994), adapted for the specific needs of this study. Mitcham’s model and definition of technology and attitudes towards technology are probably the most generally accepted today within technology education and the philosophy of technology. Mitcham’s fourfold description of technology is employed to identify various aspects of technological activity and learning in the children's free play; technology as *volition*, *knowledge*, *activity* and *object*. Technology as *volition* comprises the will, wishes and intentions that start the technological activities, and *knowledge* consists of the skills and knowledge necessary to perform these activities. Technological *activities* are performed to reach a goal or fulfil wishes, either by designing and making or using technology. *Objects*, i.e. technological artefacts, are used in technological activities or are a result of these.

The empirical study is based on qualitative data collected by observations of and informal talk with teachers/minders and children inspired by an ethnographic approach (Hammersley & Atkinson, 1995), in two preschools in Sweden. Contact was established with the headmasters of these preschools according to a strategy selection (Bryman, 2001). Both preschools receive children from one to five years old, and neither of them has any special pedagogical ideology, except, of course, for the general directions laid out in the Swedish preschool curriculum of 2010. The staff consists of preschool teachers and childminders working in teams. The preschools are located in the south of Sweden, in one of the larger Swedish municipalities – *kommun*, an administrative division consisting of both rural and urban areas. *Preschool one* is located in a small village in the countryside, and consists of three different departments with a total of 120 children. *Preschool two* is located in an urban area and consists of 20 odd children in each of its departments, in sum 45 children.

The focus of the observations was on the children's "free play", both outside and inside the preschool. The observations also included activities and actions where children, preschool teachers and childminders were involved together. The study is based on fieldwork on nine occasions of two to six hours each in the two preschools. Ethical considerations have been important during the whole research process, in getting access to the field as well as in relations during the fieldwork (Roberts, 2008; Alderson, 2000).

Results

Both girls and boys use technology

The observed situations show that both girls and boys use technology in their daily life in the preschool. They use it both in situations which are planned as technology activities by the preschool teachers and in their free play. When the children play outdoors the central place for relating to technology is the sandbox. Children make sand cakes, they construct roads and transport different kind of materials on these roads. The sandbox is a place which attracts children of all ages in the preschool.

When the children play indoors both boys and girls are occupied with different kinds of construction play. One of the preschools has actively gathered different construction materials aimed at encouraging this kind of play.

At a group level the analysis shows that both what kind of play the children are engaged in and what kind of toys the children use are gender marked. For example, boys play to a higher degree with toys that can be categorized as typical "toys for boys" (cars, cranes etc.).

Construction *as* play versus construction *for* play

Construction play is a common activity among the children in the study. The empirical data indicates that there is a gender difference regarding how children use construction in their play and what purpose construction has for them. We have analyzed this main difference as construction *as* play versus construction *for* play. The observations show that boys more often construct things where the process or activity is central:

> David and Hampus [5 year old boys] are playing in the preschool yard. They are building a little house together with the help of battens. They discuss and negotiate how to make it as strong as possible. They spend much time constructing. During one film sequence they are building the roof. David is at the top and Hampus ... gives him battens. When the roof has been laid the house is finished (field notes).

The above situation shows that for David and Hampus the activity to construct is the main purpose of the play. Construction can be seen as the play itself; the boys are focused upon making the construction as solid as possible, which is why during the play they negotiate about the best building methods. In their play they also use advanced language for their age. For instance, Hampus asks David for a drill pin (*borrstift*).

> Four girls of different ages are playing with battens in the preschool yard. They want to play chute-the-chute and come up with the idea that they can angle the battens against the fence. They then ride the chute made up by the angled battens.
>
> Malin and Ronja [four year old girls] are playing with battens. They use them as tools in making letters (field notes).

One interpretation of this is that for boys the construction is at the centre of their play. When they are finished they tear it down to start all over again, while the girls in the above example build something they want to use. The girls seem to be more interested in technology as an object to use, while the boys favour technology as an activity. The girls are users of technology, while the boys are designers or builders (Mitcham, 1994; Turja *et al*, 2009).

Girls' lack of self-confidence

Generally, boys and girls have positive feelings toward technology, although boys are a little more interested in technology than girls (cf., for example, de Vries, 2005; Mawson, 2010). In our observations, however, we can see that girls and boys approach technology in different ways as regards self-confidence:

> The children work with volcanoes as a theme. The work consists of different tasks, of which the first one is to draw a volcano. The next task is to do an experiment to see how a volcano works. They first make a model of it. Then the preschool teacher asks the children if they want to put baking powder in the volcano. The children then act in different ways in relation to their gender. The boys actively tell the teacher what they want and they also show it with their body language ...The girls think that it is scary and change places so that they can sit at a distance from the volcano (field notes).

In the empirical example above the gender differences between the children are very clear. There are no differences when the children are drawing, but during the experiment, which is also quite a new situation for the children, it is obviously the boys who are the most active. We have seen this pattern on other occasions as well, for example, boys seem over all more self-confident when presenting themselves. They are also more eager to try something new.

The girls as helpers

> A group of children are playing in the construction room. The room is equipped with different kinds of materials with the purpose of stimulating construction games. Two boys [five years old] are playing with blocks. They are talking with each other and decide to build a tower as high as possible. Amanda [five years old] is looking at the boys' play but she does not touch or play with the blocks herself. After a while she starts to serve one of the boys with blocks (field notes).

Turju *et al* (2009) claim that girls generally have a lower self-confidence when it comes to activities which are seen as stereotypically male. They seem to connect failure to their own inaptitude while success is regarded as ”luck” whereas boys, on the other hand, couple failure with external variables but success with their own capability. The preschool teachers' understandings of gender are contradictory in this regard. Some say that they see no difference between the sexes concerning the free play in relation to technology. This is in line with their overall view of gender: "In technology there is no difference between the sexes until we as adults impose our own values" (Nathalie).

Other teachers are of the view that they can detect a difference between what boys and girls play with and how they do it (cf. Turja *et al*, 2009). They exemplify with the fact that boys more often build garages and roads while girls construct objects to do with, for instance, farming:

> Eva: And then I feel that, how should you deal with this, because the boys tend to play together. The boys build and design a lot . . . how can we make it more interesting for the girls? Outdoors it is easier to find solutions, take for instance the sand box . . . In outdoor activities gender makes less difference . . .

In the above quote the teacher describes how technology is easily connected to boys and masculinity, at least when the children play indoors. Nathalie also acknowledges that:

> Since everything is technology then girls also deal with technology, but girls devote themselves to specific activities. There is no buffet [of technological activities] for them.

Discussion

The focus of this paper is technology and gender among children in the preschool, especially in relation to free play where the notion of *childish science* (Koch *et al*, 2011), or rather *childish technology*, is most noticeable. The empirical material is limited but despite this there are interesting findings which are well worth investigating further. We will here discuss some interesting aspects of how girls and boys explore and learn technology in free play in two Swedish preschools. First we look at how boys and girls use technology, and, second, we deal with boys' and girls' different technological vocabulary.

The results show that both boys and girls use technology. In an interesting parallel to Mawson (2010), who shows that girls have more difficulties in defining technology, we can see in our observations that girls use technology in a different way compared to the boys. The girls more often construct *for* play, and by this we mean that they have a special purpose in building something they need in their play. If we use Mitcham's (1994) concepts, they are more interested in technology as *objects* for use than the boys. It is conceivable that technology is seen as an object part of a broader social context of play, thereby making the construction in itself less interesting (cf. Mawson, 2010, p. 3-8). The boys, on the other hand, more often construct *as* play, which means that construction is the main purpose of the play and when it is finished they often start to construct something new. In Mitcham's words the boys engage the most in *technological activities* which are enough in themselves. Technology represents, communicates and translates *knowledge* in relation to both these practices, which means that girls and boys learn to internalize these different approaches to technology (Koch *et al*, 2011; Mitcham, 1994).

It is therefore crucial for the preschool teachers to have a deeper understanding of both gender and technology. With that knowledge they can help children to choose different activities and to support them in their process of learning about technological objects and activities that are not typically associated with their respective gender. Some teachers saw no gender differences at all, whereas some were aware of the different ways boys and girls approach technology. This makes it difficult to "arrange" free play activities where there are equal opportunities for both sexes (Turja *et al*, 2009; Mawson, 2010). Ironically, the very broad notion that "everything is technology", which is contrary to much modern research in the philosophy of technology (see e.g. Mitcham, 1994; de Vries, 2005) opened up the possibility for certain teachers that not only boys but also girls handle technology in their daily lives.

We have not investigated children's understanding of technology by interviewing them, but we can see it when we analyze their conversation during play. There is a difference between boys and girls when they use technology as some boys employ specific words belonging to a technical vocabulary in their process of building. Both girls and boys interact with each other in a sense of sharing something during their play (Corsaro, 2003). In this interaction process the boys seem more familiar with using words that belong to a technological sphere, for example, "drill pin" or "we must construct a strong road so that the cars can drive on it without breaking it." The children's play is also different depending on where the preschool is located. The children who live in the countryside seem to be involved more in construction than those who live in the urban area, especially in the free play.

However, the previous teaching may also have affected the results of our research, and this needs to be investigated further. This would concern not only the environment more generally but also the way in which the children have been taught and the activities that they have previously undertaken. This, in turn, should be connected to the understanding and confidence of the teachers as well as how they relate to this in setting up activities.[2]

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The relation between students’ creativity and technological knowledge in cross-curricular technology and design projects

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Keywords: conceptual knowledge, creativity, fundamental design concepts, technological knowledge

Abstract
This study presents an analysis of how creativity in students work is related to the role of the key conceptual technological knowledge in four different cross-curricular technology and design projects in Norwegian primary and lower secondary school. All of the school projects examined were intended to be open-ended providing students with opportunities to be creative and develop their own solutions to the given task. The processes in the groups and the outcomes of the groups’ work are analyzed with regards to technological knowledge and how this relates to the students’ creativity in terms of producing genuine solutions. The analysis shows that in some of the projects the variety of solutions produced by the students is limited. In these student groups the solutions and procedures bear a high degree of resemblance to each other. The findings suggest that students’ limited conceptual technological knowledge constrains their ability to be creative and to produce genuine solutions. The findings also suggest that the projects showing less student creativity tend to be more controlled by the teacher and less open-ended than presupposed. A suggestion based on the findings is that the key conceptual technological content should be identified and communicated by the teacher prior to the project start. Discussing explicitly and exploring concepts and principles with the students before or during the project period will enhance their possibility to be more creative.

Introduction; basics of artifacts
A characteristic of the conceptual aspects of artifacts is their function. Artifacts are developed for a reason, they are intended to perform and fulfill a human need of some kind. The basic functionality of the artifact is referred to as the operational principle of the device (Vincenti, 1990). The parts that altogether form the artifact work in combination along a principle to fulfill the purpose of the device. This principle describes how the artifact actually works and thereby defines the artifact.

Arthur (2009) makes a distinction between phenomena and principles. Whereas phenomena are natural effects independent of humans, a principle is the “*idea of use of a phenomenon for some purpose*” (p.49). A principle is yet not sufficient for creating a working artifact. The principle has to be realized into a physical working artifact. This can be done in numerous ways and is not a straight forward procedure. Vincenti (ibid.) uses the term *configuration* for describing how the operating principle is realized. The configuration contains the arrangements and shapes of how the single parts of the artifact together accomplish the operational principle. As an example; the playground equipment described below would be providing opportunities for children to climb up and down a playground facility. Climbing up and down may be performed by the use of e.g. ladders, nets, ropes, slides or poles which allows for several principles for children to get on and off the facility. The configuration involves in this context how the various parts of the construction are arranged. A proper configuration would have to take into consideration differentiation of challenge for the children as well as security issues with the flow of children up and down the equipment.

The research question in this work is: How does students' creativity relate to fundamental design concepts in projects on Design and Technology in Norwegian schools? The study is conducted as a cross-case analysis of four student projects.

Invention versus designing

What are the characteristics of an invention? No unified satisfying answer can be given though some general aspects seem to be agreed upon. Unlike development and refinement of existing ideas where changes are small, incremental and usually takes place over an extended period of time inventions occur rapidly, ad hoc and unstructured. Mitcham (1994) portrays this twofold nature of designing by using the terms *invention* and *design* respectively; "*As opposed to designing, inventing appears as an action that proceeds by nonrational, unconscious, intuitive, or even accidental means. Designing implies intentionally planning*" (p.217). A similar view of designing versus inventing is found in Arthur (2009) , who uses the terms *standard engineering* for denoting normal design and *invention* as a representative for radical design.

According to Arthur (2009) there has to be a change in the operating principle if an artifact is to qualify as an invention (p.109). This view is shared by Pye (1964) who claims that "*invention is the process of discovering a principle. Design is the process of applying that principle*" (p.19).

Artifacts and processes introducing a genuine new operational principle will definitely be classified as inventions and a new operational principle will of course imply a new and hitherto unknown configuration. Also known operational principles given a genuine new configuration may count as an invention according to Vincenti (1990). He introduces three types of design; revolutionary design where the operational principle and thus the configuration is completely new, radical design where the configuration is completely new whereas the operational principle may be a modified version of a known principle, often transferred from a different domain, and finally normal design where both the operational principle and the configuration is well known for the designer and the community. In contrast to radical or revolutionary design, normal design is not associated with inventing. Any example of what we today regard as normal design will of course at a point in the past have been considered radical or revolutionary.

To qualify as an invention it seems further to be a general view that the idea has to be realized into a physical artifact. The path from an idea, no matter how detailed planned, to a complete working artifact satisfying the initial purpose is usually not straight forward.

In his thorough book of the genesis and development of technology, Basalla (1988) stresses the significance of play as a source for invention and innovation. Through numerous historical examples he shows how technological dreams, suggestions of impossible machines and popular fantasies has dominated the scope of technological novelties in history. He concludes that there exists no broad theory of technological innovation and that one of the obstacles is that such a theory would have to encompass amongst other factors the irrationality of the playful and fantastic (p.134). Similar views are given by Mitcham (1994) who advocates that from a perspective of emphasizing the historiosocial character of inventing which credits communities of inventors rather than individuals, inventions rarely occur in the chase of solutions to identified problems and needs but rather emerges in the process of playing with ideas (p.217).

Creativity

Though the term creativity is not easily defined or measured it has been given much attention by amongst others psychologists, educators and politicians. Several models describing creativity have been proposed during the last century (Lawson, 1990; Runco & Albert, 1990; Taylor, 1975; Wallas, 1926). Despite different approaches there seem to be broad agreement that creativity involves *"bringing something into being that is original (new, unusual, novel, unexpected) and also valuable (useful, good, adaptive, appropriate)"* (Atkinson, 2000). The latter point is of importance as it demarks creativity from loosely founded ideas that only differ from what already exists without judgment of its value or usefulness.

According to Christiaans and Venselaar (2005), definitions of creativity in the literature is given in terms of personal trait, the process or the product. They argue that the first two of these fail to offer reliable criteria for assessment. Based on the work of Amabile (1983), they conclude that "*..creativity can be seen as a property of products. A product is creative to the extent that observers, familiar with the domain of activity, independently agree it is creative*" (p.220). The results of Cristiaans (1992) confirmed the findings of Amabile (ibid.) that the inter-judge-reliability is high if competent observers independently judge artistic products.

Artifacts produced by the students seem thus most accessible for assessment of the students' creativity. Amabile (1996) offers a definition of creativity that is relevant for technology education and that meets the demand of assessment given by Christiaans and Venselaar's (2005): *" A product or a response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand, and (b) the task is heuristic rather than algorithmic "* (p.35) . Assuming this as part of the definition of creativity it resembles much of what is regarded as invention discussed above. In light of Vincenti's notion of fundamental design concepts it seems clear that creativity in T&D school projects would involve students either to bring up new operational principles (and thereby new configurations), or they might develop new configurations to already given operational principles. New or novel will in the educational context mean new and yet unknown to the student though it might be well known to professional designers and engineers.

The importance of authenticity is given attention by many authors. Hill (1998) focuses on the importance of open-ended problem solving in real-life contexts when working with T&D in the classroom. She advocates that these contexts are supposed to provide more of the crucial factors that foster creativity; the willingness to take risk, ill-defined problems and the tension between order and disorder. Similar views are found in e.g. Lewis (2005), Cropley and Cropley (2010) and Scott, Leritz and Mumford (2004). In order to stimulate creativity processes Scott et al. (2004) found in their comprehensive study of 70 empirical based studies of creativity training that open-ended, ill-defined problems was superior to expression of unexplored ideas in terms of fostering creativity. They further found that students should be introduced to basic concepts and principles and explore these through extensive training with various discrete cognitive skills and relevant heuristics before they turn to working with exercises appropriate to the domain at hand.

Description of the student projects

The projects were conducted at 4 different schools located in both rural and more urban areas in the northernmost part of Norway. All of the projects were intended to be authentic and open ended, and they were developed in collaboration with the researchers and the teachers in the respective schools.

Project 1 was conducted in grade 8 and the task was to construct and build a model of a drilling rig for oil exploitation. The rig was built partly in Lego with addition of other materials for the chassis of the rig. The Lego Robotics system was used for controlling the operation of the drill. Prior to the project the students were given a short introduction to the essential functions of the Robotics system and basic programming of Lego robots.

Project 2 was conducted at a small rural school including students from grade 3 to 7. The task was to design and build a model of an outdoor fireplace with shelter for thirty people. The shelter was supposed to have walls, roof and benches nearby a bonfire and was planned to be built in full scale in the vicinity of the school at the end of the school year. The students used the software Google SketchUp for making three-dimensional drawings from which they made templates correct to scale. These were in turn used to cut the parts of the construction in cardboard.

Project 3 was conducted at a rural school in grade 8. The students used SketchUp for designing models of playground equipment for their schoolyard. The design was performed initially by hand- made sketches which was transferred and reworked into detailed 3-D computer drawings. Based on these computer drawings the students made physical models of their artefacts using mainly cardboard as material.

In project 4 the students designed and constructed a model of a house fulfilling their dreams of how they wanted their future house to be. The designing started with hand- made sketches, moving forward to computer based designing using SketchUp before they constructed and painted their house in cardboard according to their final computer drawings.

Research methods

Data presented here is mainly collected by means of videotapes from the classrooms. In each classroom there were 3 cameras filming the activity. Two of the cameras were filming two groups of students respectively while the third was filming the overall situation in the classroom. Also stills were taken through the project process including photos of the products of all groups working in the classrooms. The researchers were present in the classroom engaged in observing the activity and handling the video cameras. As far as possible the researchers avoided influencing the classroom activity letting only the students' regular teachers engage in assisting them. This approach has elements of realist ethnographic nature as described by Creswell (2007). Triangulation between members of the research group has been conducted for selection and interpretation of episodes in the data material. When evaluating the variety of outcomes produced by the students the products of all groups of students in the class were taken into consideration. For analyzing the students' perception of the fundamental design concepts student-student interactions and teacher-student interactions were selected from the material.

Results and discussion

The analysis of the student products along the lines of Amabile (1996) shows that the variety in solutions produced by the student groups differs much from one project to another.

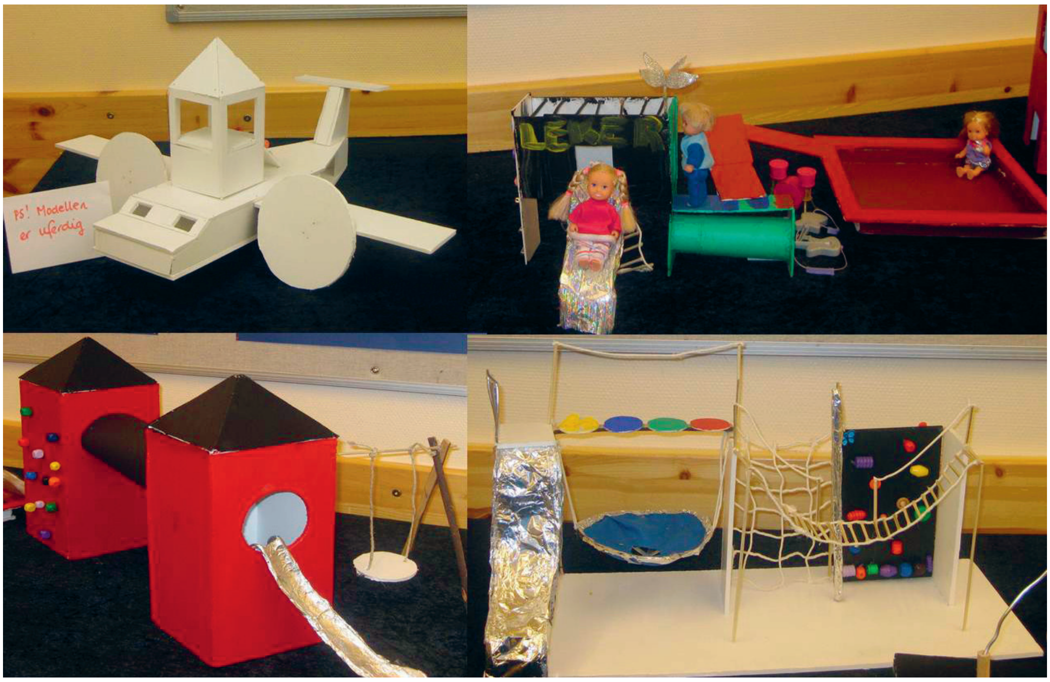
In project 1 (oil rig) the students produced to some extent genuine products; however the basic idea, the operating principle, was common for all groups. The configuration varied to some extent between the groups. Project 2 (outdoor shelter) was the project that showed least variation of the student made products. All of the artifacts were based on the same principle and had configurations that mostly bore a high degree of resemblance to each other. Project 3 (playground equipment) showed products with most variation relative to the other projects. All of the student groups came up with a genuine and unique product. Though the products were founded on basically the same operating principles, they differed significantly in configuration. In project 4 (dream house) the students produced to some extent genuine solutions, however the basic idea for their products were largely the same for most of the groups. The products of this project were evaluated slightly more diverse than those of project 1.

Also the students' perceptions of the fundamental design concepts were found to differ from one project to another. In project 1 (oil rig) the students had severe problems finding an operational principle and were dependent on teacher assistance for adopting a teacher defined principle. One of the groups succeeded in establishing their own configuration whereas the other group was more dependent on teacher guidance in the configuration process. In project 2 (outdoor shelter) the students clearly lacked understanding of the operating principle and thus needed intensive teacher assistance through the stages of the process. Even at the final stages of the process teacher interventions were necessary for the students to have progression in their work in one of the groups.

For this group the notions of normal and radical design is not applicable as they most of the time were carrying out instructions given by the teacher. The other group eventually entered the modus of normal design. In project 3 (playground equipment) the operational principle was apparently understood from the outset whereas the configuration developed through the process. The latter was not a consequence of problems that needed to be solved but was merely an expansion into more complex artifacts. As a consequence the students were in the modus of normal design most of the time where much of their effort was spent on the configuration process. In project 4 (dream house) the operational principle was evident from the start while the configuration had to be developed through the process. The process of developing the configuration was partly influenced by obstacles in the students' design process but also characterized by expansion of already successful ideas.

Images from two of the projects

Picture 1: Artifacts from project 2. This project was found to have least variety between the artifacts.



Picture 2: Artifacts from project 3. This project was found to have greatest variety between the artifacts.

Conclusions and implications

The findings suggest that the projects 2 (outdoor shelter) and 3 (playground equipment) differ most from each other in terms of the variety of the student products. These two projects also differ most in terms of students' perception of the fundamental design concepts. Project 1 (oil rig) and project 4 (dream house) are found between project 2 and 3 both when it comes to variety of products and students' perceptions of the fundamental design concepts. Normal design was found in all of the projects, yet being most pronounced in project 3 (playground equipment) where the students in an early phase of the project entered the modus of normal design. Radical design were most pronounced in project 1 (oil rig) where the students during half of the project struggled with the operational principle and eventually were depended on the teacher to bring them into the modus of normal design.

Based on these results a suggestion would be to spend more time and effort in the initial phases of the project work to assure that the students have a sufficient understanding of the conceptual knowledge and in particular the operating principle of the product they are supposed to construct. True invention in terms of students coming up with their own operational principle seems to be a too demanding task in the general case. It therefore seems necessary to introduce the students to already established operating principles and as a consequence facilitating creativity in exploring configurations. This will emphasize the notion of *design* somewhat at the expense of *invention* using Vincenti's (1990) terms. On the other hand, if students' abilities of *invention* are regarded as a crucial part of their competence gained from working with T&D in school, the tasks must be adjusted to meet this demand. Assuming a sociocultural approach to learning, and with Mitcham's (1994) and Basalla's (1988) view in mind, abilities of *invention* will not benefit from working with predefined problems. Giving students options to play with their own ideas thereby establishing operational principles regardless of the utility of the produced products seem to be more appropriate for stimulating abilities of inventing. In accordance with Scott et al. (2004) these ideas have to be deeply explored and realized into physical artifacts if they are to foster creativity. This requires true open-ended tasks where the teachers' interactions are avoided from being of instructive nature.

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Funds of Knowledge in Technology Education

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Abstract

When participating in technology education students require a range of academic, social and physical skills in order for them to collaboratively develop technological solutions to meet identified needs or opportunities. This paper reports part of a study that explores the role students' Funds of Knowledge play in contributing to learning in technology education in the primary classroom.

Funds of Knowledge are the developed bodies of skills and knowledge that are accumulated by a group to ensure that they can function appropriately within their social and community contexts (Lopez, 2010).

The study was undertaken in a primary school with 6 and 10 year old students. The data reveals that students used knowledge from their home and community to assist to make sense of their learning and to assist them in developing technological outcomes. The paper introduces two sub-categories of Funds of Knowledge and compares and the use of Funds of Knowledge within each sub-category between the two year levels and across a unit of work.

This study is significant because it highlights the use of Funds of Knowledge in technology education and examines aspects within Funds of Knowledge that are applicable to technology education.

Funds of Knowledge in Technology Education

Introduction

This paper reports part of a study that explores the nature of learning in the technology classroom using a collaborative approach; more specifically it explores the role students' Funds of Knowledge play in contributing to learning in technology education in the primary classroom. The paper outlines the scope of the study and the data gathering processes. It then reviews relevant literature, particularly on classroom conversation and Funds of Knowledge, a term used by Gonzalez, Moll, & Amanti (2005) to describe knowledge and skills gained through community and family encultureation which students bring to their learning, in the classrooom. The paper introduces two methods participants used to gain knowledge and skills from their culture and community. These are Partipatory Enculturation and Passive Observation.

The Study

The aim of this of the study was to gain an enhanced understanding of the learning that influenced students when developing technological solutions with the purpose of answering the following research question.

> How do children's prior and ongoing experiences influence their learning and action when developing technological solutions?

The study took place in a New Zealand primary school and focused on six children in each of Years 2 and 6 (six to seven and ten to eleven year olds respectively). Over the period of a year, two technology units were taught in each class. At the conclusion of Round One, six participant children were selected to be full participants in Round Two of the study.

Three methods of gathering data were employed in Round Two. The first was in-depth and semi-structured recorded interviews between the children or the classroom teachers and the researcher at intervals during the project. . The second was audio recordings of the students as they worked in groups of three; recordings were transcribed and augmented with researcher observations. Student work samples were the third, allowing triangulation of data. The last round of semi-structured interviews with the students used Stimulated Recall with students' autophotographs. The whole school technology theme for Round Two was the Olympic Games. The technology task the students undertook was to design and develop props for use in the school production. In Year 2 this consisted of acting a traditional tale from Taiwan, and in Year 6 it was the Olympic Games era of 1896-1936.

After transcription, recorded conversations were analysed and coded. Initial data suggested four distinct stages to the unit: Stage 1-The Character and Function of props; Stage 2-Planning of Technological Outcomes (Props); Stage 3 -Creating a mock-up and Stage 4- Construction of the Props.

Literature Review

There are two aspects of literature relevant to this study. The first is the nature of conversation that advances thinking in an educational context and the second, community and cultural knowledge drawn on by students to assist their learning.

Learning and the development of new knowledge involves a process of deep collaboration and inquiry. Innovative solutions arise when people in groups draw on evidence and on outside explicit knowledge and combine it with tacit knowledge in response to authentic problems (Nonaka and Takeuchi, 1995). When people work together in problem solving situations they do much more than just talk together. They "inter-think" by combining shared understandings, combining their intellects in creative ways often reaching outcomes that are well above the capability of each individual. Problem solving situations involve a dynamic engagement of ideas with dialogue as the principle means used to establish a shared understanding, testing solutions and reaching agreement or compromise. Dialogue and thinking together are an important part of life and one that has long been ignored or actively discourage in schools (Mercer & Littleton, 2007). Structured conversations based on various forms of evidence can result in a real change of learning (Earl & Timperley, 2008), however having the conversations and the evidence is not enough. In such conversations participants are required to reveal what they believe and why. Community and cultural environments impact on this knowledge (Earl & Timperley, 2008).

Gonzalez, Moll and Amanti (2005) call explicit outside cultural knowledge mentioned in the above paragraph Funds of Knowledge. Funds of Knowledge are information, knowledge and skills students bring to learning from their culture, home and community. The literature states that knowledge from experiences and activities undertaken at home or within their wider community and culture of the students are brought into the classroom to contribute to the students engagement in and understanding of the lessons being taught (González, et al., 2005) is known as Funds of Knowledge (FOK). The term was first coined by Gonzalez, Moll and Amanti in 2005. They suggest that it is the responsibility of each teacher to attempt to learn something special about each child they teach" (Lopez, 2010, p. 2). Generating an understanding of students and their families' Funds of Knowledge is one way teachers can do this.

The theory of Funds of Knowledge draws on the perspective that learning does not just happen but is a social process bound within a wider social context. People have wide knowledge, given to them through their life experiences. The knowledges that students come to school with can enhance their learning and facilitate useful interactions between knowledge found inside and outside the classroom The more teachers know about the home and cultural activities and experiences the better informed they will be to maximise learning opportunities and to make the most of knowledge and skills already accessible to some students (González, et al., 2005). Lopez (2010) and Fleer & Quinones (2009) also suggest that teachers can make more of the learning in their classrooms if they understand that students bring with them knowledge from their families, culture and background and that teachers can legitimise this knowledge through purposeful classroom engagement, "one can create conditions for fruitful interactions between knowledge found inside and outside the classroom" (González, et al., 2005, p. 20).

Findings and Discussion

The data from this study clearly demonstrates that students do use their Funds of Knowledge to contribute to their learning in technology. The data suggests that Funds of Knowledge were gained through two means: 'Participatory Enculturation' and 'Passive Observation '.

Participatory Enculturation

This involves being enculturated into an activity through engagement resulting in transferable knowledge. This engagement includes active participation, where a child is involved in the activity, and peripheral participation where the child is on the periphery of the activity but able to engage in the activity through questions and conversation. Gaining knowledge through Participatory Enculturation provided students with opportunities to know information their peers didn't and be involved in practices unique to their family and culture. Knowledge gained from these experiences can therefore provide them status or 'mana' (high status for Maori) within their peer group, and occurred through five means; family activity, afterschool activities, parents' occupation and interests, artefacts used at home and family social and cooperative practices. In the sections below each of these are discussed in turn and illustrated with a typical example.

Family Activities

Evidence of Participatory Enculturation through engagement in a family activity occurred very early in the props unit. As a part of the project the students were given a disposable camera so that they could record their process of developing a prop. The students' first task was to ask a friend to take their photograph so that the first photograph in each camera was that of its owner. Moke (Mo) was concerned that her camera was broken as this was her first experience with a non-digital camera, however Duncan (Du) was able to reassure her as he had experienced how the photos are released

Mo: Wendy my camera is broken
R: What makes you say that Moke?
Mo: I cannot see the photograph inside the camera.
Du: Oh, it's ok, you just take them to The Warehouse and they hit them with a hammer and the photos jump out.
R: How do you know that Duncan?
Du: My Dad had one and we went to The Warehouse and that's what they did

This conversation illustrates that knowledge gained through Participatory Enculturation gave Duncan the confidence and status to reassure his classmate that her camera was not broken. It demonstrates that use and knowledge of technological devices gained from home and community assist students' confidence in their use.

After School Activities

The data suggested that students brought learning from afterschool activities to assist them in understanding the character and function of props. After school activities are defined as activities that students do independently of their family. Typically going to external teachers for lessons or tutoring, playing sport or undertaking hobbies by themselves. When researching props much of the information the students came across was from the United Stated of America. This is illustrated in the example below. Alan (Al) explained to the researcher how he knew the symbol ″ stood for inches. He cited the reason for knowing about this symbol (not taught in New Zealand schools), through his active participation in War Gaming on the computer. He also indicated that the knowledge may have come from his father.

R: 13 and a half something. What does that mean?
Al: Inches
R: How do you know that, Alan?
Al: It's like probably, I just know that from my father
R: But how did you know there's, you said inches. I can't see inches anywhere on that
Al: It's those two things. That's what inches is.
R: How do you know that?
Al: Umm, because I do war gaming and that's what they use for inches

The above extract illustrates how the drawing on information gained through participation assisted in understanding and interpreting information relating to research in another area. It is a requirement in technology to interpret designs of others; this extract demonstrates Alan's ability to interpret a symbol of measurement not used in his school environment but one that he uses in his home environment.

Parents' Occupation and Interests

The significance of the role of parents' occupations in what the students bring to their learning and that students use these Funds of Knowledge to position themselves as an expert and to gain respect or 'mana' (a Maori term used to describe a person who has status and respect in their community) from their peers became evident in the data. This was illustrated by three Year 6 children in the 'microphone' group, as they discussed suitable materials for their microphone. Alan mentioned his Dad was a racing car designer and had a workshop at home. Dougal chipped into the conversation in a competitive manner explaining that his Dad has much more than blocks of wood because he worked in the construction industry. They had decided that the head of the microphone could be made from wood.

> Do: My Dad owns a whole yard of everything. He's got lots of things, yeah. He's a drain layer. He's an excavation worker. He's a construction builder. He has a yard, a whole yard.

The conversation illustrates that students use their Funds of Knowledge to position themselves as an expert and to gain respect or 'mana' from their peers. Understanding potential construction materials is a significant aspect to planning technological outcomes.

Artefacts Used at Home

The students also deployed knowledge gained through interaction with artefacts in the home environment. This was illustrated when Minnie and Dougal were problem solving how to hold the head of the microphone at the correct angle before attaching it to the stand. Dougal's photograph in Figure 1.1 shows Minnie holding the mocked-up version of this. The researcher approached them and asked what they are working on. When trying to explain to the researcher what they were doing Dougal used an example from his home computer a docking station as illustrated in Figure 1.1 however he refers to this as a 'whaling' station by mistake.

R: How are you going to attach, so what is this going to be?
Do: The bass)
Mi: It's the base) [together]
R: I know it's the base and it's to make it stand up but what does it actually do?
Do: It's going to be like a whaling station at the back and um it's like, its going to have like glue around it to stand by itself

Figure 1.1: Dougal's auto-photograph of Minnie holding his microphone head and docking station (holder)

Figure 1.2: An example of a computer docking station image from http://shop.ebay.com.au/items. Downloaded 21 September 2011

This extract and associated illustrations demonstrates how students made use of artefacts they knew, understood and used at home and in their community to make sense of learning undertaken at school. In this case Dougal employed an idea of one thing slotting into a specific place designed to hold it, to assist his design concepts and his explanation of his and Minnie's design.

Family Social and Cooperative Practices

Funds of Knowledge deployed by students were not only artefact and process knowledge and skills directly linked to home and community culture but they also deployed their community and family social skills and knowledge. This is relevant to planning design ideas in technology education because students were frequently required to design technological outcomes cooperatively and collaboratively. The next extract is a case in point, as these three Year 2 students had to agree on one final design. Rex deployed social Funds of Knowledge as he worked with Issy and Debby on the plan of their fish. Issy and Debby were having trouble deciding on the colours of their flying fish, and who decided what. Rex attempted peacemaking by deploying a strategy his father used at home.

Dy: I like the blue one.
Is: I like the green one.
Re: You can have the blue wings, the one there. The one of yours but just the wings. What one do you like?
Is I want the body.....
Dy: But that one, yeah, have the body but not the face and I'll have the face and the
Is: But I'm drawing the face. I'm drawing the face
Re: No, that one. That one, eh
Dy: No.
Re: That one
Is: Yeah
Dy: No
Is: Yes. We like it so there's cause
Re: What I used to do is if you there was two and there was one, so I did this, be cause my Dad always says, 'which one' and then the other two wanted two and then if there's one person who likes it, then we, we don't like it though,
Is: [very softly] you just have to do it

The data suggests that students gain knowledge from their home and community through participatory enculturation. Learning through Participatory Enculturation involves the students in interaction with the context of learning. This can involve dialogue with participants, active engagement with materials, activities and artefacts, and practices that are an integral part of living in a community. The literature suggests that learning through active engagement is effective. Turnbull (2002) found that learning embedded in an authentic context proved more effective than learning in contextual isolation. Hennessey (1993, p. 15) suggests learning is most successful when embedded in authentic and meaningful activity, making deliberate use of physical and social context". Rogoff's (1990) theory on cognitive apprenticeship methods of learning suggest that the enculturation of students to authentic practices through activity and social interaction facilitates effective learning. Mercer and Hodgkinson (2008) suggest that communication can be either interactive, verbal participation of both parties or non interactive verbal participation of the teacher only. Conversation in Participatory Enculturation would be of the interactive nature.

This study shows that students gained knowledge through Participatory Enculturation in a number of ways, including engagement with parents' work and recreational activities. González, Moll and Amanti (2005) state that by drawing on household knowledge the students' experiences are legitimated and thus authenticating the nature of classroom activity.

Passive Observation

This second sub-element refers to learnt knowledge obtained through passive observations where the students were non-participatory observers; for example through watching movies, television or reading books. In this method of gaining cultural knowledge and skills, the students did not interact directly with the knowledge source. The data suggests that students used knowledge gained in a passive observatory role and applied it to the learning that took place in their classroom, which illustrates students were able to transfer knowledge gained through passive means to inform their technological practice.

The students were able to locate technology in historical and cultural contexts through Passive Observation. There were two aspects of historical location identified in the data. The first illustrated below, was that the students were able to understand that props assisted in the historical location of a play or setting. The students were given a range of photographs of play props. As Minnie (Mi) talks to the researcher (R) she recognises a cart. She knows they are from the past as she had heard about them in the song Little House on the Prairie- set in pioneer times in the midwest of the United States of America.

Mi: Ohh, it's from the olden days, a cart or something
R: So when do you, when did they use them?
Mi: Probably like a hundred years ago or sooner, like. There's that song, Little House on the Prairie

The second was that students understood the function and form of an artefact in a historical setting. This is illustrated in the next extract. The students' main task was to develop props for the Olympic Games from 1896 to 1936. Alan (Al) and Dougal (Do) were able to recognise microphones from this era as they had seen on television and the movies.

R: So how did you know that microphones looked like this?
Al: Because umm, I saw a thing on TV
Do: Yeah, like on movies and stuff

This extract demonstrates that the knowledge the two boys had about microphones from the past came from watching television and movies, both activities commonly associated with their culture. This demonstrates that in technology education the students used prior observation to assist their personal construct of an object from a different era.

Students also gained an understanding of the purpose and role of props through Passive Observation. In Year 2 students listened to Julian (Ju), the props manager from the local theatre. Julian explained the purpose and function of props. He illustrated his talk with a range of props his company have used in the past. He discussed how each was used in situ. In the first extract Issy (Is) is reminded of a show she saw in the previous school holidays. As an audience member she observed one particular prop used in a variety of ways.

Is: I saw a show about a magic truck in the holidays and it changed [voice trails off
Ju: Ohh, 'Auntie McDuff's Magical Trunk' [name of the performance]. That was the show that we did in the last school holidays. Yeah, so what they did was hey had this big box and they opened up bits of the box and when they opened up the front bit of the box, they put umm, a, a, they used a blackboard and they put a little drawing of some wheels at the bottom of the box and then that prop became a train or a car and then they'd close another bit and they'd open another bit and they'd put umm, a flag on it and it would become a boat. So sometimes...
Is: ....and a dog
Ju: and it became a dog at the end. Yeah. So sometimes you can use a prop a lot, lots and lots of different ways.

This extract illustrates that Issy used the knowledge she gained from attending the theatre to assist her understanding of the definition of a technological outcome. Her input into the conversation indicated that she may have understood that the truck, as a prop, had multiple purposes.

The students continued to deploy knowledge from passive observation to assist them in the construction of their designs. This occurred when students were problem solving possible solutions to design issues thus facilitating the construction of their designs. They deployed information learned through the watching of movies and television.

When learning through Passive Observation, the students were only observers and unable to interact with the suppliers of the knowledge. Typically, this came about through reading, watching television, movies, or theatre. The data suggests that learning in technology education, obtained through passive means, is later deployed through active authentic means. These findings are somewhat surprising when taken in light of much of the research on effective learning. At the time of actual learning for these students, the context was not embedded in authentic meaningful activity; however, we can see that students deployed knowledge gained through these means to inform their practice, thus authenticating its deployment rather than the actual learning. Mercer & Littleton (2007) and Shields & Edwards' (2005) argue that teachers need to engage in quality dialogue with students and parents to help them make sense both cognitively and experientially of the world in which they live and work. By doing this, teachers may be able to facilitate deployment of knowledge and skills learning through Passive Observation. González, Moll and Amanti (2005) suggest that teachers need to know and understand the communities and cultural practices of their students. By having an understanding of the activities their students are not only actively but also passively engaged in will, assist teachers in maximising learning opportunities in the classroom by actively making explicit connections to these practices and facilitating the deployment knowledge gained.

Conclusion

The study identified two major methods for gaining Funds of Knowledge: participatory enculturation and passive observation. If teachers are aware of the activities that their students are engaged in at home and in their communities, they can then assist their students to make authentic links between home and school.

The study showed that learning through Participatory Enculturation occurred in a number of conduits: parental occupation, family activity, students' afterschool activity, artefacts used at home and through social behaviours and guidelines implemented at home. The study also found that learning through passive observation played a role in students' learning in technology in that they were able to deploy this knowledge to assist their own and other's technological practice. Funds of Knowledge had considerable impact on learning as they assisted students' understanding of the historical and cultural location of artefacts and of practices of significant adults in work, recreational and in social settings.

This study attempted to answer research questions regarding the acquisition of Funds of Knowledge in technology education. The findings in this study are significant because they indicate that students bring knowledge gained at home and in their community to technology education and use it to assist them in understanding and contributing when developing technological outcomes in a collaborative manner.

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The Role Of Indigenous Knowledge Systems In Addressing The Problem Of Declining Enrolments In Design And Technology

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Key words: Indigenous Knowledge Systems, Culture, Euro-Western, Design and Technology, Botswana, Kenya, Swaziland

Abstract

Enrolment numbers in Design and Technology and other technology related subjects are reported to be declining in Botswana and in other countries of Africa. Design and Technology enrolment in Botswana junior secondary schools have declined by up to 6% per year over 10 years, while in Kenya enrolment in Art and Design has gone down to as low as one student in a year stream in some schools. In Swaziland female enrolment in Design and Technology dropped from 200 in 2007 to 25 in 2011. Research has indicated that while a decline in enrolment numbers cannot be attributed to lack of resources alone, this is a major factor that should be accorded much research attention, at least in the African continent. Africa is endowed with indigenous materials and technologies that could relieve curriculum systems in the continent the burden of too much reliance on western systems of production that require modern materials, tools and equipment. This paper explores the role of Indigenous Knowledge Systems (IKS) in addressing the problem of declining enrolments in Design and Technology. Two examples of the same product (an indigenous design and a western design) are compared in terms of resource needs in making the products. It is concluded that the western design is far more capital intensive in terms of resources needed to make the product and therefore costly for African economies.

Introduction

The paper argues that current Design and Technology and other technology related subjects in Botswana, Kenya, and Swaziland were founded on the culture, history, and philosophies of Euro-Western thought and are therefore indigenous to Western culture and its institutions (Chilisa, 2012). As a result, sustenance of resource needs for these subjects in these countries is proving difficult. While the decline in uptake of Design and technology cannot be attributed to lack of resources alone, Gaotlhobogwe (2012: 15) indicated that lack of resources play a major role in influencing students against the subject. The concept of resources in educational terms is not very restrictive as it includes anything that can be used as an educational tool. However, in the context of this paper, resources refer to the following: materials used in the actualization of products; tools and other electronic and mechanical equipment used to manipulate materials when actualizing products.

Design and Technology in Botswana

In the 1980s the Ministry of Education in Botswana, now known as the Ministry of Education and Skill Development (MoSD) instituted a consultancy to review the technical subjects' curriculum to bring Botswana in line with international thinking in the field of technology education. This consultancy, led by Robert Fox (The Fox Report, 1988) recommended the introduction of Design and Technology modelled around the UK's Design and Technology. Following this recommendation, in 1990, design and technology was gradually introduced in schools, phasing out the old traditional craft-based technical subjects. Technical subjects were generally relegated to a position of least choice, to be taken by students who were not performing well academically. Moalosi (1999) observed that, before 1990, it was a common misconception that if a student was academically weak they might perform well in technical subjects. Technical subjects tended to be studied by boys only and were dominated by teacher-centred methods of teaching, which did not offer opportunities for critical thinking, ingenuity and creativity.

Critical thinking, ingenuity and creativity are some of the intellectually challenging key aspects of a well-developed design and technology provision and are considered important life skills. The government of Botswana supported this initiative in terms of training teachers and providing the necessary resources for the subject. However, as observed in the literature (Barlex, 2007; Keirl, 2007; Kumar, 2002) technological developments constantly transformed the face of Design and Technology. Computerization and globalization influenced nations towards post-industrialization.

According Levin and Kojukhov (2008) modern life or high-tech technologies are the basis of post-industrialization and so consistent resource allocation is required to keep up with the demands of technology. The education system failed to respond to these new demands, Evaluation reports (Republic of Botswana, 2004; 2009) noted the comprehensiveness of Design and Technology content and the lack of time to complete the syllabus within the given time but failed to report on how this impacted upon resources as well. One of these reports however, noted that teachers reported acute shortage of equipment for technology including power tools, hand tools and models for concretizing concepts in Mechanisms and Electronics and Electricity (Republic of Botswana, 2004: 70).

Art and Design in Kenya

A distinguishing feature of education in Kenya and the rest of Africa is that through western adaptations, models were integrated with little delineation between the liberal and vocational fields and this resulted in heavily academic oriented western models. These academic oriented western models came under strong criticism for failing to prepare students for productive life after school.

In response, the government of Kenya expanded technical and vocational education as an integral part of general school curriculum and art and design was one of the subjects offered. According to Lauglo and Maclean, 2005 as quoted in Wagah, Indoshi, and Agak (2009) the rationale for introducing Art and Design in Kenya was to educate and develop the whole person, and to provide equality of opportunity by catering for a wide range of talents. Like in many countries of Africa the introduction of Art and Design as a vocational subject in Kenya met challenges some of which were attitude problems.

Wagah et al (2009:449) reports that certain forms of Art and Design products were regarded as fetish due to Christian beliefs which regarded certain performances and presentations as a form of idolatry and incantation. Mapara (2009:139) makes the same observation that imperial conquests were not only largely military but were also meant to purge the colonies of what were referred to as heathen and backward practices.

Due to cost implications the popularization of Art and Design has not materialized to date because parents are expected to pay for consumables. A study on *Factors that determine students' and teachers' attitude towards Art and Design curriculum* in Kenya (Indoshi, Wagah, and Agak, 2010) observed that schools lacked materials, equipment, and facilities.

Design and Technology in Swaziland

As British colony, Swaziland adopted the Cambridge O' level curriculum from Britain and this curriculum existed in Swaziland until 2006 when Cambridge stopped O' levels. Within the O' level curriculum were practical subjects such as: Agriculture, Home Economics, Business Studies, Technical Drawing, Woodwork and Metalwork. The technical subject of Technical Drawing, Woodwork and Metalwork experienced problems of declining numbers throughout the years. This decline in numbers was attributed to a number of factors, including: lack of a clear philosophy for the subjects; lack of clear, well defined career progression route; and lack of higher degrees in local tertiary institutions.

In 2006 Swaziland then adopted the International General Certificate of Secondary Education (IGCSE) curriculum that came about with subjects like design and technology. This was a paradigm shift from the technical subjects. The introduction of IGCSE brought a lot of changes in terms of subject content and teaching methodology. The new curriculum was divided into three components namely: graphics; resistant material; and systems and control. Soon after that Swaziland started developing its own curriculum to be known as Swaziland General Certificate of Secondary Education (SWAGCSE) that would conform to local technologies.

Within the SWAGCSE, Design and Technology is an elective subject and falls into the technical field of study which include Accounting, Business Studies, Geography and Information and Communication Technology. It is viewed as an answer to fulfil the government's desire to give pupils opportunities to develop essential skills that include:

- Problem solving skills
- Technological awareness and applications
- Critical thinking skills

To achieve the above, there was need for change in terms of philosophy, content, approach and teaching methods. However, to date there has not been any great change in terms of classroom settings and facilities, teaching and learning activities compared to the traditional technical subjects. As a result the decline of numbers in Technical subjects experienced before the introduction of Design and Technology continues.

Linking IKS with Design and Technology

To appreciate fully and understand the concept of linking IKS with lack of resources in Design and Technology and other technology related subjects in Botswana and in other countries of Africa one has to have a full understanding of the concept of IKS.

According to Mapara (2009) "Indigenous knowledge systems are a body of knowledge, or bodies of knowledge of the indigenous people of particular geographical areas that they have survived on for a very long time" (p.140). IKS is an emerging field which is also known as Indigenous Ways of Knowing (IWK) and Ethno-Science. Mapara (2009) observes that "this area has captured the attention and respect of international scholars but also gained the support and recognition of the United Nations (UN)" (p. 139). According to DeWalt (1994), "arguments for greater attention of IKS are based on the need to:

- Create more appropriate and environmentally friendly technologies;
- Empower people to have greater control on their own destinies;
- Create technologies that would have more just socioeconomic implications" (p.123)

Africa is endowed with indigenous materials and technologies that could relieve Design and Technology related curriculum systems in the continent the burden of too much reliance on western systems of production that require modern materials, tools and equipment. According to Moalosi, Popovic, and Hickling-Hudson (2010:175) "Current design approaches within Botswana's Design and Technology with their standards, rules and guidelines, fall short with respect to issues relating to the cultural context" (p. 175). It is not surprising that current design approaches fall short with respect to issues relating to the cultural context because our Design and Technology curricula were founded on the culture, history, and philosophies of Euro-Western thought and are therefore indigenous to Western culture and its institutions. Some characteristic of IKS that can be explored in the quest to solving the problem of declining enrolments in Design and Technology are summarized as follows:

1. IKS conforms to high labour and low capital demands. Lack of resources for Design and technology comes as a result of high capital demands of modern life or high-tech technologies that form the basis of post-industrialization.

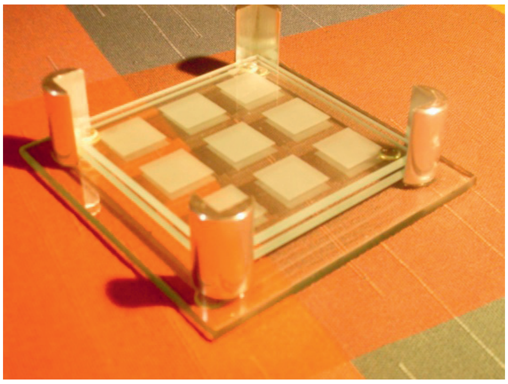
2. IKS are dynamic and have diverse adaptive strategies for use at times of stress (e.g. insufficient funds). Some IKS do not die because, as Moalosi et al (2010) put it, "no matter how people try, it is impossible for them to divest themselves of their own culture, but foreign culture dies easily in times of stress"

3. IKS are locally appropriate and dependent on locally available resources.

4. Integration with social institutions is easy.

5. IKS are flexible with considerable potential for entrepreneurial abilities.

The following example illustrates the potential of linking IKS with Design and Technology in addressing the problem of lack of resources which impact upon enrolments in the subject. In this example, two examples of the same products are compared. Wooden coasters contained in a wooden container (Indigenous design) and glass coasters in a glass/aluminium stand (Western design) are compared in terms of resource needs in making the products.



The wooden coasters and container were hand crafted using a couple of chisels, sandpaper, and some wax polish. This product was bought at a local Botswana craft market for a price of P100 / €10. On the other hand the glass coasters and stand were made from glass and aluminium, involving processes that demands expensive equipment such as CNC Lathe, glass cutting and etching equipment. This product was bought at an upmarket shop in the City of Cardiff, U.K. for a price of £35 / P350. The glass coaters and stand though expensive in terms of materials and equipment is not durable; out of the six original coasters, four have been broken and only two remain. One of the four aluminium holders has snapped from the glass base.

Conclusion

Recognizing the value and role of IKS is an important first step in addressing problems experienced in Botswana, Kenya, Swaziland and other African nations as a result of adopting western models of Design and Technology related curricula. Scientific/Western knowledge systems are not only capital intensive and expensive to African economies but they disconnect people from who they really are. As a result of this indoctrination that Scientific/Western knowledge systems are superior to IKS, African systems including education are always playing the catch-up game with Western systems.

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What can we hope of a technology education, which breaks off design to espouse science, mathematics and engineering?

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Abstract

From various forms of art and craft education, technology education has been based traditionally on the articulation between design, technology and use. It aimed to improve understanding of the existence's mode of the technical objects, through the social organizations by and for whom these objects exist. Based on concepts and references borrowed from sciences and the social sciences, this education privileges an approach by problem solving. It gives a broad place to the creativity and activities of group work.

Beyond these intentions, such structures are not simple to implement, at least in the French school's tradition. In fact, this teaching was organized according to logics of guidance and control opposed to these ambitions. In addition, under the pressure of the disaffection of the pupils for the scientific studies, many are those who think that it is necessary to reinforce the links between sciences and technologies in order to increase the social purposes of sciences. In this perspective, technology appears as applied sciences, or as applications of sciences.

To build a social meaning between sciences, technology, engineering and mathematics, the privileged link would be the process through which the mathematical modelling founds the production of the scientific knowledge, which organizes the process of engineering and induces the technological choices. This rationality excludes the design from the process and thus the links with the social sciences and the development of the creativity. For which benefit? We tackle this question in this presentation.

What can we hope of a technology education, which breaks off design to espouse science, mathematics and engineering?

Jacques Ginestié

Introduction

Linking science, technology, engineering and mathematic in education is a very recent approach of the school. This link questions the contemporary curricula organisations, the purposes assigned to these school subjects and the relevance of the knowledge to teach in each field thus built. Today, it is commonplace to say that academic disciplines are social elaboration that does not give directly and simply an account of the fields they are supposed to represent and they are supposed to refer. These recent evolutions are really and fundamentally different of the situation in the early eighties, when we introduced in France Technology education (TE). This introduction was different at the primary school, the lower secondary school and the upper secondary school. At the primary school level and at the lower secondary school, TE comes from an old tradition of handicraft education. The main idea is a progressive elaboration through the educational activities, to observe, to manipulate, to experiment, to make, to manufacture, to design. Pupils experience by themselves the structuration of the different subject from a sensitive and intuitive perception of the environment to rational relationships through knowledge (Ginestié, 2011b). At the lower secondary school, education takes the form of distinct subjects and "*technology*" takes a specific place distinguished of *"sciences"* or "*biology and geology*". At the upper secondary school, TE becomes optional with a great emphasis of industrial sciences and mechanical approaches.

At the same time, French system knew a strong generalisation of the access to upper secondary and higher education. This generalisation focuses on the aims of the school with a bipolarisation between general education and professional integration, in the context of disaffection and depreciation of the pupils for sciences, specifically at the university level. Giving more importance to education induces to rebuild the links between different fields of knowledge and their social role. This transition from school subjects, based on academic references (more or less legitimate), to educations to, based on social references closest familiar environments of students is not easy in it. It causes a break with a long established school tradition, rather badly by the teachers who live it as a challenge to their professional skills. The stakes are high and we will in this presentation, discuss some of the terms.

Knowledge, object and subjects...

The organization of general educations aims the goals of understanding through the methods, the knowledge and the point of view of the particular field of the school subject. Understanding an environment carries with the implicit need to establish relationships with the things comprising it. A thing becomes an object when a person (subject) establishes a relationship with it (object): S –> R –> O. The nature of the relationship defines the nature of the object. This relationship primarily involves constructing a meaning that will influence the subject's actions. From this point of view, learning bases on the process that involves forming relationships that will allow the subject to act upon and with objects built in this way.

Evidently, the same thing generates different objects according the kind of relationships established. This construction is individual and each person forms its own relationships. Each pupil will thus build in each teaching his own relation with each thing which he will have to study. However, objects are social constructions that fit into social meanings or contexts that are pre-established and shared within a given culture. From this perspective, school is the place of institutionalisation of a wide range of objects in which pupils will construct meaning about these objects and about people's relationships to these objects generally shared by society. Hence, a link exists in this process between, from one hand, the pupil's individual actions who build his own knowledge and, from another hand, the social "togetherness", which bears the knowledge giving meaningful to the objects shared by the community. From this point of view, the school subjects appear as fields of significances of the objects give to study by the teacher to the pupils. For example, the definition of the school disciplines, like mathematics, sciences, biology, technology…, delimits some collections of objects, more or less complex, and some families of relationships, more or less sophisticated. In fact, if one changes the global aim of education, one changes the delimitations of the collections of objects and, in consequence, the families of relations.

Understanding the world through the production of Technical Objects

As we said it, the introduction of TE in France aims various goals: understand the contemporary world, understand the mode of existence of the technical objects, and understand the social organization of work. Let us examine the technical attribute that one normally accords to a class of objects (Andreucci, 2006, 2008; Andreucci & Ginestié, 2002). An object is technical since it brings a technique with it, a manner of doing something in order to achieve a goal (Séris, 1994).

More simply, a technique can be defined as a traditionally effective act (Haudricourt, 1988; Mauss, 1936, 1948); we can also underline the fact that there is no technique without transmission (thus without tradition) not more than there is no technique without real (describable) effect (Sigault, 1988, 1994). The technical nature of the object means that one is presumably going to view it as something manmade and used in the good way, without ambiguity, by the subject (Simondon, 1989, 2005). This definition of the technical nature can be described as being external since it integrates the material nature of the object, the fact that it results from a human intention of manufacture and that it explicitly carries the goal for which it was designed.

As we can see it in TE, this understanding initially relates to the understanding of the mode of existence of the technical objects as well in their social existence as in their existence at school. As in many countries, TE was based on, in France, the articulation between design, technology and use of technical objects. This articulation is significant of the modern evolution of the relationships between the designer, the maker and the user, in the context of industrial production. Different points of view are possible to consider it; in France, we can summarize this through three. The first supports the entry by the human organisms of the production of these objects, and, in particular, the industrial production studied within the framework of the mechanical engineering. In this perspective, school activities must be relevant to the professional activities and they aim to understand the opportunities of professional careers; this pedagogy refers to social practices (Lebeaume & Martinand, 1998; Martinand, 1989, 1995). The second point of view is the entry by the methods of organisation of industrial production of objects. In this way, school activities are relevant of the different methods, skills and tools used at each stage of the process that goes through from the initial idea to the end of life of the object (Crindal, 2001; Ginestié, 2002; Rak, 2001); pedagogy is based on the method of industrial project (IPM). The third one gives higher rank to the human interactions through the articulation of the design, the making and the use of technical objects. This way focused activities on problems' solving and researches of resources (Deforge, 1993; Ginestié, 2005, 2008). More or less, TE, such as implemented in France, is a blend from these three points of view; that gives an approach specific and original but at the same time that weakens considerably this teaching, which has difficulty finding its legitimacy.

The introduction of innovation, as a motor of development, strengths the necessity to develop the creativity as way to produce different solutions for the same things (Atkinson, 2000; Barlex, 2007; Chevalier, Fouquereau, & Vanderdonckt, 2009; Kimbell, 2000; Lindfors, 2010). This approach may be considered from a longitudinal viewpoint and from a horizontal viewpoint. The competition between different companies, who produce the same range of products, imposes the differentiation of the products. The designer is in charge of this. He designs a new product, enough different of the others, specifically to allow the identification of the company but, at the same time, enough similar to identify it in the same range and family of objects. To grow, companies must develop new objects, which differ from previous generation, must mark the most explicitly the novelty included, in accordance with the tradition of the company. In the both cases, horizontal and longitudinal, creativity is the main motor of innovation and the designer is the professional in charge of the process of evolution and distinction of this new product.

Many times, we can observe many tries to introduce innovation and creativity as one major determinant of this process (Chevalier, Anceaux, & Tijus, 2009; Christiaans & Venselaar, 2005; Dorst & Cross, 2001). One noticed many nice experiments and pedagogical organisations to promote creativity, as motor of innovation and we are many to investigate the way to open school situations to the creativity's development for pupils. In France, for instance, there is a wide development of investigations around this link between design and manufacturing. Based on ergonomic approaches (Bonnardel, 2009), we try to understand how the creativity is taking account by designers and how we can introduce it in education. This conceptualisation gives us the opportunity to understand some key concepts of the teaching-learning process at school.

Creativity in the school situations is not so easy to be qualified (Rutland & Barlex, 2008). The production of several different solutions can be considered as an excellent indicator of creativity. The difficulty lies in the characterisation of these differences. It shows that the multitude of solutions is not a sufficient criterion of creativity and it is not sufficient to ask students to produce a multitude of solutions. This description of the differentiation of solutions produced imposes to find some criteria of the diversity and the originality. The educational management of this creativity through the diversification of solutions produced by students has a direct impact on possible pedagogical organisations (Barlex, 2007). At the lower secondary school, these difficulties have an impact on the pedagogical dynamic and one observes a phasing out of situations that might develop creativity. It costs much more, in terms of teachers' commitment, to develop activities in which students can experience their own logic relating to design, manufacturing and use (Ginestié, 2011a). Teachers use the models more and more formal from engineering of industrial production. In doing so, they focus on the part of manipulation of tools and methods – and therefore the time spent to the learning of these operations – at the expense of the construction of social meanings of these manipulations.

A more global understanding of the world

From the social point of view, innovation and creativity are main motors of development of the modern companies, one most significant symbol of high-tech industries (Lindfors, 2010). TE has to deal with this concept by which the innovation and the creativity would be one of the engines of economic development, opening the occasions to keep a high level of social development. Recent economic and social evolutions, the emergence of new economies like China, India, Brazil..., fossil limits of the exploitation of resources and ecological balances..., equilibration of the North-South development..., all these reasons and beyond, show the limits of a model of growth based on the consumption and, in fact, the limits of a TE based on this logic. The technological project-based method is not enough significant to give the understanding keys of our contemporary world. It needs to be more situated on the global understanding of the interactions between the human activities and the world balances (Kimbell, 2000).

Our recent evolution minimizes the place of academic knowledge to the benefit of "educations to". To play a role and have a fulfilled citizenship in our contemporary environment focuses more attention on general skills and understandings to elaborate, to analyse and to interpret the facts (Zeidler, Sadler, Simmons, & Howes, 2005). School is no longer just the place where children learn the basics to read, write and count. It is no longer, at least in its part of education for all, the place of familiarization to specialized knowledge in a particular academic field. It is not, either, the only exclusive place, outside the family circle, of transmission and construction of institutionalized knowledge in which the teacher is simultaneously the referent, the guarantor and the transmitter. Inseparable from the three skills (to read, write and count), the ability to reason is fundamental for children to reach this rank of the reasonable, thoughtful and social adult who takes its place in society (Middleton, 2005). Probably, the articulation of design and technology as school subject has not developed (or insufficiently) the capacities to reason (Leplat, Veloso, & Aamodt, 1997). Many researches have shown that the implementation of this teaching has largely relied on the modelling in school of some methods borrowed from industry. At least in France, this focalisation on this kind of structuration left a small space to the student's initiative for problem solving or solutions finding. This trend increased with the development of the use of computers and CAD softwares.

This set of concurrent facts leads at focusing on engineering methods at the expense of elaboration process of several different solutions. Gradually, one abandoned the idea that the design of an object, which can bring the human dimension of its use, and based on the determination of the use functions and the esteem functions, was an essential phase of the TE. There is in the process to articulate science, technology, engineering and mathematics, simultaneously the will of a global approach but an approach based on the rationality of mathematical, scientific, technological or procedural modelling (Ellis, 2007). That is at the expense of rationality for developing any solutions in a design process that relies on the integration of constraints, their possible prioritization, the choice of the best solution, the most relevant, the most economical or the most environmentally friendly... In this sense, there is a risk through the generalisation of the STEM approach to lose this construction of meanings by reinforcing the acquisition of formalized procedures in the technical languages to the detriment of the development of semiotic thought.

This is particularly important because, many researches have showed that, the construction of knowledge that allow to act on his environment - and understanding is one of the first level of action - involves this dual structure of procedural and semantic cognitive schemes. This is one of the major contributions of research on teaching-learning processes, analysed through activity of the pupil, the teacher and the interactions between the two. In terms of "education to", STEM represents a significant development by the opening up of academic disciplines. This orientation strengthens the relationships for the students between the different fields of knowledge by expanding the scope of their understanding. However, the structures of teaching, the choice of the situations and teaching methods that will be implemented are crucial. It is another conception of the teacher's profession, who will have difficulties for positioning themselves against the academic traditions. That means that we have to develop some training plans for these teachers, and beyond, to accompany this major evolution. Without doubt, this is the point, in France, we will probably give us the most difficulty due to the deterioration of teacher training organisations.

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Using e-portfolios to support trainee Design and Technology teachers in developing their subject knowledge

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Abstract

Stefani, Mason & Pegler (2007) reflect that the underlying pedagogy with e-portfolios is based on 'constructivist educational principles'. Our emphasis in this research was for the e-portfolio to be a student led development process rather than teacher/lecturer led, with the student creating their own resource of their knowledge and understanding, reflecting on their progress and identifying their own learning needs and understanding. Online technologies, sometimes referred to as 'web 2.0' tools, such as blogs, e-portfolios and wikis allow learners and educators to learn more, create more and communicate better (Richardson, 2010).

Students in the second year of an undergraduate teacher training programme are beginning to think of their future careers as design and technology teachers, developing their awareness of what sort of teacher they want to be and what skills they want to develop. To support the students they are asked to evidence their growing range of skills, knowledge and understanding in particular areas of Design and Technology education through the use of an e-portfolio.

As future design and technology teachers, the students were encouraged to make a start at building up their own online learning resources. This will hopefully lead to a growing body of knowledge that they can draw on in their subsequent careers. At the same time, and for purposes of assessment, it provides evidence of their learning. A significant reason for using e-portfolios is to enable the students to share information outside the constraints of time and place, i.e. asynchronous learning (Garrison, 2003).

Asking students to develop an e-portfolio presented them with an alternative way of recording their learning. Learning was gained from their experiences even if their experiences were regarded as failures, such as ruining a sand-cast aluminium part (the process, background information and the student's reflections were recorded). The expectation was that students would find this an easier medium to evidence their learning rather than through a folder with notes and diagrams.

It is hoped that students will continue to use their e-portfiolios long after the end of the assignment period or learn from their experiences to create new and better personal e-portfolios. It is anticipated that these e-portfolios will accompany the students well into their teaching careers continuous education (Attwell, 2007) allowing them to build up useful resources and ideas.

This case study gives some direction towards improving the effectiveness of using e-portfolios in developing trainee teachers' subject skills and their use of online learning resources.

Introduction

The purpose of this study is to explore design and technology education students' activity and their use of e-portfolios as a device for developing their own subject knowledge and understanding and how they use it to reflect on their progress and identify their own learning needs and understanding.

This paper consists of four parts. After the introduction, the second section outlines the context of the study, which highlights the authors' common philosophical perspectives and views on how e-portfolios are to be used in Initial Teacher Education. Thirdly, the paper will present an analysed case study, chosen to enable the authors to allow 'new lines of thinking to emerge' (Eisenhardt, 1989) during the exploration of collected data. The paper concludes by presenting identified implications from the analysis.

Context of the study

Department Philosophy

The case study focusses on students in the second year of a three-year undergraduate BA (Hons) Secondary Design and Technology Education course in a post-1992 University based in the East Midlands, UK.

The authors ascribe to the view of teachers, including trainee teachers, who construct their own knowledge and determine their own priorities for learning. Within a design and technology setting the authors believe that this can be done through solving problems in design situations: 'what do I need to know/find out to solve this problem?'

Combining self-constructed learning and the use of emerging technologies, e-portfolios can be a powerful tool in supporting the students' ability to construct knowledge (Tam, 2000). The portfolio enables students 'to record information for future reflection and objective analysis'.

Students in the second year of the undergraduate Technology Education course are beginning to think of their future careers as design and technology teachers, developing their awareness of what sort of teacher they want to be and what skills they want to develop. Subject knowledge is determined by the Design and Technology Association (D&TA) minimum competencies for design and technology teachers (Design and Technology Association, 2010). To support the students they are asked to evidence their growing range of skills, knowledge and understanding in particular areas of Design and Technology education through the use of an e-portfolio.

Swennen, Lunenberd & Korthagen (2008) call 'congruent teaching' when 'teacher educators should not confine themselves to (1) modelling, but should also (2) explain the choices they make while teaching (meta-commentary), and (3) link those choices to relevant theory' (pp. 531); The teacher educators/ lecturers of this course ascribe to this philosophy and the use of web 2.0 technologies in departmental assessment and teaching is one example of the authors' congruent teaching. Web 2.0 tools, such as blogs, e-portfolios and wikis, allow learners and educators to learn more, create more and communicate better through collaboration online (Richardson, 2010)

The lecturers use web 2.0 technologies as part of their planning and departmental activity, for example a wiki and Twitter was used to coordinate our research, plan the structure of the paper and edit. In their classroom practice the authors use web 2.0 technologies, such as wikis, discussion forums, blogs and screencasts as part of their teaching. Explicit links (meta-commentary) are made between the student learning and teaching strategies. Finally, links are made to relevant theory related to web 2.0 technologies in the classroom.

The department's philosophical viewpoint of congruent teaching is to also model the use of our classroom practices to influence the students' future practices as a teacher in design and technology; the hope is that use of e-learning technologies with university classes will positively influence their use when teaching design and technology in schools. E-portfolios are primarily used in design and technology assessment, for example for GCSEs (General Certificate of Secondary Education) at the age of 16 (OCR, 2009: 49). The authors see their use as more than an assessment tool, as an online scrap book and sketch book which can be referred back to when designing and making in design and technology.

Stefani, Mason & Pegler (2007) reflect that the underlying pedagogy with e-portfolios is based on 'constructivist educational principles'. Within one of the course modules the use of e-portfolios was formalised as a reflective and developmental tool as well as a method of assessment. This meant that students had to compile an e-portfolio of their own developing work. The emphasis was for the e-portfolio to be a student led development process rather than teacher/lecturer led, with the student creating their own resource, gathered from their knowledge and understanding, reflecting on their progress and identifying their own learning needs and understanding.

In summary, the authors' position with regard to the work to be carried out for this taught module and subsequent research:

- Student/ designers develop the needed knowledge as part of problem solving a design situation
- Congruent teaching: the tutors for the module are demonstrating a method of learning which our trainee teachers can use with pupils in schools
- Students construct their own knowledge through open tasks and personal engagement with the e-portfolio
- Producing work helps students to construct and build on their own learning

E-portfolio

The e-portfolio tool used by the students is held within the university's virtual learning environment (VLE); it has a number of areas within it (Figure 1).

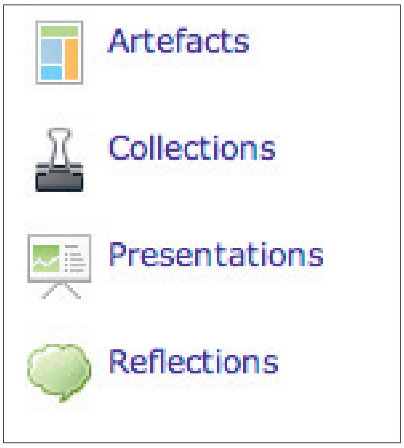

Figure 1: screenshot of areas within the e-portfolio

The three areas used by students, and referred to in this paper, are:

1. Artefacts are files or forms that students add to their e-portfolio. They can be reflected on, shared with others and displayed in presentations.
2. Presentations enable students to showcase work by selecting artefacts, reflections, and comments to present through one or more web pages.
3. Reflections are a way for students to record thoughts. Students can reflect on existing artefacts and presentations, or can create independent reflections that aren't associated with other items in the portfolio.
   (Desire2Learn, 2012)

Other users of the VLE can be invited to view, review or comment on any of the artefacts, presentations or reflections within a student's e-portfolio. The two researchers who assessed the module were invited by students to review and comment on their presentations as part of the assessment process.

Assessment method for the module

The e-portfolio was used by students for two modules: Product Design and Advanced Manufacturing; for this case study we are only considering the e-portfolios produced in Advanced Manufacturing. The module is assessed through:

1. Manufacture a reasonably complex apparel (textiles) product from supplied drawings.
2. Manufacture a reasonably complex product from supplied drawings.
3. E-Portfolio of evidence: Place artefacts into the e-portfolio area of NOW and create a presentation for the Resistant and Textile Materials skills audited from the Design and Technology Association's Minimum Competencies for Trainees to Teach Design and Technology in Secondary Schools (Design and Technology Association, 2010)

Learning outcomes (assessment criteria) and the minimum competencies for becoming a design and technology teacher were shared. It was routinely suggested that students might explicitly link the e-portfolio to these structures.

Analysed case study

Research method and question

The research is an exploratory, single within-unit case study (Baxter & Jack, 2008; Gerring, 2004); the unit was the sixteen students studying the advanced manufacturing module, the case is the students' e-portfolio work relating to this module. The case study method was chosen due to the cohort size been small (N=16) and the researchers wanted at this stage to only explore the use of the e-portfolio. The case study method allowed us to 'illuminate features' (Gerring, 2004:343) which may 'pertain to a broader' unit (Gerring, 2004:344), As a team we want to continue using e-portfolios and through this exploration hoped to identify features which would develop our personal use and students' use of web 2.0 technologies, specifically e-portfolios.

The study was structured to collect data from three different sources:

- Semi-structured reflections by the students
- Module evaluations and
- Evidence from the students' presentations submitted for assessment.

This data was discussed and analysed by the researchers after the completion and assessment of the module.

The authors had two main reasons for retrospective analysis, ethics and distance between completion and reflection. Two of the researchers (Researchers A & B) were module tutors and assessed the work of the students, the third researcher (Researcher C) is the students' course leader therefore to avoid compromising the students' assessment the students' reflections were completed after work had been returned. Secondly, a proposition of the research was the students' value of the e-portfolio beyond its use for assessment and so by asking students to reflect on their use of the e-portfolio after a period of not using it the researchers were hoping the students would look back with a more objective view, in order to consider how they might use their e-portfolio in their teaching careers.

Researcher C administered the student reflections several weeks after the students had received their assessment marks and feedback. The reflections were completed online in an electronic form, which once saved, became an artefact within the students' e-portfolio. Of the sixteen students, fifteen completed the electronic form.

The research question was: how effective is using e-portfolios for developing trainee design and technology teachers' subject knowledge?

Findings and analysis

The authors thought students would use the e-portfolio initially to collect evidence of their subject knowledge that they would reflect on as part of their process for constructing knowledge. Analysis of their reflections and evaluations contradicts this, ten of the students reflected that collecting evidence within the e-portfolio was a method for recording evidence and others for organising work:

> '... it was a tool used to <u>record</u> the practical activities...' Student C (line 5)

> 'I added pictures and videos to my e-portfolio to <u>show what I had done</u> through the unit' Student P (line 20)

> '...helped me to <u>organise</u> my work....' Student K (line 5)

A variety of approaches were taken for organising the presentations, three different approaches are evidenced in figures 2-4:

- Individual pages representing each learning outcome (Figure 2)
- one or several minimum competencies presented on a page (Figure 3) and
- each page focussing on an activity or process (Figure 4).

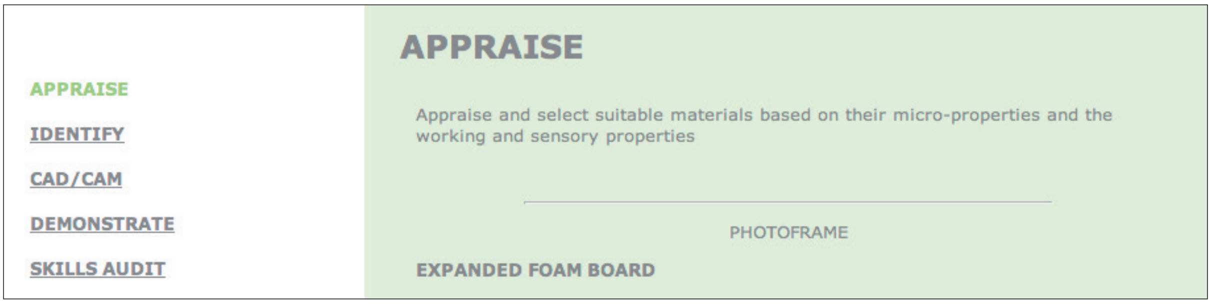

Figure 2: Organised using the learning outcomes (student Q)

Figure 3: Organising related to Minimum Competencies
(Design and Technology Association, 2010) (student H)

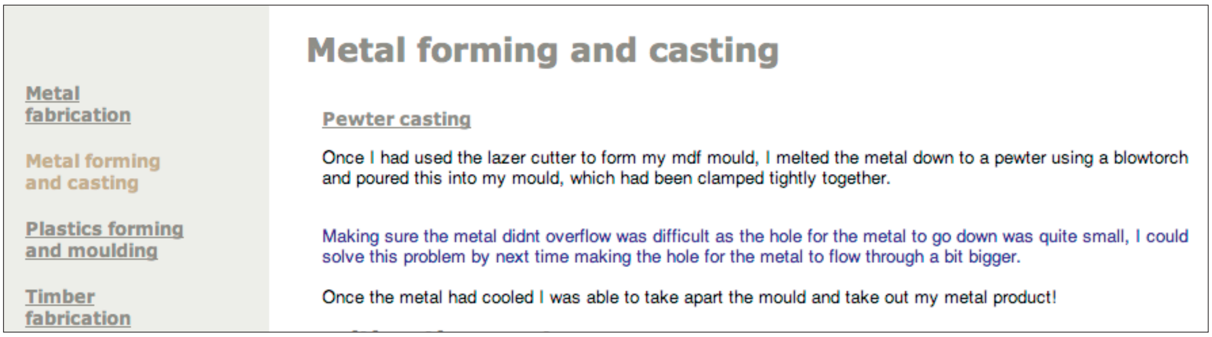

Figure 4: Organising using activities/ processes (student A)

> 'By setting out the presentation pages under the headings of the LO (learning outcome) I was able to make sure that I met each of the LOs' Student Q (line 21)

Some were quite emphatic in their response to the question, 'To what extent did the e-portfolio affect how you developed your subject knowledge?':

> 'the time spent on the e-portfolio could have been time spent actually learning more about other areas of the assignments.' Student A (line 5)

> 'i found it time consuming to update frequently and this would mean it would get in the way of important work.' Student M (line 5)

In their reflections, fourteen of the students said the e-portfolio did not help them develop their subject knowledge, only one student (student H) commented that the 'amount of words' she wrote whilst compiling her e-portfolio helped her develop her knowledge.

Analysis of the modules evaluations suggests that it was the 'practical hands on tasks' that helped some of them to learn new skills.

> 'using new techniques to produce my stool' Student H

> 'being able (to) do what we wanted with making the stool' Student F

Evidence from the student reflections and their e-portfolios indicated development of personal subject knowledge resulting from meeting the assessment rather than from using the e-portfolio. Student L commented '...the learning outcomes were something to meet on the e-portfolio, by meeting these I developed my knowledge a bit.' (line 6).

There is a difference of perception between the tutors and the students, in some cases:

> Student D: ' this didn't show I could do any advanced manufacturing work – it showed I could upload pictures and write about them' (line 18)

Looking at the description of the image (Figure 5) recorded in student D's presentation the authors decided that this student is constructing knowledge and this would lead to the student determining their own priorities in their learning. However, it is not the e-portfolio that is determining this but the student reflecting as they are planning the making of the stool.

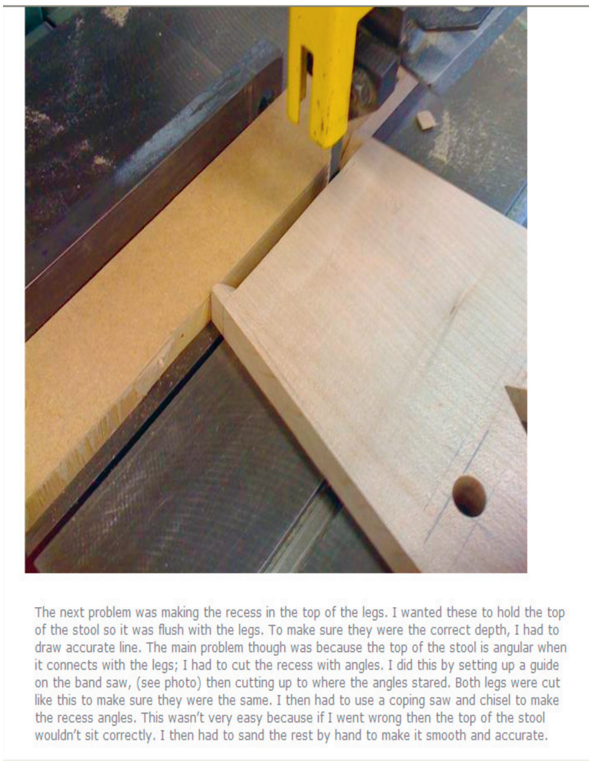

Figure 5: evidence of reflection from student D's presentation

Some students did however identify that the e-portfolio had supported their own reflections:

'I feel that I was able to reflect more as I could look at what I had achieved, consider the problems I overcame and consider what I would do if I were to do it again.' Student Q (lines 11-13)

'Reflecting on my work was useful, and certainly made me think about where my next improvements could be made.' Student M (line 18)

Evidence of students reflecting on material choices and design decisions was seen in several presentations (see example in Figure 6 where the student discusses the decision making about material choices through modelling their stool (figure 7)).


Stool project

Material Selection

I wanted to use oak because it can be finished to a high standard, it's aesthetically pleasing and has good strength. (Albert 2005) When I was making a model of the base of the stool from pine it kept splitting, the mortise joints are quite big compared to the amount of wood left to support the weight (see back view of stool) so I needed to use a hard wood. I used a coat of sanding seal (water and PVA) and then briwax to finish the wood because I wanted the grain to be visible and natural.

I used aluminium for the legs; I had considered using stainless steel but it was much more expensive and would be considerably heavier. The aluminium I used has a good strength to weight ratio and can be easily polished to a high standard. (Hicks 1975). However the aluminium legs mark easily and although shine well when first polished they dull due to the surface oxidization.

Figure 6: screenshot of student L's reflection on material choices

Figure 7 (figures 5-6): **Screen shots of student L's modelling and finished stool**

The main issue for students was the actual e-portfolio tool, particularly its design and uploading limitations. Some students commented that the inflexibility of the presentation caused them frustration. The students are familiar with the instant access of websites such as Flickr and YouTube where pictures and videos can be uploaded using mobile phones and tablets; the e-portfolio tool used at the university doesn't have this facility so students could only upload one artefact at a time and had to be at a computer to do this.

Identified implications from the analysis

The research question for this case study was to evaluate the effectiveness of the e-portfolio tool in helping students develop their subject knowledge. Reflections from the students and observation by the authors do not agree that the e-portfolio has made this happen in any meaningful way. However the evidence from the reflections and the completed e-portfolios have led the authors to believe that the tool has had a positive benefit in helping students organise their knowledge and structure their work. In drawing conclusions from the analysis of the findings the authors have identified the importance of the module learning outcomes (assessment criteria) in supporting the students with their individual progress and identification of the next steps within their learning. Organisation is a big part of the students' development in knowledge construction and the authors have begun to look towards knowledge organisation, through the e-portfolio presentation tool, and as a precursor to knowledge construction.

The process of organising knowledge demands that knowledge is first acquired. Knowledge is gained by new experiences, doing and being told information. We group and categorise knowledge into concepts as we develop, and concepts themselves change as knowledge grows and is refined. In our case, the concept of how to make a stool grows by looking at different types of stools – legs, seat, joints, seat back. It leads to knowing how a stool can be made, what materials can be used and what skills need to be learned – through observation and experience.

Looking back at the research question: how effective is using e-portfolios for developing trainee design and technology teachers' subject knowledge? The authors have identified that through structured organisation, the students are being selective in promoting evidence of important knowledge they had gained and they are using the tool to record information, with the growing start of some future reflection.

It is hoped that students will continue to use their e-portfolios long after the end of the assignment period or learn from their experiences to create new and better personal e-portfolios. It is anticipated that these e-portfolios will accompany the students well into their teaching careers continuous education (Attwell, 2007) allowing them to build up useful resources and ideas.

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Unboxing technology education part I – Starting point

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Abstract

The Boost for Technology (Tekniklyftet) is an on-going education program run by the House of Science (Vetenskapens Hus) and financed by ESF (European Social Fund) involving 28 secondary schools within the Stockholm region. The goal is to enhance the technology teachers' competence as well as strengthen the technology subject. In what way does this intervention influence the teachers' work with technology education?

A pre-test questionnaire has been launched in order to collect data concerning views and practice as well as official documents have been studied in order to find the starting points of the project. This paper will provide descriptions concerning the starting points.

Introduction

Numerous supervision reports of different municipalities conducted by the Swedish Schools Inspectorate (2009a, b, c) confirm that the situation for the mandatory technology subject is alarming. They even state that the teaching of technology is not even accomplished enough (in quantity) to give the students the opportunity to reach the targets in the national curricula. The supervision reports are in agreement with the report by the Association of Swedish Engineering Industries (ASEI, 2005) and Teknikdelegationen (2010). Teachers who teach technology often lack teacher training in the subject matter and many teachers feel insecure when teaching it (Teknikdelegationen, 2010; Nordlander, 2011; CETIS unpublished). The teaching in technology also varies among teachers and schools and it is not always aligned with the current steering documents (ASEI, 2005; Blomdahl, 2007; Bjurulf, 2008; Klasander, 2010). A survey among ninth graders showed that they felt that technology education was invisible and not so important for their future (Teknikdelegationen, 2009).

Prior reports have highlighted the technology subject as neglected (Fabricius et al, 2002; Skolverket; 2005; Teknikföretagen, 2005; Statskontoret, 2007). The government's appointed Teknikdelegationen (2010) highlights the importance of technology for the country and as Sweden's first astronaut Christer Fuglesang put it:

”Technology is everywhere – except in school.” (Ny Teknik 2010-02-09)

This quote is particularly interesting and can be used as a starting point for the intention to un-boxing technology education in the Swedish compulsory school, which Hagberg and Hultén (2005) has identified as little investigated.

Description of the project

Tekniklyftet (the Boost for Technology) is a two-year (2011-2013) education program run by Vetenskapens Hus (the House of Science). The main purpose is to mobilize in the amount of youths in the further studies in technological or science educations and to strengthen the teachers' competence and self-confidence in technology in compulsory school. The project involves 28 schools from 5 municipalities within the Stockholm region. In order to strengthen the sustainability in the project all personnel at the schools are involved in the project in various amounts. Tekniklyftet is mainly focusing on the technology teachers in secondary grade. In addition to them, the whole structure with established contacts between schools, companies and science centres, are involved for mutual exchange.

The Swedish educational system is currently undergoing major changes; e.g. new national curricula with syllabuses for the mandatory subjects, teacher training, and new educational act, including stricter rules concerning who may teach which subject. E.g. from 2015 only a certified subject matter teacher can grade the students (SKOLFS 2010:800). This will have the effect that teachers teaching technology are at risk of getting un-employed when lacking a certificate. This is why the Tekniklyftet is financed by ESF (The European Social Fund). Tekniklyftet aims to build a platform for the mandatory subject technology and, in prolong, also contribute to create a teacher training in technology education in the European frontline.

When un-box the tutoring of the subject, different attempts to establish the starting points of the on-going educational program Tekniklyftet, have been undertaken and will be presented in this paper.

Prior and Current situation for Technology education in Sweden

Several reports show that technology education is not present to the extent in compulsory school which is needed for the students to be able to reach the goals stipulated in the curricula (ASEI, 2005; SSI 2009a; b; c;). When looking for the Swedish student´s educational position in technology education as a group, the information is somewhat limited (Teknikdelegationen, 2009; Hartell, 2011).

The national timetables for technology education are 800 hours together with natural science during the nine years of compulsory school. Every school head is free to plan the teaching of every subject to fit their organization as they please; as long as their student's reach the goals set by the national curricula (SKOLFS2010: 800; Klapp-Lekholm, 2010). The distribution of the minimum time varies and some schools choose to schedule the teaching of the technology subject an hour a week, in eight or ninth grade when the grading starts[1] (Hartell, 2011). Still, according to the national statistics compiled by the NAE in SIRIS, for pass or higher, technology education in ninth grade is among the highest of the 16 mandatory subjects (SIRIS, 2009).

Research questions

The overarching research question is

How is technology taught in schools before and after entering the Tekniklyftet?

In order to answer this question a starting point is needed. This is the purpose of the sub study described in this paper.

Method

In order to determine any effect of Tekniklyftet, the project will be studied in an explorative approach and adjustments in the data-collection will be undertaken with respect to the results from the data analyses along the way.

[1] Grading starts in eighth grade, from fall 2012 it will start in 6th grade.

In order to create the starting point for the project we have used two different kinds of data:

First, two different public databases (SIRIS[2] and SALSA[3]) compiled by the state agency Statistics Sweden (SCB) presented by the NAE have been used. We have chosen to describe the participating schools by means of the statistical tool SALSA and SIRIS since they are often used in various settings when describing results of schools in Sweden. These databases give access to general information concerning the schools and their students but data concerning information about the teachers and the teaching practice is hard to come by.

Second, to remedy the lack of information, the data from the official records was supplemented with a pre-test questionnaire to the teachers and the other school-staff launched on the day of the kick-off for the project in August 2011.

SALSA

SALSA is a used when presenting results of grading on municipality and school level with respect of the composition of the students. The merit points are compared with the background factors of (1) parents' education level, (2) percentage of students born in Sweden with foreign backgrounds, (3) the proportion of students born abroad and (4) the distribution of boys and girls. The greatest impact on the results from this model, have been identified as parental level of education (http://salsa.artisan.se).

SIRIS

SIRIS is a tool with statistical information on various levels e.g. municipality, school and country, about school's results, quality reports, regarding students, costs, various documents on different levels level. It is used to see changes over time and how different interventions affect different factors in school. (http://siris.skolverket.se)

A description of the questionnaire

The questionnaire consisted of 45 questions. Most of the questions were on a 5-grade Likert scale, concerning views, practice, teacher training, facilities, assessment and practice. The questions were selected from a "pool" of questions gathered from other technology education studies (e.g. Nordlander, 2011; Cetis unpublished; Skogh, 2004) complemented with new ones to fit the purpose of this study. The questionnaire was tested several times among other researchers, statisticians, relatives and friends. The guidelines provided by Statistics Sweden were followed for the layout and questions (http://www.scb.se; Cohen, 2007; Djurfeldt, 2003).

The questionnaire was constructed to cover and identify three different groups in Tekniklyftet. The three groups were;

i. School staff working as technology teachers (all 45 questions)
ii. School staff working as teachers in all other subjects (26 questions)
iii. School staff working in schools with non-teaching task (13 questions)

The questionnaire was distributed to the participants as they were arriving to the introduction of Tekniklyftet. They all answered the questions and returned the questionnaire before entering the kick-off activities/ lectures. The filled in questionnaire were then transformed to a web-file by means of the researchers and assistants. The resulting data file were organised in Excel and analysed in SPSS. Final diagrams were processed in Excel.

In total 651 people (teachers, school staff) participated, to different degrees, in the questionnaire.

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[2] SIRIS: the National Agency for Education's online information system on results and quality.

[3] SALSA: the National Agency for Education's online tool for Local Correlation Analysis.

Results

Description of the participating schools

According to the SALSA model, the schools participating in Tekniklyftet is similar to the rest of the country and region with respect to distribution of boys and girls, merit points[4] and parent educational background. The Stockholm region has a somewhat higher parent educational background compared to the rest of the country. The participating schools, as a group, have slightly lower values on this parameter than the region and thus are in parity to the country. The amount of students born abroad is about the same as the region, which is higher than the country. Tekniklyftet differs from both the country and region on respect of students with second-generation immigrant background. About 22 % of the students are second-generation immigrants, which are twice as many as within the Stockholm region and 3.5 times the whole country. To be conclusive the 28 participating schools considered as a group, does not by large, differ from the rest of the schools in the country or the region except from the amount of second generations immigrants.

When, where and by whom?

When?

Our data shows that technology is mostly taught in the school year 7-9. Please note that the amount of teachers, who teach in year 7-9, is more than those who teach in year 1-6 in the sample. When crosschecking with previous results such as ASEI (2005) and SSI (2009, a, b & c) this confirms the notion that technology is mostly taught in the higher years of compulsory school.

Where?

In the participating schools in Tekniklyftet, technology is mostly taught in regular classrooms or science classrooms. The data also shows that the students are taught in whole class and/or in some cases in half groups. Neither of the schools uses gender grouping and only one use ability grouping.

By whom?

From the data collected in the questionnaire we can see that the typical technology teacher with some academic credits in technology (TTAC) also teach mathematics and/ or biology, physics and chemistry (i.e. natural sciences). Diagram 1 shows the connection between formal teacher training in the subject and the tutoring of the subject. It shows that many teachers who teach technology do not have any formal training in the subject. This is more accentuated in technology compared to the rest of the subjects. The data also shows that the TTACs do not have so many academic credits in the subject, see diagram 1 and 2.

[4] The summary of all 16 grades is in total 320 merit points (20 per subject).

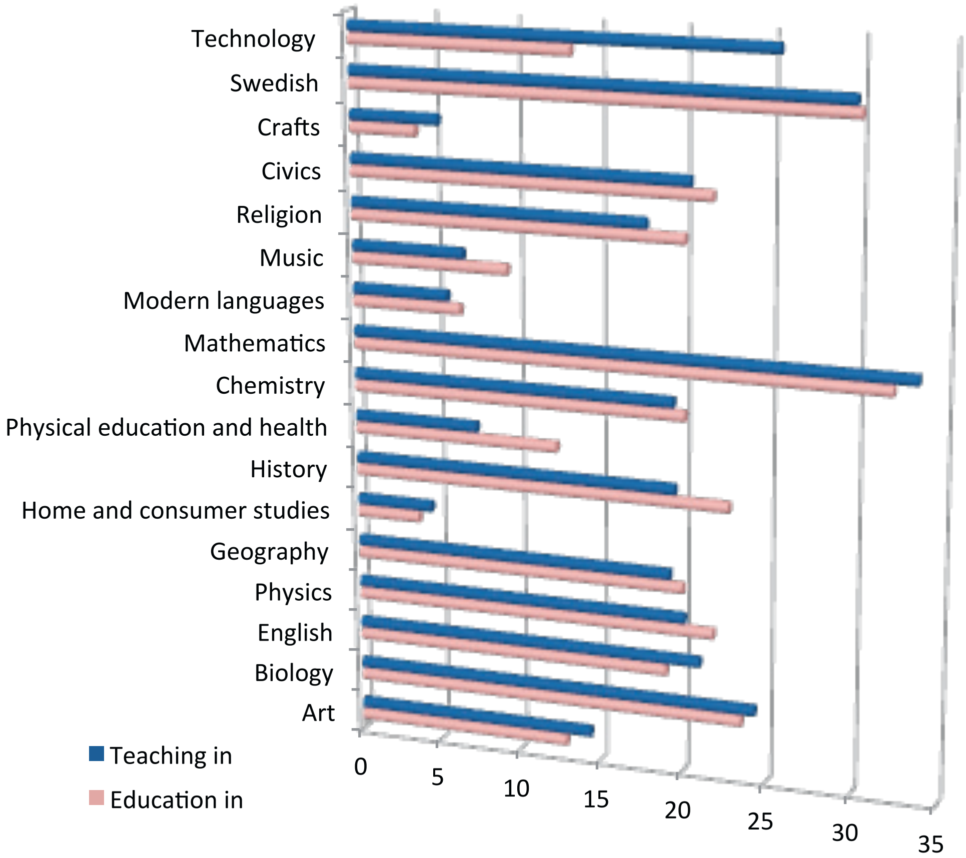

Diagram 1 shows the percentage of teachers teaching in the subjects and teachers with formal teacher-education in the subjects.

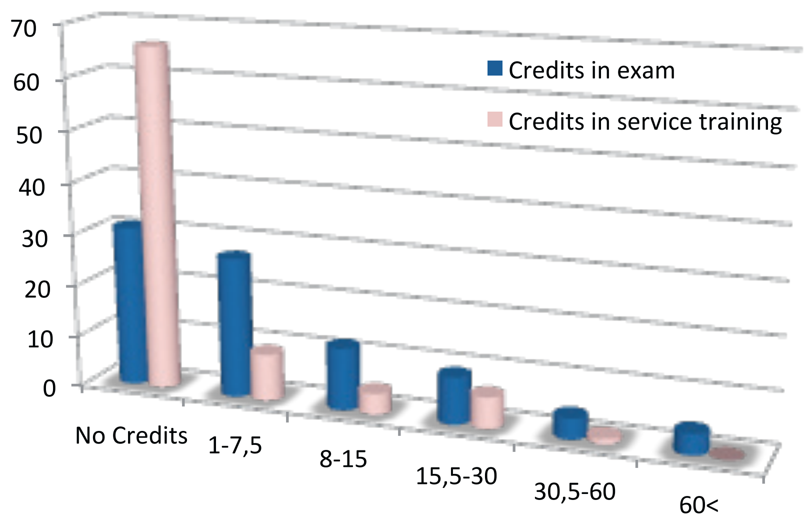

Diagram 2 shows the number of technology teachers and their amount of academic credits in technology. Please note 30 hp is one full time semester.

Grouping of teachers teaching technology

There are 533 teachers in total answering the questionnaire. 166 teachers answered the questions about technology. This group of teachers teaching technology has been divided into three sub groups on behalf of teacher training in the subject, in order to identify any differences. These groups are

1. All teachers in the questionnaire (All) (n=533).
2. All teachers who teach technology *(ATT All Teaching Technology)* (n=166)
3. Teachers with academic credits in the subject *(TTAC Technology Teacher Academic Credits)* (n=63).

Diagram 3 shows that the TTAC teachers' views about technology education are more connected

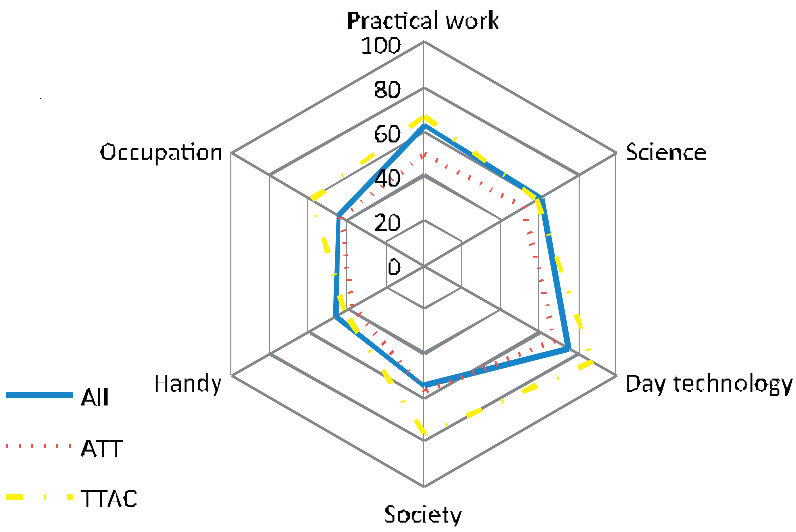

Diagram 3 Teachers' opinion about technology education.

Diagram 4 shows the informants' views on whether other mandatory subjects are more important than technology. The three core subjects Swedish, English and Mathematics differ out from the others. TTAC teacher are them who most see this difference.

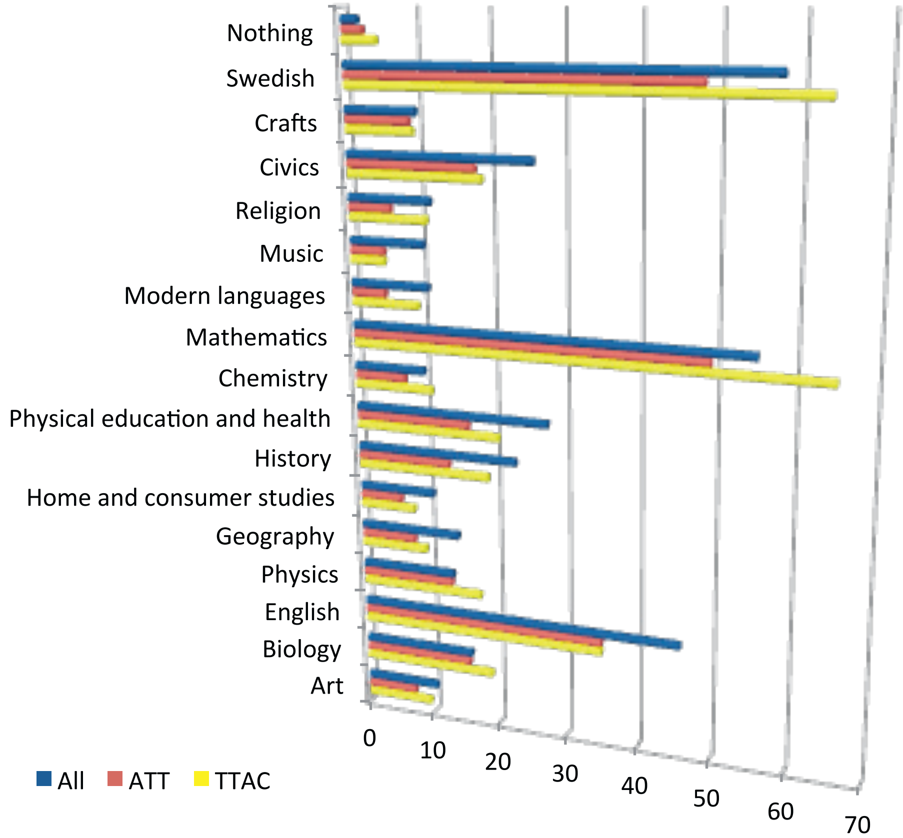

Diagram 4 Percentage of all participants' views on whether other mandatory subjects are more important than technology.

Satisfaction and influences

Diagram 5 shows how the technology teachers are mainly satisfied with their teaching surroundings such as premises, equipment and material. They are not equally satisfied with the storage facilities. The scale in diagram 5,6 and 8 goes from 1 to 5, where 5 is best or agree most.

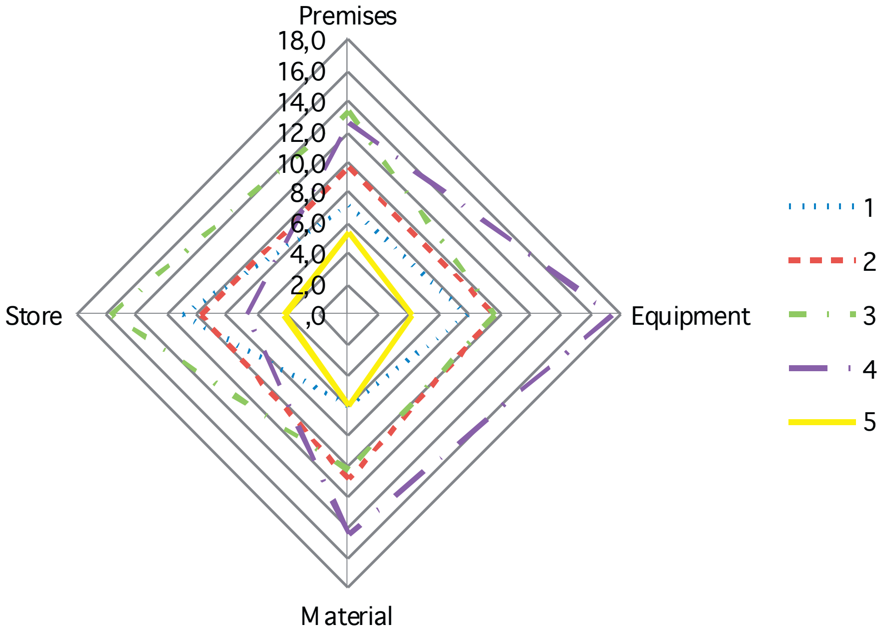

Diagram 5 Technology teachers' satisfaction with their teaching surroundings.

Our data shows that the technology teachers are more influenced by the national curricula than the local working plan. Diagram 6 shows that the teachers teaching technology (ATT) are not satisfied with either their timetable or the distribution of time.

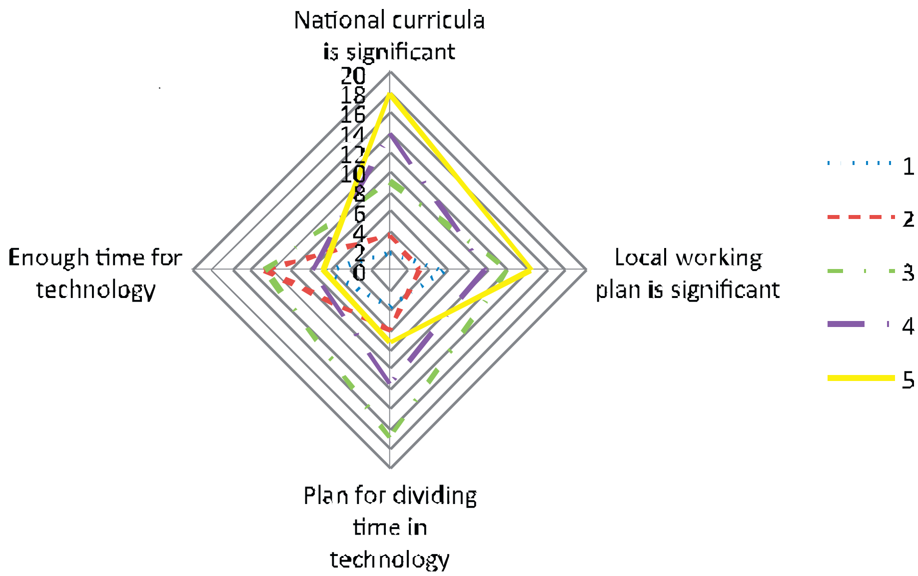

Diagram 6 Technology teachers' influence by curricula and satisfaction with time.

Integration of technology in other subjects

One of the aims for Tekniklyftet is to strengthen the subject technology education in all subjects e.g. to make teachers in other subjects, e.g. social sciences, aware of the connections with technology, to integrate and envision technology in their subjects.

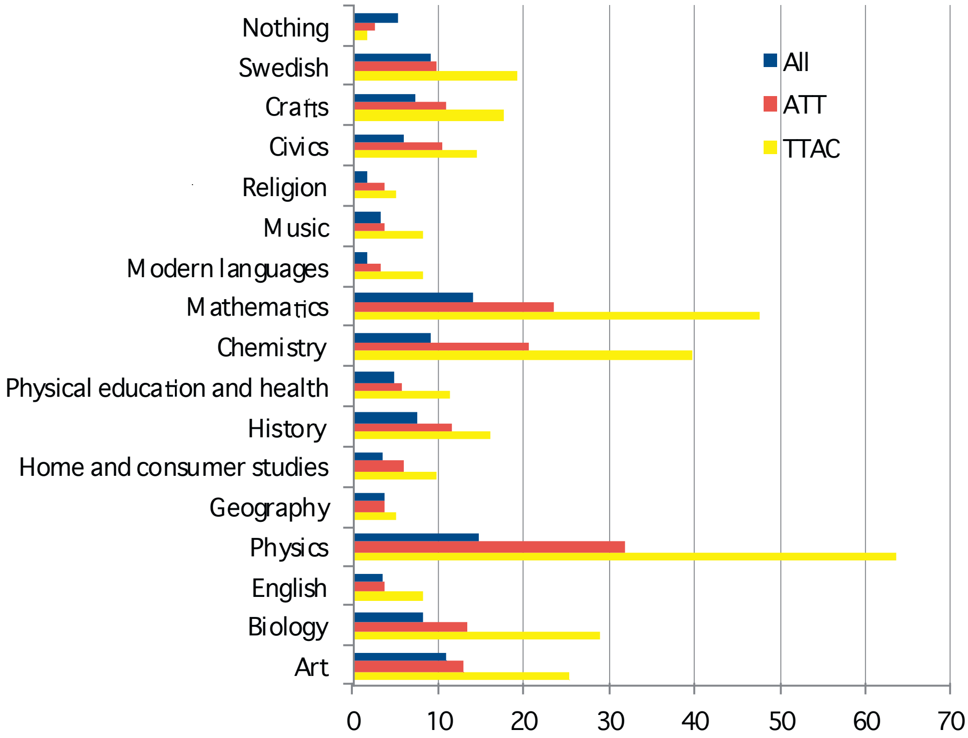

Diagram 7 Percentage of teachers' experience of integrating technology in other subjects.

Diagram 7 shows the experience of integration of technology in other subjects. It shows that technology is often integrated in the natural sciences and especially in physics. When crosschecking with previous results presented here, we find e.g. that the typical teacher in technology identified in this project teaches the science subjects as well. Is it possible that the teachers are integrating technology in their own subjects by themselves?

Assessment

Tekniklyftet started at the same semester as the new regulations was introduced (autumn 2011). The starting questionnaire included questions regarding the confidence of the teacher when assessing their students, describing the goals in the national curricula and so on with respect to the former curricula and syllabus (LpO-94). Diagram 8 shows how all the teachers in Tekniklyftet experienced confidence when informing their students about the curricula and how to concretize the (former) curricula. The diagram also shows their experience of the IDP[5] documents. This is a general overview. When including findings from the different groups of teacher and shortfall into the questions the results show that there are differences among the groups of teachers. E.g. technology teachers without academic credits seem less confident in general.

[5] Individual Development Plan with written assessment, a Swedish mandatory follow-up document (Hirsh, 2011)

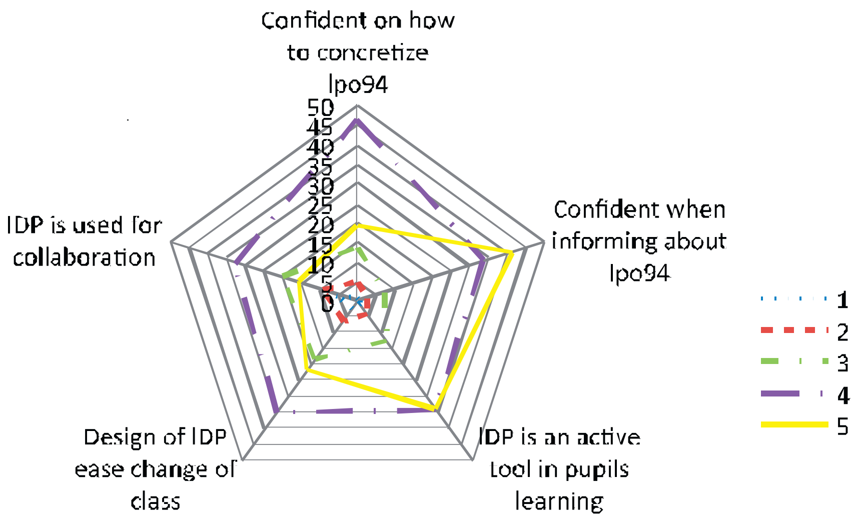

Diagram 8 Teachers experienced confidence when informing about and how to concretize the (former) curricula and their experience of the IDP documents.

Discussion

When the teachers in Tekniklyftet teach their pupils in technology, it is likely to be in the later years of schooling, in whole class or divided in half and in ordinary classrooms as they do in science. The students are likely to be taught in the subject by a teacher who also teaches mathematics and/ or natural science. When taught in technology the students are likely to be taught by a less certified teacher than in all the other subjects. When the subject is integrated in other subjects it is mostly done in science and/or mathematics. The results show it is most likely that these teachers are the same individuals as them teaching technology; thus it is very likely that the persons who integrate the subject technology are doing it by themselves in their own practice.

The technology teachers show a general satisfaction when it comes to teaching conditions such as premises and equipment but not with the storage possibilities or the timetable for technology. Many of the teachers lack training in the subject. When trained they are most likely to have less than half semester of training. These results are consistent with previous reports e.g. Teknikdelegationen (2010).

The teacher in technology generally seems to follow the rest of the teachers when it comes to confidence in interpreting the (former) curricula. Some differences within the group of technology teachers have been identified though between those who have academic credits (TTAC) and those who lack academic credits (LAC). The foremost difference is the willingness to answer the questions in the questionnaire. The shortfall is larger among the LAC-teachers all troughs the questionnaire but especially about those in assessment in technology. When regarding these issues it can be seen as a sign of a general insecurity among the technology teachers where LAC seems less confident than the rest. This results raises further questions and need more investigation.

The collected data have been used and presented here, as un-boxing the starting point for the project Tekniklyftet. The results from available official data-records show that as a group the participating schools does not differ from the rest of the country or the region on behalf of available statistic data. Views about their working condition and about technology have been investigated in the questionnaire for the teachers at the participating schools. Questionnaires have its limits as well as official data. Some results are presented on part of the starting points. There are socio economic differences within the group of participating schools and there are some differences between the different groups of teachers. What are they and in what way do Tekniklyftet affect them? There is a need for more data to provide answers. Data will be supplemented in triangulation with documents from the schools, photographs from the classrooms, interviews as well as questionnaires along the way during the project. The unboxing will continue and the findings will contribute to provide answers on how Tekniklyftet has influenced teachers' practice.

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Transformation by Design

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Key words: Design knowledge, Design capability, Design drawing, Analogy, Metaphor

Abstract

This paper will argue that design capability is one of the most significant capacities of the human mind and is therefore essential for young people's education. Underlying this assertion is the belief that design capability distinguishes technology from technicity (procedural knowledge in a technical context).

Extrapolating Ryle's (1949) ontology to technology education, the author has previously asserted that

Know that)
Know relevance))-----→ Strategy knowledge
Know how)

inserting *know relevance* into Ryle's two-fold distinction.

Additionally, the role of the inner eye is central to design: *seeing in* (Wollheim, 1987) and *seeing as* (Wittgenstein, 1989). The recognition of the use of extrapolation, simile, metonym and metaphor transforms Ryle's distinction between declarative and procedural knowledge into something much more powerful for thinking about design processes. In a technological context, it represents the transformation of an initial perception of possibility into an innovative product, process or system.

This theoretical understanding grew from the author's doctoral research into young children's use of drawing as a tool for designing, part of which involved a 2-year longitudinal study in which the purpose of using drawing for designing was explained to a class of 6-7 year olds using the dual metaphor of drawing as both a container and a journey. This metaphor enabled them to understand the potential and purpose of using drawing to support the generation and development of design ideas. Not only were these young children able to use drawing in a much more powerful way than previously observed in children of this age, but the products and design solutions that they produced were more creative and effective.

Within education, as in the real world, the ability to transfer and apply knowledge from one area to another is highly valued. Within technological design, an effective solution frequently requires the ability to extrapolate, to use metonyms and metaphors from other realms of experience and expertise. The success of the container / journey metaphor depended on this capacity.

The transformational capability of the human mind, to see things from multiple perspectives and to take leaps of imagination stems, this author believes, from our love of story. Essentially, I told the children a good story. To apply narrative to the use of science to engineer a solution is, I believe, a uniquely human capability and empowering children to do so may be imperative for all our futures.

Knowing What is Relevant to the Problem

At the heart of what a designer / producer is trying to do is transformation: the changing of something into something else which, in some specific circumstance(s), is (hopefully) going to be useful.

In contrast to the scientific quest for a "one-size-fits-all" theory of everything, technological knowledge is heuristic, specific, opportunistic and pragmatic. The strategies employed to solve a problem may be practical, theoretical, imaginative; involving analogy or metaphor, prior knowledge and / or experience, social awareness, empathy, cultural traditions, religious or ethical beliefs. There is also the "real world" of what the materials and components will actually *do*, what someone might do with them, and the consequences of success or failure in the attempt, which can all be on an personal, community and / or global scale. Designing technology is complex as are the strategies employed.

Designing is messy; intellectually that is, not just the dust and glue and bits all over the floor when making the product. It comes under Rittel and Weber's (1974) classification of "wicked problems", or as Buchanan (1995) calls them, indeterminate, in which no answers are true / false only better / worse. Every situation is unique and designers are continually required to flip mentally between the general and the particular, which sheds a different light on Ryle's neat division of knowledge into "what" and "how". If every design situation is new, then how can rules about what counts as knowledge within this messy field be decided? Not only do designers have to think about the materials, procedures, economics and so on, but also the needs and desires of a client or potential user, and perhaps also about the shelf-life and disposal of the product once obsolete or broken. Plus the product may need some aesthetic appeal in order to be taken off the shelf in the first place.

Middleton (2000) provided a model (Fig 1) for designing in which his "search and construction space" is replete with backtracking, diversions, cul-de-sacs, and end-points. The "satisficing zone" may not be the only idea, not even the best there is, since it may be refined later or new technology may affect its efficacy, but as the idea or solution of the moment, it is sufficient.

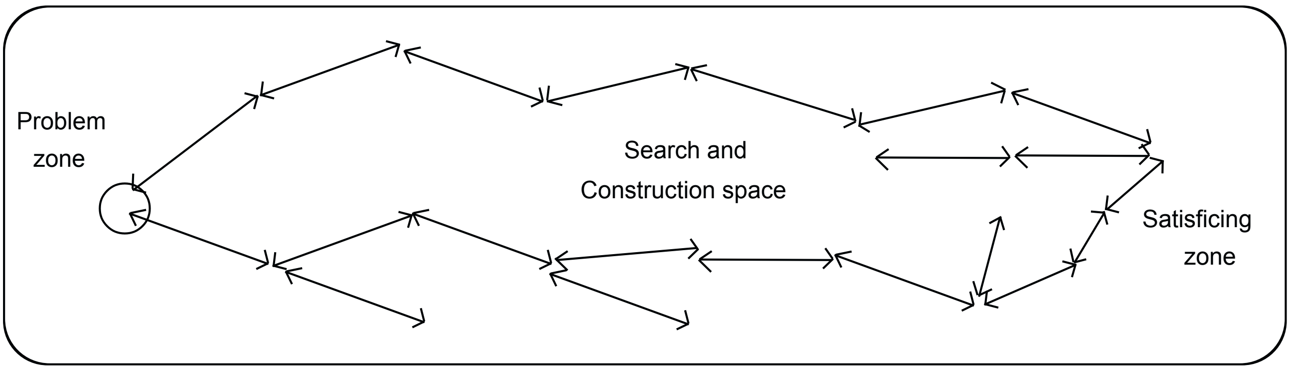


Fig.1; from Middleton (2000)

A useful analogy here is that of the key in the lock, provided by Von Glasenfeld (1987):

> "Knowledge can never be interpreted as a picture or representation of [the] real world, but only as a key that unlocks possible pathways for us." (p.194)

Von Glasenfeld rejected the view that knowledge should *match* reality (like paint matching some already on the wall), asserting that if we say that it *fits* in sense of a key fitting a lock then a totally different relation exists between solution and problem / idea and opportunity. The fit describes the key, not the lock and many keys fit same lock.

Deciding which strategy to follow can be seen as an expansion and development of Ryle's (1949) division of knowledge into *knowing how* and *knowing that* to include the lateral thinking often employed by designers as well as their skill, experience and understanding in judging which of these flights of fancy are most apposite to the design opportunity or to solve the problem in hand (Fig 2)

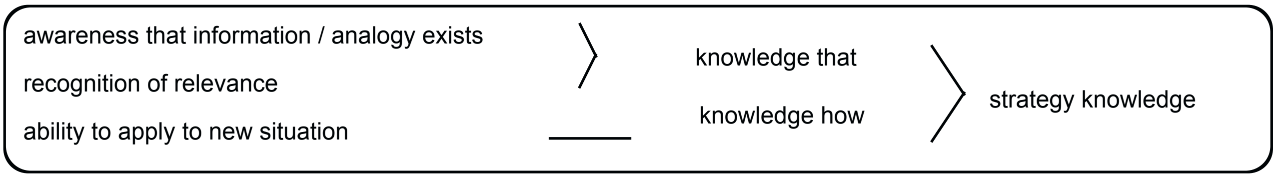


Fig. 2: know that / know how / know relevance

"Strategy knowledge" is defined here as underpinning the choice of procedure to follow in a specific circumstance, a combination of *know how* and *know that* which has power when linked to *knowledge of relevance* to the problem or opportunity. This informs the way in which a new project is approached and carried through. Once a strategy has been mastered and internalised, it then becomes part of the *know that* and *know how* which makes solving the next similar problem so much easier. This creates a cognitive network of strategies, linked by simile and analogy, which enable life-long building of learning to deal with both the familiar, the new and the totally novel, leading to the ability to create new ideas that will work in the real world.

In this model, *know that* is a combination of knowing of the existence of particular information and of its relevance to the current design situation. The designer does not need to know all the details; they can search the internet, consult an in-house expert or be able to work it out in practice. *Knowledge of relevance*, therefore, is more pertinent to design opportunities, than knowing all the facts. Knowing how to use the relevant information, or knowing someone else who can, may lead to design success. The way forward, *strategy knowledge* in a design context ("What we could do is…"), is parallel to the breakthroughs of science or the finding of a new melody or the use of a striking metaphor in a poem. The choice of appropriate strategy in any design situation depends on the depth and salience of this three-fold knowledge base: *know that*, *know how* and *know relevance*.

The understanding of relevance is key to children's developing design capabilities. Donaldson (1992) found that 6 year olds had difficulty in solving adult-defined problems because they could not solve "this problem and this problem only"; they wanted to re-invent the rules of the game:

> "They did not have a clear conception of this problem - this one and no other - which they could hold on to and use in deciding when the problem had been successfully dealt with, so that thinking about it should cease. Such a conception is the very foundation of relevance. And there can be no intellectual power where a sense of relevance is lacking." (p.135)

Choosing to conduct my research with 6-7 year olds, therefore, was risky, but a risk worth taking. This age group was purposely chosen because they were on the cusp of this perceived understanding of what is relevant to solving a design problem.

Extrapolation, Analogy and Metaphor

Lurking behind *know relevance* is to "see analogy" or "perceive metaphor". The relevance of prior knowledge or new perception may be realised through a flight of fancy, a side-ways jump of the imagination or a new way of seeing old knowledge.

This may be through:

- Realising that the situation has similar but not identical features to one encountered previously (extrapolation)
- Seeing the new situation as if it were an example of one taken from a different field of experience (analogy)
- Applying thinking, concepts and vocabulary from a different conceptual system to enlighten thinking within the present situation (metaphor)
- Using a symbolic system (e.g. drawing) as a way of supporting thinking about a solution that will be realised in different materials or systems (metonym).

Although they are specifically discussing language, Lakoff and Johnson's (1980) *Metaphors We Live By* demonstrates how knowledge is built across many different fields, including designing. Concepts come with attachments (entailments) and when these encounter each other, then new ways of seeing will arise. Veale's (1999) term "conceptual scaffolding" which (also discussing language) he describes as "an architectural guide, or blueprint, for the assembly process, but may not constitute an element in the final edifice. That is to say, conceptual scaffolding possesses a transient existence to serve as a temporary representational purpose" (http:/www.compappdcu.ie/~tonyv/papers/CogSci.ps,gz).

In the context of design development, drawing, mock-ups, maquettes and prototypes would all fit under the umbrella of Veale's conceptual mapping. Roberts' (1994) helpful distinction between "modelling of" and "modelling for" extends and defines the way in which designers use these design tools for imaging the future and putting the ideas in the mind's eye into the public world, available for evaluation, scrutiny and improvement. Likewise, Baynes (1994) definition of modelling as the *language of design* also is helpful in opening up the ways forward in accessing the literature on language theory and applying them to our field. The way in which language works, by constantly reapplying a set of words and rules in new situations and in novel ways in order to communicate, project ideas and influence the social world, is parallel to the way in which people use materials, components and systems to create new products or use existing products in new ways.

Gentner (1982) saw models as "structure mappings" from one domain to another since it was often the overall structure of a problem that was transferred analogically from one domain to the other, rather than a specific feature or characteristic, and this too can be seen within designing. A design drawing or model is both metonymic and metaphorical, as defined by Miall (1982), a transaction between contexts, enabling the construction in one symbol system a pattern for construction in another, whether through drawing, a 3D mock-up or cutting up old newspaper. A design drawing can be seen as a metaphor, or perhaps more strictly speaking a metonym, since it stands *instead of* rather than *parallel but in a different plane to* the idea in the mind's eye and the product to be created. Creating a parallel system in which to think about and plan a product to be made in something else falls within Wittgenstein's (1969) phrase "*seeing as*". In using drawing to design, the drawing is *seen as* if it were the product; putting ideas on paper enables these to be viewed and evaluated, changes made and practical problems of construction thought through. Design drawing is "*place holder*", an external memory system that allows the examination of thoughts and ideas, allowing the brain to get on with the higher order functions of evaluation and improvement without being cluttered with having to remember what the potential product might look like.

A Metaphor to Teach By

This final section of this paper describes the research context from which the preceding theoretical perspective emanated. From boldly claiming that "drawing is a metaphor", I quickly side-stepped into something that could be empirically proved in a classroom: that a good metaphor is a good teaching tool. I was also building on Egan's (1996) insight that children did not understand the purpose of using drawing to support designing.

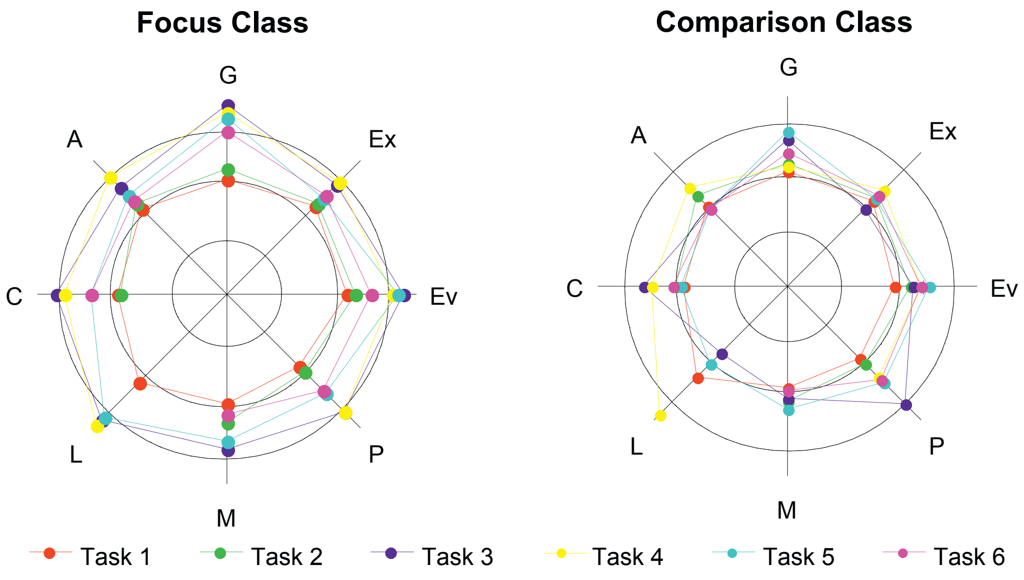
The dual metaphor that I used with a class of Year 2 (age 6-7 years) children to explain the purpose of drawing for design was the *container* and a *journey* from Lakoff & Johnson (1980). Across a 2 year longitudinal study, I taught design & technology to one class (the Focus Class), while an experienced colleague taught the Comparison Class. The only difference was the *purpose of design drawing* was explained to the Focus Class using the metaphor. They were not taught any specific drawing techniques, nor were they told to spend more time drawing than were their peers. This, however, came to be so by the end of the study as a by-product of their understanding the way in which drawing could help develop their thoughts and ideas.

The purpose of using drawing to support design development was explained to the Focus Class children by means of a narrative involving this container/journey metaphor. They were shown two sets of drawings done by Year 4 children, one of which were design drawings and the other not, and were asked what kinds of drawings they thought the two sets were. "Planning drawings" were one child's immediate response to the design drawings, which enabled the introduction of the metaphor. I explained that the drawings both *contained* ideas but that those ideas were on a *journey* that ended, not on the page, but in the product that was finally made. It was stressed that only part of the journey might be contained in the drawing and that this might be a different part on different occasions; that different people might use different kinds or numbers of drawings; or that some people might want to draw a lot and others not much. What was emphasised to the children was that the purpose of the drawing was to help them design; what kind of drawing they did was up to them. The drawing was part of the journey, not part of the destination – like the carrier bag that contained your picnic when you went on a day out but might get to contain daisies or pebbles during the day, which would be played with when you got home, but was itself only the container used on the journey.

Between the assessment tasks, both classes experienced similar design activities, largely dictated by the long-term plans that were in place in the school, with permitted variations. For instance, the Focus Class made sandals while the Comparison Class made hand puppets when the long-term plans indicated mastering skills of using templates based on personal body measurement. As they moved into Year 3, both classes were set a design problem by the school catering manager: designing a packed lunch. Not all the projects involved drawing; transferability of the metaphor to other designing media was seen as important for deep understanding. For instance, a marble run was designed through making mock-ups in mouldable material, card and small recycled components. Care was taken to ensure that the Focus Class were not asked to do more drawing than the Comparison Class and thus benefit simply from practice effects. The pedagogical difference was in the way the purpose of design drawing was conveyed to the children. To ensure the difference here, the teacher of the Comparison Class was not made privy to the *container/journey* metaphor used with the Focus Class.

At regular intervals, both classes took part in an assessed design task. Fig 3 shows the profile of both classes across these activities during the two year period of the study. Appendix A contains the assessment criteria to which the quantification of the evaluation of the different aspects of the children's drawings refers.

Fig. 3: Comparison across Assessment Tasks



Key

G = Generating and Developing Ideas
Ex = Exploring the Possibilities of the Task
Ev = Evaluating Whilst Planning
P = Planning Construction
M = Basis for Making the Product
L = Planning the Look of the Product
C = Communicating Ideas
A = Addressing Tasks Constraints

Task 1: Design a Pizza
Task 2: Problem-solving - getting Frosty the Snowman across the lake
Task 3: Design an Easter Egg Holder
Task 4: Design a Greetings card
Task 5: Design a travel bag for the class mascot
Task 6: Problem-solving - helping Theseus escape from the Minotaur

The immediate success of the *container/journey* explanation can be seen in Fig.4. Tasks 1 and 2 preceded the explanation, since it was necessary to firmly establish that there was no initial difference in the children's capabilities through conducting two different design tasks: a problem-solving task and a product design task. Assessment Task 3 was conducted 4 weeks after the *container/journey* explanation and its immediate effect can be seen.

As can be seen from Fig 4, there is a sense of the Focus Class' design capability expanding after the *container/journey* metaphor was introduced. The Comparison Class' profile swings about wildly but does not significantly expand. The aspect on which they do well in each task tends to be the area of designing on which the task centred. For instance, in making a greetings card (Task 4), they did well on thinking about how the product will look; on making the Easter Egg holder (Task 3), they did well on planning construction. The Focus Class' profile not only expands but it does so in a balanced way; their overall design capability had improved.

Wittgenstein (1969) referred to systems of thought as "language games". Being able to think the thoughts requires knowledge of the rules and ciphers of the language game (e.g. philosophy, mathematics). In school, children are expected to pick up quickly on the language games being played by the teacher. By using the *container/ journey* metaphor, I had provided a story-line that enabled the children to understand the purpose of using drawing for designing. In accepting my story-line, couched in the *container/journey* metaphor, and learning to use it as a framework for their design activity, the Focus Class children learnt the rules of the design game. The constraints imposed by role-taking, learnt as part of children's normal play activities, are essential for developing problem-solving skills. Learning to accept *"these rules and these rules only"* (Donaldson, 1992) as part of social play powers the development of design capability. Learning to accept constraints, not just on actions but also on what is allowed to be imagined within a given context, is dependent on the acceptance of a situation-as-defined, of socially mediated thought and action.

In Conclusion

In this paper, I have argued for a design ontology that goes beyond Ryle's *know how* and *know that* to include *know relevance,* but, as importantly, to recognise analogies and metaphors within the sphere of knowledge and its exploitation. The key skill of a designer is frequently more than just know what will work but to think laterally and to see the apparently irrelevant as essential. Being able to apply reversals and inversals may be the greatest design skill.

This metaphorical thought within designing has been illustrated by reference to the research that I conducted with young children. Their understanding of narrative and their willingness to play the design game my way was, I believe, a key factor to the success of my teaching. This lead, finally, into the assertion that the role-taking and accepting of socially-mediated game rules within children's play contributes considerably to their ability to take on the role of designer, to accept the constraints of a design challenge to produce a novel and pleasing solution that works.

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APPENDIX A : Assessment Criteria

Generating and Developing Design Ideas

1	2	3	4	5
Drawing a picture, not designing a product	Simple sketch, showing object to be made	Design ideas generated but not developed	Progression of ideas across or within drawings	Uses drawings reflectively to generate new ideas

Exploring the Possibilities of the Task

1	2	3	4	5
Design possibilities are not addressed in the drawing	Stereotypical response, showing little creative thought	Recording possible creative solution(s) to the task	Using drawing to develop novel design solution(s)	Combining novel solutions to produce innovative design

Addressing the Constraints of the Task

1	2	3	4	5
Minimal understanding of task / user needs	Drawing shows some understanding of task constraints	Records way to address task &/or client needs/ wants	Task constraints considered as the design proceeds	Task constraints treated as part of iterative process

Planning the Look of the Product

1	2	3	4	5
Appearance of a product is not considered	Little consideration of final appearance of product	Overall decorative scheme considered	Ideas about finishes are added to design whilst drawing	Ideas about finishes develop within overall designing

Communicating Design Ideas

1	2	3	4	5
Use of narrative or other drawing genre	Simple unlabelled sketch(es); relying on shared meanings	Conveys some sense of the object to be made; e.g. indicates materials	Conveys sense of object to be made; e.g. working diagram	Clear enough for someone else to make the product

Planning Construction

1	2	3	4	5
Not planning to make the object as drawn	Minimal consideration of construction whilst drawing	Drawing indicates some consideration of construction	Drawing demonstrates consideration of construction	Constructional issues considered en route to final design

Evaluating whilst Drawing

1	2	3	4	5
Yet to define the design task	Minimal evaluation at drawing phase	Considered and rejected a range of ideas	Decisions made about product whilst drawing	Changes made as result of considering design drawings

A Basis for Making

1	2	3	4	5
Making an object is seen as separate new activity	Product relates to ideas recorded in the drawing	Object is one of the ideas drawn	Clear development path through drawing into making	Using drawing as resource during making

Technological systems across contexts: Designing and exploring learning possibilities in Swedish compulsory technology education

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Jonas Emanuelsson, University of Gothenburg

Abstract
In the world we live in there are powerful broad frameworks for understanding specific objects, relationships and events. This paper focuses the learning and understanding of one such framework, namely, technological systems, which are complex systems of technical and human components that facilitate much of the experienced needs of modern society. Technological systems are constituted of transformation and transport, acting on matter, energy and information. This paper outlines a larger project, which is expected to contribute substantially to a pedagogical knowledge base for systems thinking in technology. The specific focus of the paper will be the first step in the project – the development of a design for learning technological systems in Swedish compulsory school based on previous empirical studies as well as theoretical principles. The core of that design revolves around creating patterns of variation supporting the separation and differentiation in and between four empirically identified dimensions of variation: resource, intention, internal structure and external structure. It also includes patterns of variation that support the fusion of these dimensions and simultaneous awareness of several different technological systems, focusing their systemic nature.

Introduction

In contemporary society technological systems encompass much of what characterises technology: Technological systems are goal-directed, delivering both to society and to individuals, but have also unwanted effects. Many such effects concern detrimental influence on the environment, and in understanding the grounds for sustainable development, understanding the systemic aspects of technology (and nature) are paramount. At the same time, technological systems are not tangible, and as such is a theme less supported by informal learning than other themes in technology.

The topic of 'technological systems' form an important part of the school subject Technology in Swedish schools, where it embraces a broad definition of technology related to human endeavours. The syllabus for the Swedish national curriculum in technology in the lower secondary school includes such items as "How components and subsystems work together in larger systems, such as the production and distribution of electricity... The Internet and other global technical systems. ... Systems – their advantages, risks and vulnerabilities."

Empirical studies so far suggest that the basic capability in (complex) systems thinking is the recognition of a meaningful framework of relationships connecting seemingly isolated events and components to become an interconnected whole, also operating on a different level (Assaraf, Dodick & Tripto 2011; Jacobsen & Wilensky 2006) – i.e. seeing something *as* a system (c.f. recognising a phenomenon, as described in Marton & Booth 1997). This is difficult since many aspects of systems are never directly experienced (Hmelo-Silver & Azevedo 2006). Some tentative characteristics of thinking and reasoning in relation to complex systems are to

- recognise multi-causality and emergence – that several different events on one level may give rise to a qualitatively different pattern of events on another level (Jacobsen & Wilensky 2006).
- identify cycles of matter, energy and information (de Weck, Roos & Magee 2011; Eliam 2012; Svensson 2011b; Svensson & Ingerman 2010)
- recognise the nature of temporality, directionality and (dynamic) equilibrium (Jacobsen & Wilensky 2006) and
- consider consequences of and on human interaction with the world (de Weck, Roos & Magee 2011; Mohan, Chen & Anderson 2009).

Recent work concerning technological systems as an educational topic, highlighting descriptions in textbooks and national guidelines as well as teachers' efforts to include this theme also form an important background for the project (Klasander 2010).

In the project outlined here, the aim is to explore teaching and learning of technological systems for pupils in school years 7 – 9, and the relationships and mutual interdependencies between individual learning and collective learning comes into focus. In collaboration with the teachers we will design lessons that vary over different technological systems as well as aspects of them.

The central research question is:

> *What does it take to learn, and what does it mean to teach for learning, Technological Systems, their constituent parts and the relations between them when the systems are embedded in different contexts and encountered in different pedagogical structures?*

From the overriding research question emerge three sub-questions:

- What do students in the lower secondary school understand of technological systems in terms of their constituent parts when given opportunities to explore systems in different contexts?

- What can teachers offer as a platform for developing a general understanding of technological systems with recourse to different systems set in different contexts?

- How are technological systems expressed in different contexts in different pedagogical structures in the classroom arena?

Empirical design

Data will be taken from the lower secondary school, years 7-9, wherever examples of technological systems are being taught.

The empirical data generation will include four steps.

1. Establishing a team of 8-10 teachers and the researchers from the project with common grounds on the knowledge theme and common basic ideas for a pedagogical approach. That will include a "course" for teachers on technological systems, following Klasander (2010).

2. Develop in the team a shared plan for teaching over a series of lessons (cf. Vikström 2005), that converges what is understood as intended outcomes, and what may be productive learning activities in terms of establishing overall patterns of variation, as drawn from the work of Svensson (2011a) and Klasander (2010). This plan will explicitly make use of variation in context as a way of exploring the abstract technological system, expanding the understanding and ways of expressing these understandings in classroom interactions – in verbal, written and representational forms. It will also cut across different pedagogical structures – teacher centred, group discussions, practical activity, and assessment activity.

3. Audio and video recording in classrooms with focus on whole class teaching or group discussion and activity as appropriate. We anticipate recordings from 3-5 lessons per classroom. Copies will be made of students' written material, textbook pages, and worksheets used in class.

4. Data collection to inform the research questions as a whole: Relevant parts of the teachers' planning, assessment, and documentation, which may include written documents, as well as recordings of conversations with and between teachers will be collected throughout the planning and implementation.

Analytical design

The project will be framed, both theoretically and analytically, by the qualitative research approach of phenomenography and variation theory of learning. This approach is capable of supporting the investigation of the process of learning in naturalistic settings close to educational practice in a way that reflects that it is a process of learning specifically about technology and technological systems.

Phenomenographic studies aim to reveal qualitative variation in the ways people understand specific phenomena (Marton & Booth 1997) – for example, the force concept or technological systems (Svensson, Zetterqvist & Ingerman 2012) – and the critical differences that distinguish one way of understanding from another. Variation theory (Ingerman, Linder & Marshall 2009; Marton & Booth 1997), as well as the associated action research approach, learning study (Marton & Pang 2006), offers a theoretically and empirically grounded path to systematically fostering the affordance of understanding a phenomenon – an object of learning – as constituted in pedagogical and classroom practice. The core of the variation theory of learning concerns what is critical for learning, and what essential variation around critical aspects is offered to the students in a pedagogical situation. Teaching design based on such identified essential variation results in remarkable and reproducible gains in learning outcomes in the teaching of various subjects (Marton & Pang 2006).

The project will investigate and relate two levels of the process of learning: one is an aggregated level and one is a moment-to-moment level. Here, *aggregated* refers to the results that describe the overall recurrent structures of understanding and communicative acts, which is taken to include acts that rearrange some aspect of the physical world, and, such results are the outcome of a phenomenographic study. In addition to offering guidance on the organisation of learning activities, variation theory has much to offer in analysing communication for knowledge performances as a *moment-to-moment* production of learning (Ingerman, Linder & Marshall 2009). A micro-analysis approach entails analysing the constitution of variation of critical aspects of systems – potentially embedded in the task at hand and pedagogically activated by the students and teachers. This encompasses classifying the kind of possibilities the students develop in terms of variation, or patterns of variation, in critical aspects, and looking at how the students develop their understanding of the situation, as manifest in their communication with each other and the world.

A tentative design for learning technological systems

In this paper, we focus on the first step of the full project – the design of teaching of technological systems, to be based on previous empirical research, theoretical considerations and identified good practice. Below we describe a tentative design, to be further revised in collaboration with teachers.

The design is based, with respect to previous research, on results emanating from three research perspectives: 1) variation theory design principles, 2) empirical descriptions of key challenges in understanding complex systems, and 3) empirical descriptions of aspects that are critical for learning technological systems in the targeted educational level. The base of identified good practice is on the one hand general and based on research about pedagogical conditions that are favourable for learning, e.g. a student centred and learning focused approach. On the other hand, more specifically, lacking solid empirical results in the area of technological systems, the design is based on good practice in technology education in lower secondary school as identified by the teachers and researchers involved in the project. Such identified good practice may be refined and developed during the project through the collaborative work as well as through the analysis of practice inherent in the project.

The basics of variation theory design is the explicit use of focusing variation across what can be identified as critical aspects of what is to be understood. Such critical aspects can be identified through empirical investigation of ways of understanding, in this case, technological systems. Based on such empirical investigations (Svensson 2011a;b; Svensson & Ingerman 2010; Svensson, Zetterqvist & Ingerman 2012) we identify four dimensions of variation:

- Resource – What the system acts on, in terms of matter, energy and information.
- Intention – What can be identified as the system's intended function (c.f. the intended function of artefacts, de Vries 2005).
- Internal structure – How the systems is organised in terms of components, framework of relationships and human agency.
- External structure – How the system is organised in terms of how it interacts with the surrounding world, such as other technological, natural and social systems.

We emphasize that a dimension of variation is constituted of the ways in which people understand that phenomenon and is not inherent in the phenomenon as such. In each of the dimensions of variation, ways of understanding that dimension of the system can be seen as either referring to systems characteristics or non-systems characteristics. It is essential that patterns of variation in the classroom support the pupils in experiencing such qualitative differences in each dimension through recognising examples that are systemic and differentiating them from examples that are not – this is in variation theory termed as a pattern of separation through contrast. Further, the scope of the pedagogical design must be able to afford a fusion of these dimensions into a whole –seeing different aspects of technological systems as aspects of the same phenomenon, that is, technological systems in general. This is in variation theory termed as a pattern of fusion (patterns of variation are further explained in Marton, Runesson & Tsui 2004).

Through analysing the four dimensions of variation, patterns of separation through contrast can be identified as below. In the dimension of resource, there is a qualitative difference between discussing a *specific* resource, such as the electric current in a desk lamp, and a *systems* resource, such as the energy distribution in the village. A specific design will preferably exemplify resources of different distinct character – only matter, energy or information – where the resource is tightly connected to the idea and delimitation of the system. In practice, working with a mobile phone communication system, an electricity provision system and a goods transport system will provide opportunities to differentiate between resources, as well as between a systems resource and a specific resource.

In the dimension of intention the qualitative shift occurs between on the one hand, a specific person seeing a need and ascribing a technological artefact and its intended function as a way of addressing that need, and on the other hand, when a need becomes recurrent, and a community is established as committed to sustaining a shared intention. For example, contrasting a situation when it is possible for everyone to take their bowl to get drinking water from the river, with when the water that is taken from the river is distributed by communal means, whether piped or bottled, is one way of affording relevant variation in the classroom.

In the dimension of internal structure, the difference lies between seeing components of a system as being organised in a linear format and seeing them as being organised in a network (framework of relationships). This implies differentiating between components and their relationships, where the first transform the system resources, and the second transport them, and seeing both transformation and transportation in relation to the system intention. For example, the distribution of mail includes a series of transformations of the incoming set of mail each day, such as pooling mail from different mailboxes, sorting mail to different destinations, as well as transport between the different points of transformation. Controlling disturbances in the system, such as unclear addresses, weather conditions, strikes and illness, and non-adherence to payment regulations, contribute to the non-linear nature of the system. Creating a pattern of variation highlighting the important differentiations in this dimension of variation is complex. For example, one starting point may be to contrast the structure of messenger-direct-delivered mail with a postal service.

The dimension of external structure is not critical in the same way for the basic capability of recognising a series of events as being organised in a system. Nevertheless, recognising the limits of a system and what surrounds and interacts with it is important for the differentiation between the particular system considered, and other possible systems that could have been considered, add to the critical differences aligned with the other three dimensions.

Following such patterns of separation, variation that cuts across the individual dimensions is necessary, to afford a fusion of their meaning into an interconnected whole. There are probably several levels in understanding both specific and general technological systems; a start for fusion may be pedagogical tasks focusing the same technological system and comparing different historical and national installations of the system, for example, food provision systems. A further step necessitates the simultaneous discussion of several fully-fledged technological systems differing in the dimensions as described above.

In our design we have identified three major pedagogical contexts in which the four dimensions of variation will be present for pedagogical and research purposes:

- Analysing problems, such as considering how the systemic nature of a particular system changes when a central component or aspect of the framework of relationships changes. Examples are the break of power wires connecting northern and southern Sweden and the merging of the mobile and land-line phone communication systems that is underway.

- Working with representations. Examples are the tram time-tables in conjunction with the map of destinations, or a flow chart of normal mail distribution, and diagrams of power usage across different times of the year and times of day.

- Experiencing systems, coming into experiential rather than conceptual contact with systems. Examples involve visiting central components in different systems, such as airports, sewage works, or inspecting a power generator.

Conclusion

We have now outlined the overall aims, intentions and theoretical considerations of the research project as a whole, and given more detail of the first phase in which the research team and the teachers involved will establish a framework for designing lessons on technological systems. The design principles are now well founded and need to be put into practice through intensive dialogues with the teachers who will be working in the classrooms, with respect not only to the pedagogical and system theories involved but also with respect to productive examples for the different pedagogical interventions. The extent to which a common ground is established is an empirical question that we will be addressing continuously as the project evolves, along with the research questions on which the project is founded. The extent to which the chosen pedagogical situations for research are productive for underpinning understanding of technological systems will be a major result of the project.

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Technology Education as 'controversy celebrated' in the cause of democratic education

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Keywords: controversy, controversial issues, curriculum, design and technology education, democracy, 'technology wars'

Abstract

This paper is motivated by the challenge that Technology Education seems to encounter in the area of curriculum stability and identity. The search for 'common ground' amongst colleagues, theorists, or governments would suggest that finding agreement is an almost impossibility.

The position is developed that, when Technology Education is viewed from a range of perspectives, controversy is an ever-present phenomenon. The spirit of the paper sees this phenomenon as an asset to the field and to society in general and, as such, it is something to be celebrated.

The paper discusses the role of controversy in democratic and educational life using the notion of democracy-as-controversy. In turn, technologies are framed as sites of controversy and the concept of technologies as 'controversial propositions' is offered.

The paper illustrates the range of sites of controversy present in Technology Education itself, including: competing stakeholder claims, curricular and epistemological contestations, professional values differences, and pedagogical genres.

In 'celebrating controversy', it is argued that, despite systemic and governmental pressures toward conformity, controversy as core phenomenon of Technology Education should be embraced. This can be seen as (assertively) the emergence of 'technology wars' or (benignly) as Technology's own complicated curriculum conversation (after Pinar et al. 1995).

Introduction

> 'Between two children choose both. Between the lesser and the bigger evil, chose neither' (Novak, 2009).

Three framing remarks are necessary. First, this paper is not primarily intended as some kind of remedy for a perceived problem (although it could be taken in that direction). That would be both reactive and an inadequate construction of the phenomenon under discussion. Rather, the idea is to open up a particular possibility for 'seeing' TE in a way that can help celebrate matters such as flux, change and problematics as *catalysing ingredients* of a worthwhile holism. In times of political, systemic, curricular and even collegial pressures toward conformity and acquiescence, Technology Education might do well to celebrate controversy as a rich asset.

Second, the discussion is above all a curriculum discussion where 'curriculum' is understood in an expansive sense and as a site of political contestation. This is returned to below. Similarly, 'Technology Education' is itself understood in an expansive way. The term is used to represent both a *subject* and, more openly, a broader *field*. Also, whilst the term 'Technology Education' is used hereafter, it is intended to represent inclusively subjects such as Design and Technology, Technology Studies, and others. There are multiple jurisdictional variations in both naming and scope of coverage in relation to this 'curriculum drama' (Layton, 1994a:13).

Third, the author is mindful of how many Technology educators (and others) can become isolated and encamped, with allegiances spoken or unspoken. The paper is in part informed by the witnessing of a spectrum of professional discourses which, when probed sufficiently, amount to controversies. Layton's (1994b) work gave strong evidence of this spectrum and these matters are arguably even more a concern today.

On controversy...

For this paper, controversy is chosen over other words characterising dissonance. There is no shortage of related terms, for example: contestation, debate, discussion, argument, disagreement, discomfort, confusion, contradiction. Controversy is used because it articulates both a sense of the public arena and matters of societal impact as well as a recognition of unresolved value differences. Thus, where there is controversy groups of people sharing particular values counter others who hold opposing values.

Controversy can often be seeded in the fact that *concepts* fundamental to the controversy are themselves 'initially ambiguous' (after Gallie, 1956) and, further, views can be held aggressively or defensively. (Polemic is sometimes used as a term for a disputatious position taken with regard to a controversy.)

Writing for the educational context, Stradling et al., (1984:2) offer '...the term *controversial issue* for those problems and disputes which divide society and for which significant groups within society offer conflicting explanations and solutions based on alternative values.' We could use such a clarification to identify some of the 'problems and disputes' that might constitute today's controversial issues. However, there are also the temporal and the geographical to consider. Some controversies, for example of a political or religious type, have spanned centuries. Some remain within particular societies: for example, over the nature and provision of health care or education or around issues of sexuality or law.

Stradling et al., (1984) also offer the phrase 'conflicting explanations and solutions' to highlight how controversies might be perpetuated because of inadequate information – or its inappropriate or under-use. Simon's (1957) explorations of 'bounded rationality' illustrate the phenomenon whereby two parties faced with the same evidence are able to arrive at differing conclusions. It is not uncommon for a controversy to be aggravated by the improper or partial use of information by one party. Here, we are reminded of the reality that what happens (or does not happen) within controversies is education- and, significantly, values-dependant.

It should also be said that it is hard to imagine life without controversies and that pursuit of their eradication might be fruitless or, if attainable, lead to what might be called 'a life of vanilla and beige'. It is worth noting controversies' positive value, for example, as articulations of dialectics where, from thesis and antithesis come new settlements themselves bringing new values disputes with new opportunities where creativities come into play that bring new ways of seeing things or moving forward – where controversy's literal meaning of 'turning against' brings rewards.

Thus there is a sense in which controversies are what might be called 'necessary tools' and the concept of *democracy* serves to illustrate the point. 'Democracy' here is taken to be an idealised concept seen as 'the most ethically defensible form of government'. Thus, *as an ideal* it is unattainable because it remains imperfect, in continuous need of refining, advocacy and defence. Given such a dynamic, it remains ever-contested. However, the requisite arguments in such contestation are *ethical* ones – simply put as answering the question of 'how should we live?'. (Such a simple take on *democracy* is not only contestable within democracies but can be controversial beyond them.) However, as a working notion, it can be seen that multiple controversies are 'necessary tools' to the healthy pursuit, and defence, of the democratic ideal.

If the tools of controversy are necessary ones, then it occurs that they might be either under- or over-used. Under-use can occur when a democracy's members are disinterested (a matter for education and the media perhaps), distracted (eg time is prioritized otherwise), or enculturated away from discussing certain matters ("We don't discuss politics or religion here"). But inaction can also arise from the paralysis of analysis – the phenomenon of information- and/or issue-fatigue through the talking-out or confusion arising from interminable analysis of issues. Thus, we begin to see why it might matter that we educate citizens in the value and workings of controversy as a tool for democratic life. Without this, democracy is prone to apathy and atrophy. Understanding, and being engaged with, controversies matters.

Technologies as sites of controversy and as 'controversial propositions'

At the very least, technologies are sites of academic contestation (if not yet fully controversial). Technology as a field of psychological, sociological or philosophical study remains under-explored. Knowledge formulations remain tentative and relationships amongst technologies, people, other species and environments remain under-theorised and under-researched. While deep and significant work has been carried out with regard to technologies per se, (see, eg Winner, 1977; Csikezentmihalyi & Rochberg-Halton. 1981; Bijker et al., 1989; Green & Guinery, 1994; Mitcham 1994; Feenberg, 1999; Dusek, 2006) much has yet to work its way through education and the media into the public psyche.

So long as the phenomenon of Technology (big 'T') and the actualities of multiple technologies (little 't') remain in the uncritical shadows then they also remain under-exploited as sites of controversy. Sclove's (1995) 'living with the sleeping elephant' analogy is realistic so far as public engagements with Technology or technologies are concerned and, while we might slumber on along some *seemingly* deterministic path, when our awakenings happen they do so as controversies.

This is not to imply that we can avoid controversies by designing technologies using the 'right' intentions. Ihde (2006) demonstrates the phenomenon of the 'designer fallacy' (the idea that designerly intentions in any way guarantee outcomes). Elsewhere (Keirl, 2009) has suggested that technologies, rather than being understood as entities, can be considered as having five co-dependent phases to their being, namely: *Intention, Design, Realisation, Use,* and *Consequences*. In such a portrayal, matters of ethical decision-making, values clashes and, thus, controversy are lurking at every phase - they are not solely presentations of the last phase.

Thus, the commonly held orthodoxy that technologies are *neutral* is seen as a fragile orthodoxy now disavowed from many perspectives. Winner's (1977) 'reverse adaptation'; Schumacher's (1986) 'Small is Beautiful'; Mitcham's (1994) 'four manifestations'; Sclove's (1995) 'elite Luddism'; Nixon's (1996) 'function creep'; Tenner's (1997) 'unintended consequences'; Eisen's (1999) 'suppressed inventions' are a sample of the problematics of technologies that harbour controversies. In turn, such focussed conceptualisations feed meta-analyses of how technologies (in the collective sense) can be deemed 'autonomous' (Winner, 1977); 'polyvalent' (Sclove, 1995); or, 'multistable' (Ihde, 2002).

All these studies and analyses offer openings for seeing technologies as sites of controversy and, given the under-exploration of the controversies (covert and overt) that technologies embody, it is argued that all technologies might be seen as (no more than) *controversial propositions* brought into being with uncertainty of outcome - be it environmental, social, legal, ethical, political or whatever. There are surely educational implications here.

Democracy, education and curriculum as (controversial) technologies

As human-designed entities intended (sic) to address some purpose and achieve certain (sic) ends, democracy, education and curriculum can readily be seen as technologies. (They certainly all qualify as controversial propositions). If democracy is the ideal condition of an ethically defended co-existence, then education is its instrument and, in turn, curriculum is education's instrument. As White (1973) cogently argued, education is a necessity of the wellbeing of both democracy and its citizenry: 'There is at least *one* policy which *must* be in the public interest in a democracy. This (policy) is an appropriate education for a democracy.' (White, 1973:237 original emphases). Put otherwise, education is needed *about* democracy (what it is), *in* democracy (how to practice it), and *for* democracy (how to maintain it).

In line with this, it is argued that if democracy itself is controversial and embraces controversies for its very health and existence, then so should the related education ('Education system' is eschewed here) and, in turn, so should the related curriculum. However, while there are plenty of controversies *around* matters of education and curriculum, that is not the same as an *education in* controversy.

An expansive view of curriculum

In such a view, 'curriculum' is recognised as a site of political contestation. Reid and Johnson (1999) reject notions of curriculum as a 'thing or artefact' and adopt their particular 'rhetorical structures' around the notion of curriculum as '...socio-political discursive practice...something that is being made through such varied processes as debate, struggle, dissent, agreement, experience, success and failure.' (Reid & Johnson, 1999:ix). These authors draw on the work of Pinar et al., (1995) whose research sought to include the 'null' or unstudied curriculum and '...the "hidden curriculum" consisting of the "ideological and subliminal messages presented within the curriculum"' (Reid & Johnson, 1999:ix).

The same source (Pinar et al., 1995) articulates Pinar's potent construct of 'curriculum as complicated conversation' (rather than as some quantifiable entity readily deliverable and capable of measurement and surveillance by non-educators). Curriculum critiques such as these articulate the expansive view of curriculum, help challenge taken-for-granted assumptions about schooling, and destabilise 'givens' such as 'subjects' which are often confusions of traditions, privileged knowledge and political footballing.

Ideology and the curriculum

Much curriculum contestation has links to issues of globalisation. The obvious example is that of 'testing the basics' and the creation of league tables first within countries and, subsequently, internationally around 'literacy' (however construed) and 'numeracy' (however construed). National language, Maths and Science are now the official tail that wags many a curriculum dog. Such a competitive ideological agenda (see Apple, 1979; 2001) shaped by the capitalist club (the Organisation for Economic Cooperation and Development [OECD]) offers no guarantee of curriculum harmony.

Three curriculum 'wars' are readily identifiable and each is ideologically fought. First, the literacy wars (Snyder, 2008) pitch critical literacy theorists against those whose traditional approaches seek to maintain a status quo of literacy basics for the masses alongside a rich, elitist literacy reserved for the few. Second, the science wars engage epistemological differences – the positivist traditions versus postmodern and feminist challenges to the 'scientific method' and claims to 'objectivity' and 'truth'. Third, the history wars witness oppositions over the aims and methods of history education in schools. Nationalism is often a core driver where a particular (group's) view is privileged over that of another. Sensitivities also surround historical method and questions of interpretation of findings.

Controversy and critical pedagogies of process

It follows from what has been said that, if curriculum is highly contested then the associated pedagogies might be too. So far as an education in controversy (in the democratic sense) is concerned, the associated pedagogy is unlikely to be one in facts, figures or any other perceived 'truths'. The question is a classic educational one around the relationship between content and process, what emphasis to give each, and what actually counts as knowledge and learning. When Stradling et al. (1985) were writing, they devoted specific chapters to teaching about: Northern Ireland; teaching for (sic) unemployment; sexism in the curriculum; Third World issues; and, nuclear weapons. They could have seen these as 'topics' for study but, as they show, whatever might be meant by 'topic' or 'study' would not be enough. *Process* matters because these are controversial *issues* and, as they say, 'It is this kind of issue, arising out of a conflict of values, which confronts the teacher with the most fundamental pedagogic problems.' (Stradling et al., 1985:2).

To take a process-based approach is, drawing on Stradling et al. (1995:3-5), a means to an end. It is to develop academic and study skills; it provides *context* for practising life skills of communicating, empathy, understanding, influencing others, cooperation, activism and so on; and it uses case study experiences for 'comprehending theories, concepts, and generalisations'. All such ingredients contribute to the democratic end of an education in controversy yet, laudable as such an end may be, it does not sit well with today's politically driven assessment regimes.

Stradling et al. (1985) offer three central concepts to the pedagogy of teaching controversial issues: balance, neutrality and commitment. (These are not explored here as they warrant debate when, for technologies per se, 'balance' and 'neutrality' are potential mirages.) In recognizing the political nature of education such a pedagogy embraces continuous value-challenging and contestation through critical pedagogies of process which help counter indoctrination, passive enculturation, uncritical socialisation and, the concern of this paper, the blind or somnambulant (Sclove, 1995) adoption of technologies.

Technology Education as a site of, and for, controversies

Having argued that technologies, democracy, education and curriculum are all sites of controversy, how does their confluence manifest itself in Technology Education? The following are some examples of sources of controversy - actual or potential – in the field:

- Just as Technology per se is philosophically controversial and emergent, so too is technology education
- Technology Education engages multiple, competing epistemologies. The pursuit of a 'body of knowledge' for the field is arguably also a mirage.
- Technology Education finds itself in a fluid condition unable to ground itself amongst multiple binaries such as arts-science, utopia-dystopia, subject-object, skills-design, vocational-liberal, academic-practical). (Keirl, 2010),
- Technology Education is a site contested by multiple and, at times, ideologically incompatible, *stakeholder interests* – differing political-economic formulations, professional interest groups, the green agenda, feminist interests, democracy defenders, liberal educators, civil libertarians, and so on (after Layton, 1994a).
- Technology education is ever-vulnerable to being uncritical in its relationship with emergent technologies. Controversy exists when what is done in the name of education is merely socialisation towards technologies or training in their use.
- There are multiple ways that Technology curriculum can be designed and managed (see, eg de Vries, 1994:32).
- Local Technology Education can be shaped by a particular technological focus (eg materials, processes, systems or concepts) whilst ignoring other possibilities.
- There is an ever-playing tension between D&T as a (specialist) subject and its role as a part of the general education of all children, thus...
- ...interpretations of technological literacy and technacy are not consonant (see eg ITEA, 2000; Petrina, 2000; Seemann 2003; Dakers, 2006; Keirl, 2006)
- Implicitly from the above, a rich spectrum of pedagogical genres is available to and used by technology educators. The take-up of some pedagogies varies according to the

personal-professional values held by individual teachers.

- Finally, any design-based pedagogy or process is, itself, a site of controversies – of competing variables and solutions that are ever-provisional, never simply 'right or wrong'.

Technology Education as controversy celebrated in the cause of democratic education

Despite systemic, curricular and governmental pressures toward conformity, there is much to be gained by embracing and exploiting the controversies that inhabit Technology Education. It has been argued: that controversy and its maintenance is key to healthy democracy; that another key to a healthy democracy is a democratic education; and, that Technology Education is a site rich in controversies where (democratic) education *in, about and for* democracy, controversy *and* technologies themselves can be carried out simultaneously.

It would seem that Technology Education can celebrate controversy in four broad ways. First, pedagogically by being design focussed, process-centred (see eg DETE, 2001), and nurturing critical dispositions in teachers and learners alike.

Second, through curriculum policy, as player in the compulsory education of *all* students for democratic global citizenry as well as being a field of practice offering focussed pursuits to particular cohorts of students.

Third, professionally through strong engagements with research, development of theory, and policy formulation. Thus Technology Educators are constructed as richly multi-faceted, for example, as leader-learner (Lingard et al., 2003); ethical (Campbell, 2003); activist (Sachs, 2003); reflective (Schon, 1987; Killen, 2006); and, socially critical (Smyth et al., 2000).

Fourth, by practising, advocating and defending a technological literacy which honours all of the above whilst also articulating Technology Education per se as a *required controversy* playing a key role in a democratic education for democratic life.

All of these ways of celebrating controversy themselves contain multiple embedded controversies. This is intentional and necessary. To do otherwise would be to nullify the paper's thesis. Besides, it should be clear that any perceptible alternative to 'controversy' - for example the idea that consensus or agreement over any aspect is attainable – is anathema to the paper's spirit. This is not a matter of choosing between pessimism and optimism – another binary within which technology plays. If the language of the military metaphor is preferred, then the paper can be seen as a clear contribution to the 'technology wars'. If vanilla is the preference, then the paper is offered as a part of Technology Education's much needed complicated conversation.

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Theory and Practice in Technical Vocational Education: Pupils', Teachers' and Supervisors' Experiences

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Key-words: Experiences, Phenomenology of the Life World, Technical Vocational Education, Theory and Practice Relationship, Qualitative Interviews

Abstract

A gap emphasised in technical vocational education is the theory-practice divide. In relation to learning in technology and learning a vocation, the concepts of theory and practice are often mentioned and how to handle them in education is discussed and problematised. This paper is an empirical contribution to the discussion about theory and practice in technical vocational education. This study takes its point of departure from the pluralistic phenomenology of the life world and the research questions concern pupils', teachers' and supervisors' experiences of theory and practice in relation to teaching and learning in technical vocational education. Pupils', teachers' and supervisors' narratives from qualitative interviews have been analysed thematically, focusing on the content concerning theory and practice. The result indicates there are experiences of theory and practice concerning a traditional dualistic view, but there are also experiences concerning a more interwoven view. The concepts can be handled in a more interwoven way if the individual has a deeper, more complex underdstanding of them.

Introduction

In relation to learning in technology and learning a vocation, the concepts of theory and practice are often mentioned and methods of handling them in education are discussed and problematised (e.g. Bengtsson, 1995; Bjurulf & Kilbrink, 2008). The concepts can be handled on different levels and are often used concretely, meaning: school versus workplace, reading versus doing, or language and thinking versus physical work (Berglund, 2009). This dualistic and dichotomised divide between theory and practice is criticised by many researchers (e g Allan, 2007; Bengtsson, 1995; Berglund, 2009; Goodson, 1996). Furthermore, different suggestions on methods for how to bridge the gap between theory and practice in learning technology have been suggested in different studies (Allan, 2007; Tempelman & Pilot, 2010). There are also arguments for handling theory and practice as interwoven, in order to learn wholeness (compare e.g. Bjurulf & Kilbrink, 2008). One way to handle theory and practice as part of wholeness is to use the concepts of theory for *knowledge about* and practice for *knowledge in*. This has previously been done in studies about teacher education (e.g. Bengtsson, 1995). Similarly, theory has been used for *knowing that*, and practice has been used for *knowing how*. This discussion often refers back to Aristotle (Gustavsson, 2002). Nevertheless, the concepts theory and practice often appear in the context of learning technology and learning a concrete vocation. Therefore, there is a need for empirical studies on how these concepts are actually handled, and how this relates to the theoretical discussions about theory and practice.

Aim and Research Questions

This paper is an empirical contribution to the discussion about theory and practice in technical vocational education. The aim is to reveal how theory and practice are experienced by people being in a technical vocational education, with the point of departure in the following research questions:

> *How do pupils, teachers and supervisors experience theory and practice in relation to teaching and learning in a technical vocational education?*
>
> *How do the concepts of theory and practice differ and relate in pupils', teachers' and supervisors' narratives?*

Hence, this study is not aiming to find generally applicable definitions of the concepts, but to describe how theory and practice appear in the informants' narratives about technical vocational education and how the concepts are related.

Theory and Method

Theory and method in this study refer to the phenomenology of the life-world and narrative tradition. According to this phenomenology, there is only one world, but we experience it differently according to perspectives, positions and previous experiences (Bengtsson, 2005). Therefore, the lived and experienced world is the focus of the research. Consequently, meeting with the people involved with the part of the life world we want to study is necessary, in order to say something about phenomenon in the life world. In this study, semi-structured group interviews, as well as individual interviews (Kvale, Brinkmann, & Torhell, 2009) serve as the empirical basis for the results. The informants' narratives from the interviews have been analysed thematically (Polkinghorne, 1995), focusing on the content concerning theory and practice.

Informants

The informants in this study all participate in the *LISA*-project (*Learning in Several Arenas*), where pupils, teachers, and supervisors at companies in vocational education are followed for a period of three years. They are all involved with teaching and learning in the Energy and Industry programmes at Swedish upper secondary school, in a vocational school system, where half the time is spent in education at school and half the time in workplace training. The empirical material for this paper is based on sections of interviews with two teachers, four supervisors and two pupils, where experiences of theory and practice are brought into focus.

Results

In the presentation of the results, the informants' narratives about theory and practice are synthesised into common narratives. Quotations from the interviews are interwoven in the description of the themes below, in order to keep the presentation close to the empirical material and to raise the informants' voices. These quotations are marked with quotation marks. The themes have emerged from the data and aims to reveal the informants experiences, as they are expressed in their narratives about theory and practice. The themes were not predefined, and the result does not claim to answer what really happens in the vocational education, but to present told experiences of people being in vocational education.

Practice as it Differs from Theory

Practice as using the body and different senses
In the study, there are many examples of experiences of practice as using the body and different senses. It can be about watching, touching and seizing. By working practically, you are able to get a feeling for how to do, "that, you cannot get from a theory book", supervisor Ernst says. Furthermore, practice is often related to working with the hands. Student Emanuel tells that practice for him is to work "with the hands" and supervisor Ingemar says that practice is "what they do with the hands, starting the machines".

Practice as something physically heavy
Some of the informants talk about practice as something that is physically heavy. This is a theme that foremost has emerged in the narratives from the supervisors at the energy programme, those who work as plumbers. Supervisor Ernst tells that it is important to be strong when working practically. He contrasts this practical work to a theoretical person, "who will fail" and says that is not possible to carry a heavy furnace down a stair "if you don't have a body for it".

Practice as using what you have learned
One theme is about practice as using what you have learned; to apply what you have learned theoretically on something. Student Isak tells that "theory, that's what you learn for work, what you do at school is theory, I suppose, what you learn and read. And practice is when you use the theory". Supervisor Ingvar says, in relation to theory and practice, that it is not obvious that you know something, just because you have read about it; "but if I have done it a couple of times, then at least I know better".

Practice as the workplace training
In Swedish vocational school, the word practice can be used as a common word for the workplace training. Student Isak says that he is not allowed to weld at the workplace "practice", but at school. He tells that he has been welding at school, but "on the workplace practice I don't do that" and "here at school in the beginning, we had a lot of theory, and then I was able to weld a lot". Accordingly, the place, and not the action, is related to practice in this theme. Teacher Erik tells that the pupils "can go out to workplace practice directly, without knowing anything, but at the same time it is good to have some knowledge before".

Theory as it Differs from Practice

Theory as a starting point for practice
This theme pertains to experiencing theory as something you have to read, or understand, before you are able to perform actions in a certain way. How much theoretical knowledge you have gained also influences how you learn. Supervisor Ingemar tells that theory "goes more in depth" and that depending on how much theory the students have studied before they go to practice, they learn differently. Student Emanuel tells that theory is about preparing and that theory takes time. Furthermore, he tells that you prepare at school, before going to the workplace, and that "theory, yes it is, just sitting at school reading about heating and sanitation".

Theory as experiencing
One theme concerning theory is that theory has to be experienced. When some things are studied at school, "it gets a bit abstract for them [the students] at the beginning, they need to get out to see and to hear the differences" says teacher Ivan. Supervisor Ingemar agrees that "it must be expe-

rienced" in order to be memorable, if the students just study something "in theory" and "are not able to use it quickly enough" they will forget it. Furthermore, theory is also about talking, showing and explaining to the students. Teacher Erik tells there is theory in the workshop hall in the school, because he "always talks to them [the students]" and tells the students "look; now I do like this". Student Emanuel tells that if there is time, they also have theory at the workplace, because he "asks a lot" and that theory is about "things we point at, and talk about".

Theory as non-perspiring work
There are no obvious definitions of theory and practice. At first, teacher Erik says that it is really easy to define the concepts, but then he changes his mind and says that it can be complicated. For him it is not a matter of course to separate them in his teaching, but still he tries to define theory as "when you don't get sweaty". Supervisor Ernst tells that some pupils do not handle the physical work properly and that those pupils "probably are better suited for theory".

Theory as knowledge about something
A common theme in the narratives is theory as knowledge about something, that you understand something, or that you learn something new. Student Isak tells that theory at the workplace concerns learning something new; "they have a lot of courses here [at the workplace] sometimes too, then all are gathered together and learn something new, and if it is new, then it is a bit of theory, I suppose." Furthermore, supervisor Ingemar tells that there is some theory at the workplace, even if he thinks that theory mostly is connected to school. At the workplace "we read drawings, following the whole process when you receive a product, that's things you do." Teacher Ivan tells that theory exists foremost in books, "or in my mouth". If something happens, if there is a problem, an alarm for example, the students have to know what to do, and this knowledge is in the books.

Theory and Practice as Parts of Wholeness

Theory and practice in different arenas
The division of theory and practice often refers to what is done in the different arenas, i.e. school and workplace, where the theory is connected to school and practice to the workplace. Supervisor Ingvar says that "at school, there is more theory" and at our workplace it is "just practice". Supervisor Ingemar tells that "many times, theory is what you do first". The theory is the fundamental thing, and that is what "you learn in the first semesters at school." Also, the teacher Ivan says that the students "get the basics at school." Furthermore, this basic education the students need in order to "develop further at their workplace learning" Ivan continues.

Theory and practice as a whole
In order to understand wholeness, both theory and practice are needed. Student Emanuel tells that "at school, we can use paper and try to check the drawings and how it should be done, but firstly, when you are out here [at the workplace], you can understand how it works." Supervisor Ingemar tells that financial reasons can be an obstacle for conducting the education as you wish. Often theory and practice are alternated in the vocational education in this study, and Ingemar tells that "we would like to have a machine" for practicing programming at the company, but "unfortunately it is not possible in reality" and then "we have to do the practice and theory in relation to that we run [the machine] with a product that we will have to get paid for". Furthermore, specific learning content can be introduced from different angles. Either you can start in theory, or you can start in practice. Teacher Erik tells that "if you are supposed to explain something difficult to the students, then you can either start with theory, or you do the opposite way, you start with the practical part. Nevertheless, it is good to have two entry keys".

Discussion

In this study, theory is often related to school, to think and read and to prepare for workplace training. Furthermore, practice is related to the workplace, to physical work, to use the body and the hands, and it is also related to using what you have learned. However, it is also more complicated. When deepening the discussion, it is not obvious how to divide or define the concepts of theory and practice. Hence, there are two levels of experiencing theory and practice in this study. In the first dimension, it corresponds to the dualistic division presented in earlier studies (compare e.g. Berglund, 2009), but in another dimension, when there is a deeper discussion about the concepts, they become more interwoven in the informants' narratives.

Some of the themes emerging in the narratives correspond to the dualistic division of theory and practice, where for example the learning arenas serve as the basis for the difference between the concepts, as in *Theory and practice on different arenas*. Furthermore, theory is experienced as the preparation part of the education in the themes *Theory as knowledge about something* and *Theory as a starting point for practice,* whereas the practice is experienced as the application or use of the theory in the theme *Practice as using what you have learned*. Moreover, there is a division on the individual level, concerning which parts of the body are used for the different concepts, where *Practice as using the body and different senses* and *Practice as something physically heavy* refers to using the whole body in a way that is not visible in the theme of *Theory as non perspiring work*. In the results it seems to be important, according to the narratives, to define this division at the beginning of the students' learning, where the basic knowledge and preparing part is related to school and described as a prerequisite for further education and work for the students. However, the further into the education and the deeper the knowledge that the discussion concerns, the more interwoven the concepts of theory and practice appear. Hence, there are themes where the concepts of theory and practice are experienced as more complicated. A more holistic view of the concepts theory and practice can be seen in the themes *Theory as experiencing* and *Theory and practice as a whole*. The informants present more nuanced experiences, when the discussions about the themes are deepened. For example, theory and practice can be seen as different "entry keys" to learning, and there is theory at the workplace and practice at school. Some experiences also refer to the students sometimes having better possibilities to participate and try different tasks that are experienced as practical at school, rather than at the workplace training. This indicates that time consuming tasks that the learner needs to have practical experiences in to facilitate learning are not always better learned at the workplace. Although authentic learning at the workplace is argued for in other studies (e.g. Billett, 1994), the result from this study indicates that the education needs to be complemented with conformal educational settings, including aspects of the education that are commonly experienced as practical.

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Primary pupils' thoughts about systems. An exploratory study

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Keywords: primary pupils, systems thinking, qualitative study, main- and subparts, input and output, system boundaries

This paper presents a study into systems thinking among 27 primary school pupils, 8-to10-year-olds, and their teacher. The study includes, pre-test to the teacher and a group of pupils, lesson planning, the actual lesson and post-test to the pupils. The focus is on three concepts: do the pupils see a system as a structure consisting from main- and subparts, what are the inputs and output that they reason to be important for a system, and can they put boundaries to a system. Analysis revealed that the pupils showed some indications of machines consisting from parts with different functions, or that a sequence of steps is needed to complete a process. Systems, however, are mainly described in terms of what the user can experience, instead of what the machine itself does. The concept of input was more obvious to the pupils than the output. The impression of what a systems does, and what a user does, seemed to overlap, and this made setting the boundaries to a system more demanding. Nevertheless, by including basic principles of systems thinking, the teacher was able to introduce alternatives to approach the problems. Even though, the systems thinking was rather limited in larger sense, the pupils were able to reach beyond fair descriptions, and they used new practices to explain and label artefacts.

Introduction

Systems are an important concept in contemporary technology. Thinking in systems helps to understand that incidents are not isolated and independent but a part of bigger patterns (O'Connor & McDermott, 1997). Systems thinking provides universal models that can be used in, and transferred to different disciplines (Von Bertalanffy, 1979; Barak & Williams, 2007). Furthermore, without knowledge of systems thinking individuals tend to describe situations with surface features (Booth Sweeney & Sterman, 2007).

For school's design classes systems thinking could offer a broader way to use knowledge. Development of technological systems offers pupils opportunities to understand, practice, influence and engage with technology (Svensson, Zetterqvist, & Ingerman, 2012). If we want to present an up-to-date image of what technology is, then the systems concept needs to be in it as well.

This paper introduces a qualitative study into systems thinking of primary school pupils. The focus is on the basic building blocks of systems thinking. It is examined whether bringing systems thinking into design class brings new ideas and ways to approach design and technology problems.

Study into systems thinking

Literature has few answers to what are the children's pre-concepts in systems thinking in the field of technology. Booth Sweeney and Sterman (2007) discovered that both students and teachers in middle schools have limited intuitive systems thinking abilities. One-way casual thinking is characteristic to them and explanations miss a reference to time (Booth Sweeney & Sterman, 2007). However, studies have also shown promising results in re-changing the thinking of students back to the systems type of thinking (Kali, Orion & Eylon, 2003; Assaraf and Orion, 2004).

For what is meant by systems thinking, literature has many definitions to offer, although similar to each other. Booth Sweeney and Sterman (2007) define systems thinking as a group of three abilities; understanding the parts of a system, the connections among these parts, and seeing a system as a whole. O'Connor and McDermott (1997) have similar definition except they add one more ability; understanding the parts by studying the whole. Another definition of systems thinking divides the concept into seven different types of thinking skills; dynamic, closed-loop, generic, structural, operational, continuum, and scientific thinking (Richmond, 1993). In an online source Ossimitz (1997) lists four skills that are important to think in systems way: thinking in models, interrelated thinking, dynamic thinking, and steering systems.

Lack of system dynamics skills is a result of teachers' inability to apply systems thinking in their teaching (Arndt, 2006). A key to improve skills in systems thinking is to expand these boundaries and increase the amount of factors and resources considered (Sterman, 2002). Systems thinking offers tools and processes to overcome our thinking boundaries and helps in expanding them (Sterman, 2002). Arndt (2006) also describes good learning environments, which integrate learning activities into larger concepts, and tasks to authentic, realistic contexts and refer them to matters relevant to students.

This study uses the definition of systems thinking by Booth Sweeney and Sterman (2002). However, the definition is too abstract to be used in primary school, and therefore, for the framework more practical approach is chosen. For the method of the study, teacher's knowledge level on systems was investigated to increase her confidence and abilities to use it in the classroom (Arndt, 2006). And hopefully, including systems thinking into the design class, the factors considered are increased, and more resources are evaluated (Sterman, 2002) during the design process.

Participants and method

This paper presents a study into systems thinking among 27 pupils (six of them, four girls and two boys, participated on the pre-test), 8-to10-year-olds, and their teacher. The study was conducted during winter months in 2011-2012 in a Dutch primary school as a part of a technology class. Both the pupils and the teacher have prior experience in designing.

The study was designed in a similar manner suggested by Tiberghien (1997), where data is gathered in two phases. First, an idea of what the learnable part of knowledge is needs to be acquired. This is done by analysing students' prior knowledge and the knowledge that will be taught at the lesson. In the second part the different aspects of teaching situation are analysed by focusing on the teaching session and the student progress during that session. (Tiberghien, 1997)

Hence, this study (Figure 1) started by designing and implementing a pre-test for the teacher to investigate the already existing thoughts and conceptions about systems before any introduction to the topic was given. This was tested by asking the teacher to explain three scenarios and one abstract definition about systems. Based on the given answers, a session to explain systems thinking took place. After this session the teachers was assisted to design a lesson for the classroom. The actual data was collected during a 70-minutes lesson, where pupils were encouraged to use all their senses to collect information about a washing machine and furthermore, to write down what goes in, what happens in between and what comes out in the end. Two weeks later, the pupils were given an assignment to draw and explain how a bread maker works, in a same manner as the washing machine earlier. Both pre-test and classroom activities were videotaped.

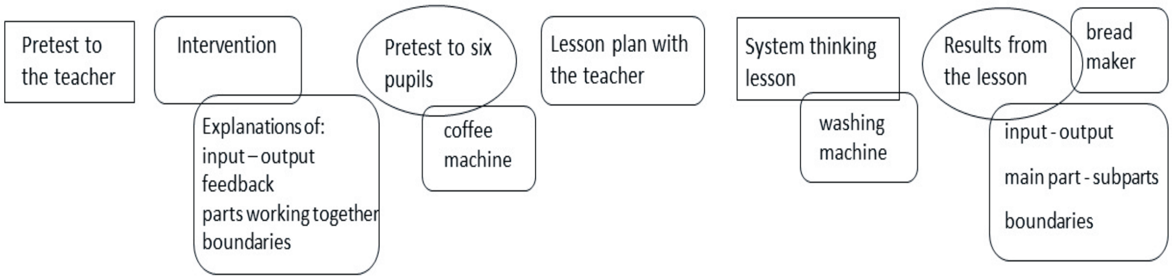


Figure 1. Design of the study

Research framework

Current perception of systems is moving towards socio-technical viewpoint. Systems are seen as multiple purposeful actors and material artefacts interacting in a way that it is impossible to separate them and analyse only parts of the whole (Bauer & Herder, 2009). In this view technical factors are considered less important and the emphasis is on the influence of social actors on technological developments (De Vries, 2005). Although social aspect of systems is relevant this study concentrates on the engineering side of systems, and systems thinking supporting technological designs.

The framework (Figure 2) focuses on practical concepts and is, therefore, built on notions about systems themselves. De Vries (2005) defines a system as a set of parts working together. O'Connor and McDermott (1997), as well as Booth Sweeney (2011), compare a system and a heap, and one of the crucial differences they draw attention to is how in a system parts are connected and they work together, unlike in a heap they do not. Together with the definition by De Vries and this dichotomy, a notion of a main part and subparts, and these parts working together is formed (this also appears in the concepts of systems thinking). The idea is to see whether pupils have a tendency towards black-box type of thinking about machines or do they recognize a connected structure inside of a cover of a machine.

The second notion is systems having an input and an output. Here, De Vries (2005) refers to German literature, in which inputs and outputs are defined as a set of three components: matter, energy and information. This categorization is used to investigate do the pupils have an idea about inputs and outputs, and what they consider them to be.

The third notion is the boundaries of a system. O'Connor and McDermott (1997) write about understanding and limiting the complexity of a system by defining clear boundaries to it. Here, the definition is used to reveal information to what extent the pupils understand what is meant by a system. Knowledge of the system boundaries is used to indicate the understanding of the complexity of a system.

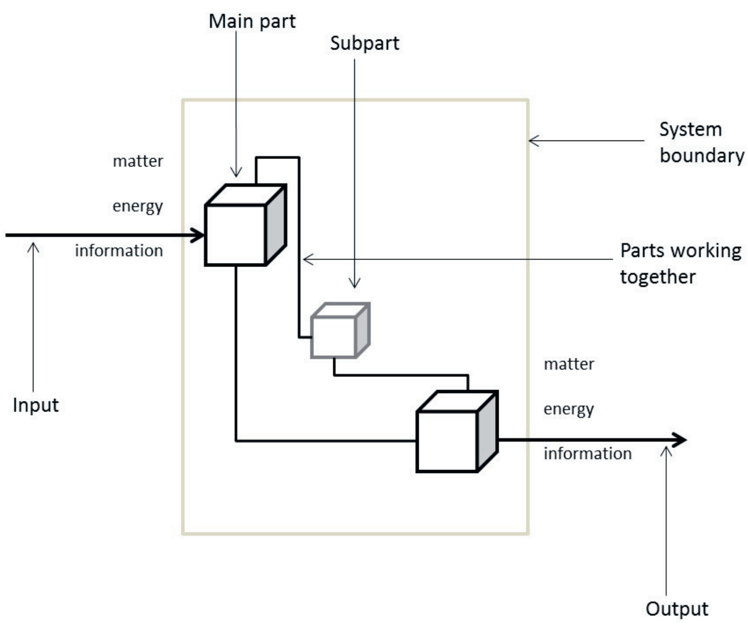


Figure 2. Research framework and its components

Analysis

Here, the results of the pre-test, lesson, and post-test are presented. The pre-test questions, for both the teacher and later on to her pupils, were concerned about how a coffee machine works. In the lesson, the pupils investigated elements of a washing machine, and a process of doing a wash. The post-test was about implementing the ideas evoked during the lesson to another machine, namely a bread maker.

In this analysis, the answers of the pupils are at the centre of the scope, and the teacher is used as an explaining factor. E.g., in the feedback session, after the pre-test of the teacher, most of her questions were about input and output. This influenced on how the teacher started to view systems, and also how she asked and directed the questions during the lesson. This is taken into account when viewing the answers.

Pre-test

The pre-test sessions started with pupils making cups of coffee in the teachers' room (Picture 1).

Picture 1. Left: pupils making coffee. Right: answering to the questions about the same machine

Figure 3 presents a part of a discussion about what is needed, and what does the machine do in order to make a cup of coffee.

....
Teacher (T): What more is needed?
Boy (B): Hot water, I think.
T: Did you see it where the water came from?
B: Hmm... (the boy hesitates)
Girl (G): Through a cord.
T: What more is needed? What happens first?
B: I heard that it first waits a bit...hmmm...Yes, then I think there is some preparations...
T: What are these preparations?
B: Hmmm, that the beans are grinded.
...
T: But, feel the cup. It is warm. Why do you think that is?
B: Because there is boiled water.
T: I don't know if there comes boiled water out of the faucet...?
B: No.
G: I think the coffee stays warm because of the cup.
T: But it is outside of the machine. Is the cup warmed first?
G: No.
T: No, but still it is warm...? I think it is because the water is warm, but where is the water made warm?
B: What I think is that this machine is like a thermos can. The water comes there through cord and then the water stays there warm and then it comes out warm.

Figure 3. Discussion between the teacher and two pupils, a boy and a girl

In this extract, an input (matter: water) and an output (energy: warmth) can be observed. The boy realised the need for water by himself, however, the output was introduced by the teacher. Similar to Arndt (2006) the pre-test showed that one type of input is acknowledged, and this satisfied the pupils. Here, the teacher knew about the other types of inputs and outputs, and therefore, she tried to trigger the pupils to think about them as well.

Furthermore, the reason why coffee is/stays warm was approached inverse by the girl. She was not concerned about how the machine makes warm coffee, but how to keep its temperature. However, what this conversation prompted was that the boy started to think about the steps, which the coffee machine needs to go thought. He said that the coffee machine resamples a thermos can, and that keeps the water warm. Hence, in the machine, there is a part that controlling the temperature of water.

Additionally, all the pupils included grinding the coffee beans into the process. In here, the boy thought of it as part of the preparations. Yet, it stayed unclear whether it is a task of the machine or the user.

In the next sample (Figure 4), the two girls considered more inputs needed for the coffee machine to function. They listed all three types of inputs: warm water (matter), electricity (energy) and pressing the button (information). The only output mentioned is the coffee coming out. These girls, like the pair in the previous sample, recognized that something needs to come from outside of the machine in order for it to function.

...
T: What do you need to make coffee?
G1: Warm water, flow through the coffee powder...
T: What do you mean with the flow?
G2: For the plug (electricity) .
T: And for what is the electricity needed?
G2: To warm up the water.
G1: For it to function, if you press the button, something is going to happen.
....
T: What steps will the machine do?
G2: Make it warm, then it is going to open a small tube.
G1: The coffee is going through something so that there won't be any pieces in the coffee.
G2: And then opens a little valve.
G1: And you have to take care that there is a cup underneath.
G2: And then it (coffee) *comes out.*

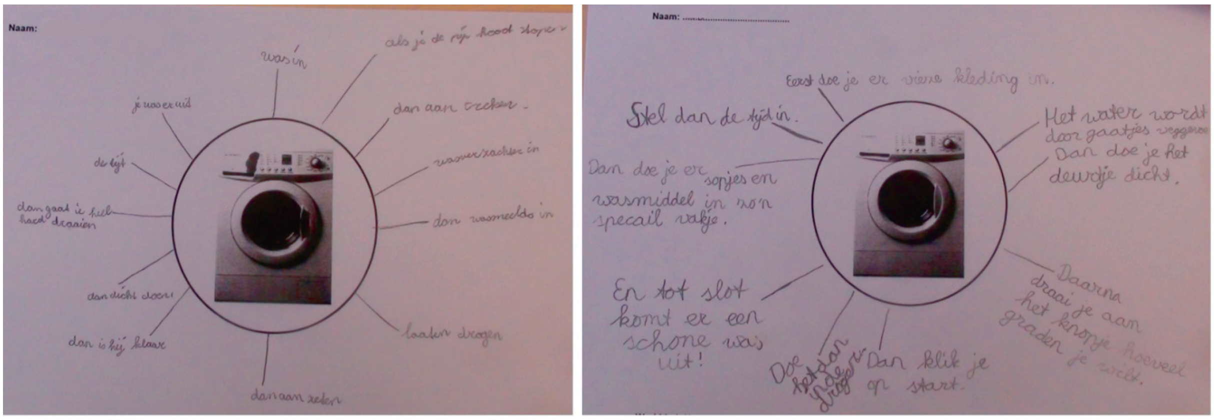
Figure 4. Discussion between the teacher and two girls

In the second part the girls are invited to think about the process as sequence of steps. They describe a linear process, with no feedbacks. Nevertheless, different phases and parts doing something together appears in the description.

During the lesson

In the beginning of the lesson, pupils received a closed envelop, which they could not open. They could only smell through the holes what was in it. The pupils were asked to write down what they smelled, and for what it is used for (envelop contained washing powder). After this, the pupils were invited to talk in groups of four about what they had smelled, and to write down a group answer. After these discussions, the pupils told their answer to the whole class, and the teacher revealed the correct answer. The warm-up session was followed by a short "history" of washing machines, and how our grandmothers did laundry. This part triggered pupils to discuss several topic regarding doing laundry, such as "*What does a centrifuge do?*" Afterwards, the whole class participated on a brainstorming session on how a washing machine works. Here, the pupils were asked to describe what they can hear, see, feel and smell when a washing machine is on. Finally, the pupils wrote down individually what goes in to a washing machine, what does the machine do, and what comes out (what happens in the end).

The answers were mostly about what goes in. Generally, the lists included fabric softener, detergent, clothes, water (matter). However, also electricity (energy), time and pressing buttons (information) were mentioned (Picture 2).



Picture 2. Example answers about washing machine

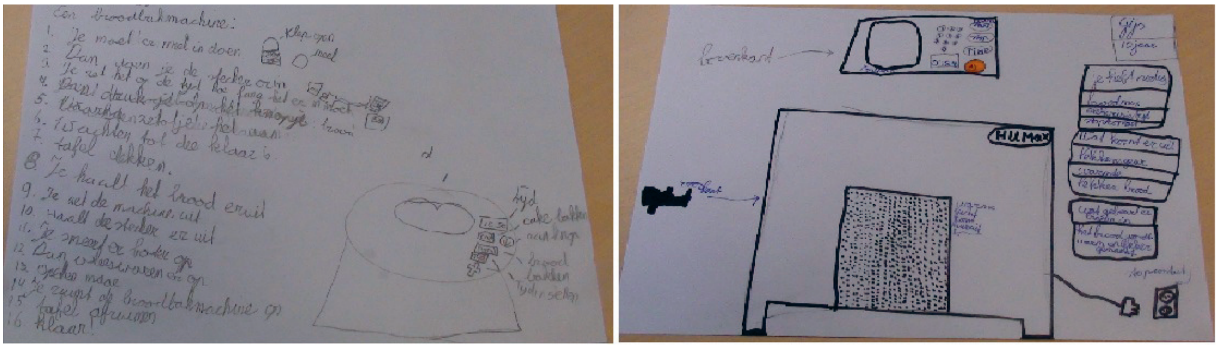
To the question what does the machine do, the pupils did not describe the different phases a washing machine undergoes, but they commonly observed it from their point of view: "*It turns around very hard*", "*Wait*", "*You feel shaking*", "*It turns hard so that the water goes out from the clothes*", "*Noise*", "*The wash turns a lot, water mixes with detergent*", and "*Moving*". Answers such as 'moving' and 'noise' are influenced by the assignment from the beginning of the lesson, where the pupils needed to imagine what they can sense when a washing machine is on.

Answers also included straight forward lists of steps to do: "*detergent, door open, wash in, door close, how many degrees, put it on, turns, waiting, ready, door open, wash out, door close, put it off, put it in the dryer, put it on, waiting, ready, wash out, put it off*". These answers are again from the user's point of view but an interesting addition on the list can be observed. While, the assignment asked about a washing machine, the pupils included steps like: *"Hang them on a line*", "*Let them dry*", "*Put them into the dryer*", and "*Laundry room*". This indicates difficulties in setting boundaries to a system.

Unlike with the inputs, the outputs were about 'end products': "*Clean laundry out*" or "*Wet clothes out*". However, also warmth, as well as an outlet and soap foam were mentioned.

Post-test

In the post-test, the pupils drew and wrote, in a same manner as with the washing machine, how a bread maker works (Picture 3). The answers covered different types of inputs and outputs. Naturally, bread mix or flour were the most popular ones, however, electricity, outlet and buttons were also common replies. Surprisingly many of the pupils replied that a bread maker will not function unless an outlet is plugged in. It could be that a coffee machine is more of a standard kitchen appliance, and therefore, does not need to be plugged in every time used. Unlike a bread maker that is more likely to be stored in a cupboard. Furthermore, because the pupils were invited to draw their bread makers, this may have caused them to sketch buttons as well, and this way they were also part of the inputs.



Picture 3. Example answers about bread maker

For the outputs almost all the pupils mentioned all three types: bread (matter), smell (information) and steam (energy). Also warmth and some sort of sound indication when bread was ready were included. The earlier assignment to use all senses likely helped to include such outputs.

To the question what happens inside the machine, pupils replied about the bread being made inside or that the machine mixes the flour. However, there was no clear indication of specific parts working together. As machines, coffee machine is visibly clearer structured than a washing machine or a bread maker. The pupils could have observed different sub functions that a coffee machine goes through, but in a case of the other two, everything happens behind/under a closed lid. What happens inside of a machine was a challenging question for the teacher as well, and therefore, this aspect of the study did not get the attention it required. Furthermore, few pupils mentioned the whole procedure from pouring the flour into the machine, all the way to eating the bread and cleaning the table. It seems that separating the tasks between a machine and a user is still problematic to some hence, the system boundaries are unclear.

Conclusion

The pre-test and the lesson showed that the concept of input is more obvious to the pupils than the output. After encouragement, the pupils came up with more outputs but often the obvious function of the machine (what it does or produces) was considered, and no further thinking was thought to be necessary. However, in the post-test the inputs were still mostly viewed in a same manner as before; generally they were about the matter but also energy and information were mentioned. The change had happened in the outputs, where all three categories were now included. The pupils were not able to explain relations connecting inputs, processes and outputs, like students Ginns, Norton and McRobbie (2005). But on the other hand, the way post-test asked pupils to draw and write on the drawing, does not invite to act in such a way.

One-way thinking, similar to the findings of Booth Sweeney and Sterman (2007), can be observed from the answers. No clear image of whether the pupils saw machines as something with a main part and subparts working together can be formed. Some indications of a part functioning inside another or sequence of steps can be observed in the pre-test. For this to happen a push from the teacher was needed. Machines were mainly described in terms of what the user can experience, instead of what the machine itself does. The comprehension of what a systems and a user does, seemed to overlap, and this made setting the boundaries to a system more demanding.

A lesson requires a firm idea of a system to be worked with (Boersma, Waarlo & Klaassen, 2011). The difference in how the example machines can be observed influences on how well the pupils can describe its functions. The difficulties in seeing system boundaries and different parts working together force the assignment to be concrete and the topic preferably something already known. Instead of the bread maker –assignment, the pupils were given a task to design a system that helps them (with homework, walking the dog etc.). Eventually, the pupils were not able to think in a way intended, their focus was on what the machine could be about, and what would be a funniest one.

This study is a small sample, but the results show that system thinking can be included to the design class and the thinking boundaries (Sterman, 2002) can be, if not overcome, expanded with a relatively straight forward lesson plan. After explaining the basic principles of systems thinking to the teacher, she was able to show the pupils a different approach to a problem. And instead of settling for a fair description of what the machine does, the pupils used other approaches to explain and label important artefacts.

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Design Mentoring and Designerly Attitudes

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Abstract

This paper explores the activity of mentoring design and make projects, with the intention of giving mentoring practitioners guidance and confidence in the activity, whilst developing designerly attitudes in their pupils. We as a team were frustrated by how little of this was observed in English secondary Design and Technology lessons, yet were aware that in many cases the teachers had on graduation been accomplished designers. It seems that the prevalent school assessment culture and inexperience of teaching the activity of designing was lowering the priority of 'designing' within Design and technology lessons. We set out to find out what University Design tutors did in mentoring and through this to establish a framework that we could use in schools with school pupils and their teachers. Our work was observed and aided by a psychotherapist and counselor who helped us to recognise some of the conscious and unconscious dynamics which exist between teachers and pupils in this setting and which can impede or act as a stimulus to the pupils creative output.

From analysis of a series of interviews we proposed that design mentors seem to have 3 roles

1. To act as teachers and managers of the activity
2. To act as mentors to the pupils, in getting them to define and manage their own learning and progress through the projectwork.
3. To act as an assessor in judging the kind and level of activity that the pupil is capable of.

We recorded and observed 12 pupil and teacher mentoring sessions using digital pens and voice recordings. The teachers then used these records to reflect on what they had said and done with the pupils and using the criteria, commented on the roles they were adopting.

The outcomes of this were that the teachers and observers gained a clearer insight into the roles of the project work tutor, and felt that their confidence in their own ability, which had previously been intuitive, was aided by having a structure on which to base their reflections. .

This was a very preliminary study, aimed at validating the 3 roles. Having done so, the team believes that through pupils being better engaged in design and making pupil autonomy will be better developed.

The next stage will be to use this structure and approach in a wider range of schools, pupils, and educational contexts.

Introduction

There is little dispute that fundamental to designing are the abilities to both deal with a complex and uncertain world and to produce 'answers', that make things 'better'. The accepted and educationally supported strategy to develop this capability is typically by engaging the learners or beginning practitioners in a series of designing activities. These activities are often presented as a series of 'open ended' briefs, with. learning objectives 'embedded' within the context and expectations as defined in the brief.

Designers are educated this way, and it is an accepted practice that through this means (approach?) their attitudes to themselves and their outcomes are 'formed'. Through doing design they become designers (Simon, 1992; Schon, 1987).

In the English school context there is an established argument through the Design and Technology National Curriculum that supports children at all levels being engaged in this activity. This is not because they are going to be professional designers, but because the skills and attitudes that are developed will enable them to be better able to make positive contributions to their own and others' lives. In short it will make them better human beings (Bronowski, 1973).

In the context of school teaching (as opposed to professional training) this means that the person running the activity has to be a teacher, a mentor and an assessor to the learners. Also the learners have to be on one hand managed and the other to be given autonomy to operate in uncertain and complex situations. And yet the teacher will try to ensure that each pupil should be shown a measure of success. Many teachers who do this well, relying highly on intuition and professional experience (Schon, 1983) to guide them, often viewing it as an 'art'. Those approaching it for the first time often find it complex and threatening.

This paper reports preliminary research that sets out to give some clarity to the activity of being a design mentor within the school teacher's role. This was approached by analysing the practice of design tutors on a higher education design programme and then using this analysis as a lens to observe school teachers' practice. The paper highlights the links and differences between professional mentoring and professional training for designers and explores the dilemmas between the complex attitudes and subsequent roles that teachers need to adopt, in order to do this successfully.

One of the fundamental yet most difficult areas of research in Technology Education is the desire to understand the act of designing and therefore be able to teach people to do it better. Attempts at an increased understanding have been influenced by both the means with which the evidence has been collected and analysed and the purpose of the outcomes: i.e. what you see, or choose to see; how you record it; and what you do with it. These aspects are intertwined, as was illustrated by the major study into Design and Technology capability (Kimbell et al., 1991) which at it's base set out to 'assess' capability. Before the research could start to assess, they had to define what they were looking at and then arrive at a 'rubric' for assessing design and technological capability.

An analysis of Leonardo da Vinci's sketchbooks, for example, can easily be interpreted as the work of a designer, but our ability to learn from the work is limited by our inability to contextualise the work. The work of the 'design methods' practitioners like Jones (1970), went some way to assembling a 'toolkit' of 'what designers did' with attempts to contextualise the activities beyond a formulaic and universal 'process'. Cross, Christiaans and Doorst (1996) took the 'same' design activity and recorded it on video and then asked eminent theorists to produce a range of 'interpretations' of the designers work. With all of these works it is evident that the way that the evidence was collected and interpreted influenced the conclusions, but there was always a concern that because of the metacognitive nature of designing that much of the ephemeral data was all but lost.

The research for this paper was largely driven by a concern that, while new teachers entering the D&T teaching profession have developed personal capability in designing, they seem to find this difficult to initiate in their schools with their pupils. The normal role of the teacher primarily focuses on:

- authority, control and behavior management;
- outcomes and expectations of progression;
- learning objectives, and their assessment;
- Schemes of work, skills progression and attitudes.

Within this there is a tendency to prioritise quantified steps which are easy to teach and easy to test. Attitudinal 'constructs' such as autonomy and understanding their own learning are therefore less easy to incorporate. Teaching and managing designing with their pupils is an area that teachers have less opportunity to develop expertise in.

Within our research we were aware of the need to include the practice of teacher reflection to ensure continuing professional development possibilities for the teacher (Parsons and Brown, 2002). The journey that the pupil makes from problem to solution, provides opportunities for them to gain confidence and develop a self awareness that can encourage the capacity to take risks in search of finding creative approaches (Black and Wiliam, 1998). Yet it would seem that without the 'will' and 'ability' to develop autonomy in pupils through designing and making, other pressures on teachers force designing down their priorities. Design activity is then at best tokenistic, but often not present at all.

The research team

The research team consisted of four people: a higher education design and technology teacher educator, two design and technology school teachers and a psychotherapist. One of the school teachers is also trained as a school counsellor. The research took place in the teachers' school.

Methodology

The work was essentially us 'marking out the pitch' by validating criteria and strategies for mentoring which could then be used in further research. Our exploration of mentoring designing followed the following stages -

1. Interviewing university design tutors.
2. Exploring mentoring from a psychological viewpoint.
3. Observing and recording teacher/ learner tutorials.
4. Teachers reflecting on the records of the tutorials.

Stage 1: Interviewing university design tutors

Interviews were conducted with four university design tutors about the design projects that they ran. The questioning was around the areas of

- What made a good design project?
- What did they do if a student was failing?
- How did they recognize excellence in student performance?
- How did they conduct their tutorial interviews?

From their answers, the following were highlighted.

- The project brief and the structure of the project embody all of the learning objectives required of the learner. These may be both functional and attitudinal objectives. A critical aspect of the mentoring is to encourage students to understand and 'modify' the brief to open up the possibilities for 'better' outcomes.
- Whilst there is an emphasis on the outcome and its success, critical aspects of the objectives may be their emphasis on the 'process' of attempting to get to the outcome. Elements of this include argument, analysis, understandings of the outcome, the human situation and understanding themselves as designers.
- Overall project and programme aims of autonomy and becoming self critical were embedded in all project briefs.
- The tutoring aimed at 'becoming a voice inside their head' as a means to develop student's design capability.

The aspects that emerged from these interviews were then incorporated into our pupil tutorials.

Stage 2: Exploring mentoring from a Behavioral Psychology viewpoint
Originally the team did not contain any 'trained' counsellors or psychotherpists but we recognised that there were aspects of what teachers were doing that were close to counselling/psychotherapy. The initial thoughts were to interview psychotherapists to find out 'how they did it'. Instead we expanded the contributors to contain a psychotherapist and utelised the skills of our teacher with school counselling expertise. The therapists observed and commented on a range of the interviews between the teachers and learners, and were involved in the reflection on activity by the teachers. Thus we were all more able to both discern and record the counselling aspects of what we were doing.

Points that emerged from our collaboration with the therapists:

- The inclination of us as teachers to be more interested in measurable outcomes as opposed to aspects which showed movement and tendency to change.
- Viewing the pupils' responses to the situation as both showing the kinds of expectations for advice and solutions they would want as well as reacting to the interactions with the teacher.
- The tendency to ignore the dynamics of the pupil group and its influence on the individual pupil having a tutorial.

From our conversations within the team we were introduced to the concept of countertransference and how it was different from 'teaching'. Because of the significance of this we felt the need to have some guidance and took this from Brown & Pedder (2010). They explain

> *"Within the special field of psychotherapy, the concept of countertransference has had various meanings; we find it helpful broadly to distinguish two uses. As in development of the concept of transference, countertransference was at first thought of as an obstacle. Any strong feelings the therapist might have had about the patient were thought to represent his own unresolved conflicts and problems, from his own past or present life, transferred on to the patient…This then is one meaning of countertransference, when the therapist contaminates the field with his own problems from elsewhere.*
>
> *However, assuming the therapist comes to the patient not unduly ruffled by his own problems and is able to maintain an attitude of "free-floating attention" or "listening with the third ear" in order to hear the message behind the patient's surface communication, then the therapist's own spontaneous feelings and emotions, as his unconscious tunes in to that of the patient, may provide the key to understanding what is at first incomprehensible. Heimann (1950) was among the first to begin turning attention to this second aspect of countertransference, which, far from being an*

obstacle, becomes an important tool in psychotherapy. She assumed that the analyst's unconscious understands that of the patient, and that rapport at this deep level stirs feelings which it is the analyst's task to sustain and use as a source of insight into the patient's conflicts and defences." (Brown & Pedder, 2010, p61-62)

In exploring the difference between countertransference and teaching in practice, our therapist commented

"It seems to me that teaching & learning is largely a conscious process. e.g.. the teacher knows what they want to achieve and the pupil understands they are being taught.

Is the teaching of project work difficult because the teacher has to balance how you do or don't influence the learner? Probably yes because the teacher is balancing keeping the student on task and developing/expanding the pupil's thinking/creativity by pressing the right buttons rather than imposing his opinions. This is to some extent about reading the pupil's responses. One way of doing this is by examining the way that pupil is making you feel.

Psychoanalytic therapists try hard to avoid telling their patients how to fix things and try to enable them to recognise their own strengths, unhelpful behaviour patterns ("conflicts and defences"). Therefore there is definitely some similarity in the balancing act we have to perform. The countertransference kicks in when, for example, the therapist experiences his patient as helpless and impotent and his instinct is to pitch in with a list of suggestions. He's picked up on how hopeless the patient feels but is in danger of doing exactly what everybody else does i.e telling him what to do & reinforcing his sense of impotence. Not helpful. For this reason countertransference is not necessarily a good thing (it's a reaction). The skill is to examine your countertransference response and find some way of using it constructively in the work. Ideally you might aim to bring the stuck feeling to the patient's attention so he feels understood and ultimately liberated from it."

Stages 3 and 4: Pupil tutorials and Teacher reflections

When pupils were engaged in project work we were exploring the idea that by seeing the teacher/design-tutor role in the areas of;

- Being a teacher; manager of the learning;
- Being a mentor; or therapist;
- Being an assessor, making decisions as to the most appropriate course of action that the learner should next take.

In this way we could develop insights into design project work mentoring, that could be a way of improving ours and others' practice.

The data for this section has been collected using digital pens, which not only captured the notes and drawings of the user on paper, but at the same time recorded the conversations that created them. It was therefore possible to have tutorial interviews with the pupils about the progress of their work, make notes, offer suggestions, agree and share targets and record the conversations that initiated those things, and then analyse those conversations later.

In total twelve tutorials were recorded in this way. The results were then analysed in discussions between the teacher and one other member of the team to add the reflected comments of the teacher, as to what they felt they were doing using the three criteria of teacher/manager, mentor/counsellor or assessor. For the benefit of this paper the data has been 'characterised' through a series of 'incidents' between teachers and learners. These have been extracted from the three of the twelve tutorials, chosen because they illustrate different approaches taken by the teachers. The identification of which of the three 'roles' the teacher was operating in was noted in the teacher reflections column when the tutorials were reviewed.

Results

We have transcribed the interviews between teacher and pupil into the first column and then added the teacher reflections and the roles that they identified they were adopting in italics in column two.

Teacher/ Pupil tutorial 1

The pupil is designing a device to create an emergency phone connection for people who get into difficulty in areas where phone signals cannot reach.

The teacher's initial comment on this episode:

> "This student is very creative with ideas and is sound in the research area but has most difficulty turning the ideas into tangible outcomes. He has chosen to explore a valid yet risky area, where the actual technologies and materials expertise is difficult to find.
>
> I have redefined this as a 'conceptual' project, where all of the details may not be defined but may be viewed as 'black box'. So the student does not have either the ability or the time to cover all aspects of the project yet is still able to make a valid contribution. They have got a sample of foil covered plastic which is a useful starting point"
>
> *(Acting as an assessor)*

Transcript of tutorial 1	Teacher reflections and roles
pupil "…also I was thinking about the most basic shape to make the balloon I can make it into a sphere, but the problem with is there will be too many pieces and therefore too much tape joining them together. So the balloon will become too heavy the second most efficient shape would be a square shape. I was trying to make one out paper but it was hard to make it airtight because of the corners."	My task for this session was to move this student towards a 'made' outcome of some sort. So that they can start to confront some of the areas that they can and can't make progress in.
teacher "Have you ever made water balloons out of paper?" pupil "You mean like an origami cube?" other pupil "I know how to make one of those I think. Well I'll try it now." teacher "The other thing is (you will probably know much more about this than I do) could you base your concept on nanotechnology?" pupil "What do you mean by that?"	*(acting as a teacher)* "This is me giving guidance without directly 'telling' the student what to do." *(acting as a mentor)*

teacher "Is there anything that you can use that is very small to connect to the balloon?" Pupil "The problem with the cable from the phone to the balloon is that a wire has to be very special and that makes it very heavy." teacher "Is there any way other way of getting signals up to the balloon other than by wire" pupils "Oh yes maybe use fibre optics?" teacher "Can you use that?" Pupil "Yes I think you could." teacher "So why doesn't this exist at the moment if it seems so obvious?" pupil "I called up the phone companies and they say it is all possible but it will be the equivalent to creating your own phone mast which is illegal at the moment." teacher " OK so let's look at what has to be done now; research the material: check out the shape of the origami balloon: research fibre optic technology. Where will you be with this when we meet next?	This is me managing the progress of the designing and making *(acting as a teacher)* This is me pushing the student to consider other alternatives *(acting as a mentor)* This is congratulating and handing over the designing to the student. *(acting as a mentor)* Managing what the pupil will do between now and next time. *(acting as a teacher)*
Pupil "I'll make a paper model by the end of this lesson, then I'll research the materials before we meet. Is that OK?"	

Teacher/Pupil Tutorial 2

The student is designing a device to remove bees' honey from honey combs. The present methods are messy and slow so they hopes to create a better way to do this.

Teacher's initial comment on this episode.

This is a student who is very strong in the area of modelling and making, but lacks confidence to have and push their ideas. They have made a range of research models around the context of the project. They are now at the point of being moved from what 'might be possible' to 'what can be possible'. *(Acting as an assessor)*

Transcript of tutorial 2	Teacher reflections and roles
teacher “So it seems like what we've got here and what you’re suggesting is that something like this is holding the honeycombs that spin around the centre” pupil “That’s right if it's spinning then the distance from the middle is important.”	Tuning into the project and reviewing the progress since the last meeting *(acting as a teacher)*
teacher “You really ought to pour honey on this model and see how it works.” pupil “I’ll do that a bit later on when I’ve got something a bit better to test” teacher This bit is horizontal? Pupil “yes”	Relating the project back to the original concept. The student demonstrates a grasp of the concept and has a strategy for how they intend to deal with it. *(acting as a mentor)*
teacher “OK what about if it's like this and spins vertically? Pupil “If it is fixed like that will we won’t need any gears at all.	Looking with ‘fresh’ eyes and making suggestions. *(acting as a mentor*
Teacher “Let’s go downstairs and try that out in the workshop. Does the distance of the thing you're spinning away from the centre make any difference? pupil “Yes it is, the further away the more the centrifugal force.	Putting the investigation within the students strongest area of expertise. *(acting as a teacher)*
teacher “This might be a much simpler arrangements and you won't need any gears to make it go fast is that right?	Extracting the science. *(acting as a teacher)* Positive suggestions. *(acting as a mentor*
pupil “So let's make a model of what we just said. This feels like it will work, yes I'll go away and make and model of this.	Student defines the strategy of what to do next *(acting as a teacher)*

Tutorial 3

This is the design of a portable seating device for use both outdoors and indoors.

Teacher's initial comments on this tutorial;

This is a very bright student, who lacks confidence in realising their ideas. It was important in this interview that they moved towards a valid outcome within a material area that they understood, that was simple enough for them to both understand and make it. It was important that the made outcome could well made. *(Acting as an assessor)*

Tutorial 3 transcript	Teacher reflections and roles
pupil "So I'm looking at something like this one, which sort of twiddles out and have something like an upturned tray on the top." (Shows drawing and photo from research) teacher "Aha that looks interesting. So when it's folded up what does it look like this? pupil. "Yes but that's not good. If it was a kind of triangle, what would that be like?" teacher "Yes that would be very good and a lot more comfortable. pupil "Do you think if it was something like that anyway, with a hinge out of metal or something, it would be strong enough? teacher "It doesn't have to be metal or magnetic it could just be fabrics couldn't it?"	This is me interrogating the ideas that the student has produced since our last meeting. *(acting as a mentor)* This is me reinforcing their ideas and contribution. (confidence is important for this student) *(acting as a mentor)* Giving ideas *(acting as a mentor)* Giving specific
pupil. "So how could we make it? teacher "you could use a fabric 360° hinge like this, It could be fabric or leather and would be easy. Pupil "Oh yes. I was thinking that it might be carried with a handle like this but that means it's can only be this long between your hand and the ground." teacher "Could it be carried in a different way, like with a strap over your shoulder? pupil "I guess that would make it a lot more possible. But wouldn't that be too heavy to carry around?	solutions. *(acting as a teacher)* Questioning so that the pupil pushes and develops their ideas. *(acting as a mentor)* A non specific answer, to encourage the student to come up with their own answer *(acting as a mentor)*

teacher “How big do you think it should be?” pupil I am worried that this will be a difficult object to carry. what will we make it out of? teacher “from anything that is not too heavy.” pupil “If I make it out of plywood how can we stop it being so heavy? teacher “Oh well how will you reduce the weight?	Questioning the weight issue. *(acting as a mentor)*
Pupil “I could cut pieces out of it” teacher “Show me by drawing on this how you would do that. Show me several alternatives of how you would reduce the weight by cutting pieces out. Yes I can see that one what about another one give me several ideas do it draw it on here.”	Engaging with and sharing the ‘designing space’ *(acting as a mentor)*
teacher “that seems very good, there seem to be a lot of lovely things you can do with that. How are we going to move this from here?” Pupil “Well I can draw some more but I think I need to make a model of this.	Managing the rest of the activity. What next? *(acting as a mentor)*
Teacher okay how long do you think that will take to do? Pupils	Managing progress *(acting as a teacher)*

“Err I can do that in about half an hour.” Teacher “Okay lets see it. Does that help at all?” Pupil “yes that helped me a lot.”	Reassurance and reinforcement *(acting as a mentor)*

Conclusions

Our initial thoughts were that the three areas of Teacher, Mentor and Assessor would be valid as ways of interpreting the activity and could be reliably identified. What we had supposed was that particular learners would require particular emphasis of one of these areas, For example the 'less able' pupils would require more managing and less mentoring. What we actually observed was a more complex and subtle movement of emphasis between the learner and teacher around all of the 3 areas in 'all' pupils, independent of their ability.

It would seem that the ways that we chose to categorise the activity of design mentoring could be reliably identified within the activity. The insights that this reflection gave us aided the progress of the tutorials, and thus that of the pupils. We all recognised that this was an activity we had previously done intuitively, but which we were now able to recognise, as criteria in our own practice.

So what are the implications for pupils being better mentored in designing activities in their project work?

In a world where the future is increasingly uncertain and complex, the ability of citizens to make improvements to their lives can be seen as crucial. Yet conversely within societies the need for politicians to justify spending on education forces a greater emphasis on measurable progression of children into mature adults. On one hand the 'society' (business and the creative industries) recognise the need for the population to be 'autonomous, nimble, creative, capable and brave in situations of uncertainty and able to make changes for the better; in our case, be 'designers'. Yet, the people tasked with the education of young people in those same societies, by their politicians, must achieve this via a series of small and measurable 'bite sized and easily tested pieces' of educational experience.

For example, knowing the names of a series of designers and what they designed is easy and cheap to teach and test, whereas giving learners the confidence to operate in the way those designers have, is much more complex to do and assess. We in the team have no doubt, however, which of these in the context of human development is more important. We would hope that this way of looking at design mentoring of pupil project work would make it more possible for teachers to encourage their pupils to behave as designers and to achieve greater successes.

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Investigating pupils' perceptions of their experience of food technology in the English secondary curriculum

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Introduction
Investigating pupils' perceptions of their experiences of learning is a powerful tool in helping to develop an understanding of teaching and learning (Benson and Lunt, 2011). Little has been published about pupil's attitudes and perceptions of food technology at secondary level in English schools. Coupled with policy changes to provide greater curriculum freedom (Academies Act, 2010; Curriculum Review, 2011) schools can perhaps explore a less descriptive dictate than that provided by the National Curriculum.

This paper reports on the perceptions of 120 Key Stage 3 (aged 11-14) pupils in seven secondary schools in the West Midlands, England. It looks at perceptions and values relating to the teaching of food technology. The evidence suggests that pupils understand that food technology is more than just learning to cook. They enjoy practical participation and engagement, active lessons and autonomy.

Introduction

Pupils' perceptions of their experience in school can provide a valuable insight to inform improvements in teaching and learning (Flutter and Ruddock, 2004; Benson and Lunt, 2007). This is combined with shifts in educational policy in the English curriculum with many schools opting for 'academy status' (Academies Act, 2010). Academies are publicly funded independent schools that have 'greater freedoms to innovate and raise standards' including a freedom around the delivery of the curriculum. By March 2012 1635 schools have become academies and therefore do not have to follow the rigours of the English National Curriculum (www.education.gov.uk). Schools can perhaps explore a less descriptive dictate, providing an opportunity to widen the scope of the subject to meet local needs.

Literature review - Food as part of Design and technology

The origins of food education prior to the introduction of the National Curriculum in 1990 (DES 1990) provided it with a craft skill, philanthropic and utilitarian function (Rutland 2006). The introduction of food as part of design and technology provided a more cognitive, conceptual and epistemic context. The evolution from home economics to food technology has proven to be popular with fifty five thousand pupils taking the full course in 2011 (www.data.org).

The value of practical skill development coupled with concerns about rising obesity rates raised the profile of food in school in the early 1990s. The Labour Government's cross department report *Healthy Weight, Healthy Lives* (DH/DCFS 2008) detailed the 'Licence to Cook' programme that provided pupils aged 11–16 with an entitlement to learn to cook. It provided a programme to enable students to develop practical cookery skills and understand the principles of diet and nutrition, health and safety and wise food shopping. The impact of this funded initiative was that 3,000 maintained secondary schools were trained and the emphasis in food education moved to basic practical skill development. OFSTED (2011) acknowledged the emphasis on cooking and healthy eating in schools during 2007-10 noting how the Licence to Cook initiative led to more opportunities for practical work and a greater concentration on making meals. For many food technology teachers this was a welcome return to the philanthropic-utilitarian function of food education. Others saw the transgression away from designing and making as a potentially limiting function as arguably, within design and technology, food looks at the wider impact of food on society (Rutland 2008).

It can be argued that food technology is about 'thought in action' (Rutland 2006) and not the rote learning of skills. Within design and technology food education provides the opportunity to think and investigate in practical ways by engaging with ingredients, processes, equipment and technologies to find solutions for a user and purpose. Ofsted (2006) articulated the concern that 'too little time is spent learning to cook nutritious meals and too much time is devoted to low level investigations and written work (p.10). However, a later Ofsted report (2011) was critical of the nature of design and technology noting that the subject holistically needed to be more intellectually challenging to include 'designing, product development, empirical testing and applying maths and science' (p.5).

The purpose of this paper is to look at pupils' perceptions of food technology so that pupil perceptions can perhaps inform the debate concerning the evolution of food technology in the curriculum. Research on pupils' perceptions of design and technology in secondary schools (Grover et al 2003, Thomas and Denton 2006,) found the elements that children found most enjoyable were making, working with tools and designing and the least enjoyable were written tasks and evaluating (e.g. Hendley et al, 1996; Hughes, 2001).

Methodology

It was decided that on-line questionnaires would be the most useful way to collect information in the time available, and with the number of people involved without the need for photocopying or postage (Cohen et al, 2007). It would have been useful to triangulate these results with interviews where the analysis provided interesting patterns, but this was not possible for this study. Both qualitative and quantitative data was collected through the questionnaires using open and closed questions. All questions allowed for cross checking; for example 'do you enjoy food technology' and 'would you describe food technology as fun'. Benson and Lunt's (2007) research into pupil perceptions in primary schools was used as a benchmarking tool for the question design.

A pilot study was conducted which highlighted issues of ambiguity, interpretation and bias. Some questions were modified in light of suggestions about wording. An analysis of the responses indicated that the information gathered should support the research.

A cohort of schools in the West Midlands was identified using the database of schools from a PGCE secondary teacher training data base. Twenty schools that teach food technology as part of design and technology were invited to join the research. Six responses came back within the time limit; it was these that were used for the research. It was decided to target year 8 groups as it was hoped that this cohort would have gained experience in food technology. Due to the policy of some schools to deliver GCSE courses in year 9 it was decided that the older year group would be less appropriate as this would target pupils who had 'opted' for the subject.

Confidentiality, consent and clear understanding as to the nature of the research were major considerations. The sample was informed by e-mail about the research, providing the opportunity to pre-view the questionnaire before agreeing to administer it to their groups. The purpose of the questionnaire was explained on the first page of the survey. It was made clear that answers would be kept confidential, and that individuals would not be identified. The school that they attended was included for analysis purposes.

Fig 1.Survey Overview

School	male	female	**Totals**
School 1	8	15	23
School 2	11	7	18
School 3	0	19	19
School 4	7	7	14
School 5	13	9	22
School 6	21	3	23
Totals	60	60	120

Findings and discussion

The information was gathered over four weeks. Six schools completed the questionnaire with teachers identifying one year 8 group that they taught. This elicited 120 responses with equal numbers of boys and girls.

Did pupils enjoy food technology?

Evidence came from three questions the children were asked in the first section of the survey: Do you enjoy food technology? Would you describe food technology lessons as boring? Would you describe food technology as fun? A majority of 80% responded that they always/usually enjoyed food technology, although 48% did consider food technology to be sometimes boring. Overwhelmingly respondents thought the subject was always/usually fun (71%). Triangulated by a latter question 81% of pupils agreed that they like food technology lessons because it is different from most other lessons. Furthermore, in response to the statement 'it puts a smile on your face when you have made something of your own' 80% of respondents agreed. Very few females 2/60 disagreed with this statement.

Gender analysis shows that the majority of responses concerning enjoyment of the subject were in the 'always and usually' category for both genders but with slightly more girls (88%) than boys (72%) making positive responses. More boys considered the subject to be 'sometimes' or 'never' enjoyable (30%) compared to girls with only 12% of girls responding that it was 'sometimes' enjoyable and 0 females responding 'never'.

Fig 2 Do you enjoy food technology? Would you describe food technology as boring?

Do you enjoy food technology?	male	female	**Totals**
always	19	28	47 (39%)
usually	24	25	49 (41%)
sometimes	12	7	19 (16%)
never	5	0	5 (4%)
Totals	61	60	120
Would you describe food technology as boring?	male	female	**Totals**
always	4	2	6 (5%)
usually	11	4	15 (13%)
sometimes	28	30	58 (48%)
never	17	24	41 (34%)
Totals	60	60	120

Would you describe food technology as fun?	male	female	**Totals**
always	15	26	41 (34%)
usually	25	19	44 (37%)
sometimes	12	15	27 (23%)
never	8	0	8 (6%)
Totals	60	60	120

These findings were very similar to those of Benson and Lunt (2007) when questioning primary school children about their enjoyment in design and technology. They also found that slightly more girls than boys always or usually enjoyed the subject but, as in these findings, very few girls chose the 'never' category. As there is evidence that girls and women are under-represented in areas of science (Smith, 2011) food technology could be a route to engage more girls into science subjects.

Characteristics of the subject that pupils enjoyed

The evidence concerning characteristics came from two open questions asking about most enjoyable features and least enjoyable. The pupils' qualitative responses were categorised using word cloud data analysis software (www.survey.bris.ac.uk).

The data analysis identified words such as 'cook(ing)', 'food', 'fun', 'practicals' and 'making' as enjoyable features of the subject. There were references to designing 'I like designing things I cook', 'I like planning what to make'. There was also reference about independence 'so you feel confident enough to go home and try it out'. Forms of the term 'eating' were prevalent as was 'getting messy' and 'getting hands dirty'. The interaction with ingredients seem to be key characteristics to pupil enjoyment supporting Rutland's 2011 research that that designing and making food products should remain central in the subject.

Results for the least enjoyable aspects were dominated by the word 'writing'. This supports findings from earlier studies in secondary schools (e.g Hendley et al, 1996; Hughes 2001 and Neal 2003). Although the cognitive, conceptual and epistemic context is important for the subject's accountability teachers need to ensure that theory is delivered through practical application as this engages the pupils and is arguably one of the unique features of food technology.

What were the pupils' perceptions about the value of food technology?

Analysis related to the qualitative question 'why do you think we learn about food in schools' included the words 'cook', 'food' and 'eat' as well as terms related to nutrition '(diet, grow, healthy) , function (feed, family, yourself, future/older, job) and process (equipment/safety, know). Apart from the vocational reference to 'job' the perceived value seemed centred on food technology in the home. This contradicted a later question asking about the vocational context of food technology where 74% of pupils (with similar responses between the genders) agreed 'food technology lessons are important for life because it is useful in lots of different jobs' suggesting a dichotomy identified by Ofsted (2006:1) between 'teaching food to develop skills for living and using food as a means to teach the objectives of D&T'. Some critics (Owen-Jackson, 2007) suggest this is a false tension as practical cookery skills and nutrition can be used to develop food products and vice versa.

Pupils concluded in the qualitative statements that the least enjoyable aspect of food technology was 'writing' the findings of 'I would prefer just to get on and make, not to design (e.g. research, think about, plan)' are not conclusive amongst boys with only 52% agreeing compared to 72% of girls. This contradicted the response given to the statement about the value of designing with 67% responding positively. 'Problem solving' generated a mixed response between both sexes with a relatively high number of 'not sure' (28%). There may be many reasons for this and without further interviewing it is not possible to draw conclusions but due to the impact of the Licence to Cook programme (2007) it may be fair to judge that pupils are not given the opportunity to 'problem solve' and 'design' in food but are given a more prescriptive curriculum based on skill development. This supports Rutland's (2008) research that questioned whether Licence to Cook was the 'death knell' of food technology due to its focus on practical skill development rather than an understanding of the properties of food so that pupils can make design decisions.

Fig 3

Statement	Agree	Disagree	Not sure
I would prefer just to get on and make, not to design (e.g. research, think about, plan).	Boys 52% Girls 72% Total 62%	Boys 32% Girls 20% Total 26%	Boys 16% Girls 8% Total 12%
I think designing is really important if you want to make a good product	Boys 64% Girls 70% Total 67%	Boys 23% Girls 15% Total 19%	Boys 13% Girls 15% Total 14%
In food technology lessons you have to think really carefully to solve problems.	Boys 40% Girls 45% Total 42%	Boys 35% Girls 25% Total 30%	Boys 25% Girls 30% Total 28%

The majority of pupils identified creativity and autonomy as positive values associated with the subject. For these pupils the opportunity to be autonomous problem solvers was evident. Work to encourage autonomy is a valued characteristic that supports Flutter and Ruddock's (2004) characteristics of a good lesson.

Fig 4

Statement	Agree	Disagree	Not sure
I like food technology because we get to use our own ideas rather than just being told what to do.	Boys 63% Girls 68% Total 66%	Boys 25% Girls 17% Total 21%	Boys 12% Girls 15% Total 13%
In food technology lessons we learn how to be creative (e.g think up ideas in different ways, try out different ways of making).	Boys 74% Girls 74% Total 74%	Boys 13% Girls 12% Total 12.5%	Boys 13% Girls 14% Total 13.5%

The final question focused on the issue of pupils cooking at home questioning Kerr and Horne (2003) noted the 'erroneous assumption' that children are taught to cook at home. This survey supported this opinion with 74% disagreeing with the statement 'learning to cook is a waste of time as I can learn this at home' with a further 7% unsure. There was a significant gender difference in responses perhaps due to the term "cooking" and the stereotypical imagery that this term may generate.

Statement	Agree	Disagree	Not sure
Learning to cook is a waste of time as I can learn this at home.	Boys 30% Girls 8% Total 19%	Boys 60% Girls 87% Total 74%	Boys 10% Girls 5% Total 7%

It must be remembered that this study was a small pilot, and whilst some evidence can be cross checked through analysis from different questions there are some areas that require further investigation through interviews with teachers and pupils. It is always tempting to offer the opportunity for further comment but this makes the data collection timely to complete and difficult to analyse. It also makes the data collection a written exercise that alienates some pupils from wishing to offer opinions. If offering pupils a choice of answers this may also limit the scope of the response.

Conclusion

It appears that whilst pupils (male and female) perceive food technology as enjoyable when it is 'hands-on'; they do not see as having a narrow "craft-skill" utilitarian function. They recognise the unique contribution it makes to the curriculum being 'different from most lessons' as it 'puts a smile on your face when you have made something of your own'.. Although popular with both genders it is enjoyed slightly more by girls. Is this a problem or could it be an advantage? With an increased emphasis on science could the subject be a route to engaging girls in the sciences?

Characteristics pupils enjoy include the practical interaction with ingredients. As with Benson and Lunt's (2007) research into primary school pupils' perception of design and technology pupils appear to enjoy thinking and investigating in practical ways and it is perhaps this engagement with ingredients and processes that is fundamental to the position of the subject in the curriculum. Designing and creativity are also features that they enjoy and through several strands of the research the theme of independence and autonomy seems to be welcomed. Perhaps predictably the least enjoyed aspect is writing but the potential to engage pupils in theoretical aspects through practical application is an opportunity so that pupils think and investigate in practical ways. Perceptions of the value of the subject seem to go beyond 'cooking' and 'food' but also to include nutrition and its functions in the home and the world of work as well as equipment and safety. Perceptions about the need to perform design, research and problem solving tasks varied and further research would be needed to investigate the reasons for this and the possible impact of the Licence to Cook programme. Whilst pupils perceived that food technology was more than just cooking they also recognised that learning how to cook was not something they would learn at home.

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Are we educating to promote students' creative capacities?: A study in Technology Education in Ireland

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Keywords: Creativity, creativity quotient, thinking, education systems, technology education

Abstract

This paper focuses on student's creative capacity, in terms of natural creative tendencies, in the three levels of education; primary (first), second, and third level. Creative capacity was investigated through a comparative analysis of creativity quotient (CQ).

Two hundred and four pupils participated in this research study, in the location of their everyday classroom / laboratory environment. Participants were assessed in terms of creative quotient (CQ) derived from fluency and flexibility values. From analysis of the mean data, third level students proved the most creative in the context of creative quotient. However, further comparative analysis occurred in terms of the statistical difference (p-value) for fluency, flexibility and CQ in the context of the three educational institutions. Overall, there is a small difference (very small effect size <0.1) between primary and second level, and primary and third level, in the context of fluency, flexibility, and CQ. In terms of second and third level, in the context of fluency, flexibility and CQ, there was no difference. It is necessary that creativity is promoted throughout our education systems to ensure pupils maintain and develop their creative capacities into adulthood. A young child may have the capacity to be creative, but as they get older, if they do not have the need to be creative, their capacity may fade. Later in life they may struggle to reconnect to the creativity they had during their youth. Education systems need to foster independent thinking, creativity and innovation. This paper portrays student's creative capacity in technology education spanning from early years through to upper secondary education and teacher education in the context of fluency, flexibility and creativity quotient.

Technology Education in Ireland

According to the Irish Central Statistics Office, 2011 census, preliminary results, Ireland has a population of approximately 4,581,269 (CSO, 2012). First, second and third level education caters for approximately 509,652, 356,107 and 161,647 students, respectively, distributed in 3,165, 750 and 33 institutions respectively. In an Irish context, first level does not have a compulsory technology education subject in the curriculum (DES, 1971; DES, 1999; NCCA, 1993). The age of primary level students ranges from approximately 4 to 12 years of age.

Second level education is divided into two main cycles; junior and senior (NCCA, 2012). The age of junior cycle students ranges approximately from 12 years old to 15 years old. Students study a minimum of eight subjects in junior cycle, of which the technology education suite of subjects is optional. Senior cycle student's age ranges approximately from 15 to 18 years of age. Students must study a minimum of five subjects in senior cycle, however to achieve entry to third level a minimum of six subjects must be undertaken. The Irish third level 'points system' has a benchmark of 600 points. Senior cycle subjects are divided into subject departments, and once again the technology education suite of subjects is optional.

Third level education is optional, but approximately fifty percent of second level students advance from second level to third level, depending on socio-economic factors and entry points. In Ireland, there are three main third level educational institutions; university, institute of technology, and teacher training.

In relation to the three levels of education in Ireland, the primary aim is to enable individuals "to realise their potential as individuals and to live their lives to the fullest capacity appropriate to their particular stage of development" (DES, 2012; DES, 2004). The aim of this study is to investigate pupil's creative capacities through creativity quotient, in Irish education systems; primary, second and third level.

Creativity expectations at the levels of education

Scientifically defining creativity is broad and context specific. Creativity, normally a right brain operation, is often stifled due to the dominance of the '3R's' (reading, writing and arithmetic), normally a left brain operation, in the current education system. Creativity can be nurtured in Technology education by "*building a responsive environment in which there is an atmosphere of receptive learning*" (Atkinson, 1994). Everybody has the capacity to be creative (Robinson, 2001). Robinson also argues that as individuals, we do not grow into creativity; we grow out of creativity (Robinson, 2001). In relation to fear, Sternberg (2006) notes that fear can act as a blockage and risk taking is necessary to produce something creative when he states that "*creativity is in large part a decision that anyone can make but few people actually do make because they find the costs to be too high*" (Sternberg 2006, p. 97).

Creativity is a term that is often used in education, but is rarely defined. Creativity researchers generally agree that creativity involves a combination of uniqueness and usefulness (Beghetto, 2005). In an extensive content analysis of creativity articles by Plucker, Beghetto & Dow (2004) it was discovered that "*clear definitions of creativity are rarely consistent, if offered at all*" (Plucker, Beghetto & Dow, 2004, p.88). Their analysis proved that the most common characteristics of explicit definitions for creativity were uniqueness (n = 24) and usefulness (n= 17) and of the ninety articles selected two articles used the term over one hundred times without defining it. Creativity involves the contribution of unique/original and useful ideas in any given situation. It was proposed that creativity is the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context (Plucker, Beghetto & Dow 2004, p. 90). Products that are novel but have no use or merit or significance are simply novel, not creative. Likewise, products that are useful but are not novel, unique, or original are simply useful, not creative (Beghetto, 2005). For the purpose of this study, the above definition for creativity, proposed by Plucker, Beghetto & Dow (2004) was used as the assessment criteria for the creative abilities of the participants.

It is important to take into account the social context, the level of the students' creativity in the three levels of education, which were assessed using the specifications of the contextual parameters. Plucker, Beghetto & Dow, (2004) stated; "*a particular 4th grade science project is creative in the context of fourth graders…at the same time, specifying context does not allow for empty realistic claims that a 4th grade science project necessarily is as creative or significant as a Nobel – Prize winning discovery*" (Plucker, Beghetto & Dow, 2004, p. 92). Hence, each level of education is seen as creative in the context of their own environment. Hennessey & Amabile, (1988, cited by Beattie, 2000) support this view when they suggest that, judges should rate creative products relative to one another, rather than to some absolute standard of creativity for the domain. Assessing creativity within a social context is important as primary level students may not have the skills to adequately express or fully communicate a unique idea in comparison to a third level student (Fishkin & Johnson 1998).

Instruments for measuring Creativity

To ensure an accurate measurement of creativity, the use of the creativity quotient was applied, which accounts for the number of ideas (fluency) and the number of distinct categories the ideas fall into (flexibility). The CQ can be represented mathematically as CQ = 1.44 ln (u+1) (Synder et al, 2004). The product (u+1) was calculated by determining the number of categories and uses within each category. This is represented in the formula $(1+u_1)(1+u_2)(1+u_3)$, where u_1, u_2, u_3 respectively are the number of uses student proposes in each category respectively. If no answer is given in a category then u=0 (Snyder et al, 2004). From each participant response, CQ, is calculated using the product number combinations to the logarithm base 2, usually used in information theory; CQ = $\log_2 [(1+u_1)(1+u_2)(1+u_3)....(1+u_c)]$

Methodology

To achieve the aim of this study, students' participated in a creativity thinking task developed by Sternberg (Sternberg, 1999, Runco, 2001).

Selection of Participants

This study comprised of a representational sample of the three levels of education systems in Ireland (Drudy and Lynch, 1993) (Lynch and Lodge, 2005). The students in second and third level are students from Technology education. This subject area does not exist in primary education. Class teachers were not involved in the implementation of the testing. The developer carried out all research activities to reduce external influencing factors on participant's creativity (Fishkin & Johnson, 1998). The participants from primary and secondary level were chosen from the final year of their respective level of education. This was decided as it would represent the output or product from this level of education. Undergraduates in the third level are training teachers for the 'Technology education' second level suite of subjects in Ireland.

Characteristics of participants

Primary school participant's ages ranged from eleven to thirteen years, while second level participants ages ranged between seventeen and nineteen years. Third level student's ages ranged from nineteen to thirty-three years. The number breakdown of participants from primary, secondary and third level in this study was 78, 72, and 54 respectively. A limitation of this study may be the 'assessment driven' nature of education, which could stifle student's creativity. This is also highlighted by Sternberg; for many individuals, not having the need to be creative has been masked by a society that encourages knowledge conformity (Sternberg, 2009). While there are differences across the levels of education in terms of knowledge and skills in terms of what is required and expected of them in school; however creativity is a skill which is an outcome required from all three levels; the ability to think laterally. This study investigates the natural tendencies of participants across the three levels of education.

Design & Structure of Research Tools

The creative thinking test was designed following extensive consultation of literature on creativity. One of the most popular and most respected methods of measuring creative ability is Guilford's paper-and-pencil, Alternate Uses Test, in which test takers are asked to list as many uses for a common object (e.g., a tin can, or a brick) as possible. Creative ability or divergent thinking tests, such as Guilford's Alternate Uses test, can provide a good prediction of a person's creative performance (Plucker & Renzulli, 1999; Runco, 2007). For this study, the test used made it possible to quantify creative ability and to compare individuals on a ‘‘standard’’ scale (Sternberg & Lubart, 1999). Questions one, two and three were based on divergent thinking tests (Sternberg, 1999). Though divergent thinking ability is not akin to creative ability, it is suggestive of the possibility for creative performance (Runco, 2001). These three questions were open-ended answer questions that allowed pupils to respond with as many answers as they could devise, within the given time (Figure 1). These open-ended questions are theoretically and empirically related to everyday creativity (Runco, 2001), by allowing participants to divergently think in an unrestrictive fun environment, generating as many different possibilities for a given problem (Kozbelt, Beghetto, Runco, 2010). While divergent thinking is not equivalent to creative thinking, it measures creativity through divergent thinking. Another question can be raised in terms of how you classify a students’ response in relation to creative or knowledgeable. Thus the reason for introducing the creativity tasks as ‘game like’ or fun, to reduce the focus on knowledge (Villalba, 2008).

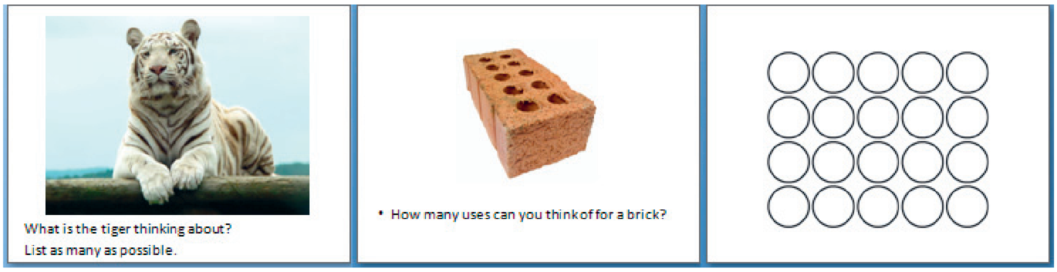

Figure 1: Creativity task, questions 1-3.

Timing of Creativity Tests

Wallach and Kogan (1965) showed that the intelligence–creativity relationship is strongly dependent on the degree of speed of test tasks. This refers to the extent to which time constrains are put on a test. For this study the importance of non speeded assessment conditions in creating a non-evaluative, game-like environment, is a necessary condition for creativity assessment (Kogan, 2008). However, in order to complete a standard task for all participants, timing constraints had to be implemented. Although a limitation to the study, this is an unavoidable consequence of ensuring standardisation across the levels of education.

Therefore research was needed to identify the time constraints applied for the tasks. Wallach and Kogan (1965) discuss that the first two minutes of the task, students are at their least creative, therefore, this study decided to allow more time. For the creativity task, each participant was given equal amount of time to record their answers; 3 minutes 45 seconds. One at a time, the questions were presented on PowerPoint or overheads, depending on school’s resources. There was no respective difference in the quality of questions presented. The author gave the same prompts and examples to every class group (Fishkin & Johnson, 1998).

Assessment Criteria

The responses were scored for fluency (no. of ideas) and flexibility (no. of categories). Participant’s creativity was then calculated by finding the average score from totalling the fluency and flexibility values. From the individual flexibility and fluency values the creativity quotient (CQ) was calculated. The mean values for fluency, flexibility and CQ were compared. However, to obtain the statistical significance of the difference between the three education systems the P-value was calculated. A p-value below 0.05 is generally considered statistically significant, while one of 0.05 or greater indicates no difference between the groups. The effect size of this difference was also analysed is using Cohen (1988) criteria of 0.1 = small effect, 0.3 = medium effect, and 0.5 = large effect (Pallant 2007) (Cohen, 2000).

Results

This paper reports the responses for the main question to assess student's creativity quotient, '*how many uses can you think of for a brick*'. Participant's flexibility was derived from the number of categories students noted in relation to uses of a brick. The number of ideas, fluency, in each category, was also calculated. From this the CQ was calculated. For example, the responses by Third level participant 9; are illustrated in Table 1; this student suggested 7 uses for a brick, which fall into 4 categories. This resulted in a CQ value of 5 (Figure 2, Appendix 1). Table 2 illustrates the fluency, flexibility and CQ values for the three levels of education, as total counts and average values.

Table 1: Sample response, uses for brick, participant 9

Categories:	Break something	Build something	Alternative positive uses	Alternative negative uses
Ideas	*Break a window*	*BBQ*	*Use it as a wedge*	*Use it as a weapon*
		Steps		
		House		
		Wall		

$$
\begin{aligned}
CQ &= \log_2 [(1+u_1)(1+u_2)(1+u_3)\ldots(1+u_c)] \\
&= \log_2 [(1+1)(1+4)(1+1)(1+1)] \\
&= \log_2 [40] \\
CQ &= 5
\end{aligned}
$$

Figure 2: Calculating the CQ for participant 9

Table 2: Fluency, flexibility and CQ values for three levels of education

		Count	Average
THIRD LEVEL	*Fluency (no of ideas)*	281	5.2
#54	*Product (1+u)*	3329	61.6
	Flexibility (no. of categories)	189	3.5
	CQ	230	4.3
SECONDARY LEVEL	*Fluency (no of ideas)*	312	4.3
#72	*Product (1+u)*	2470	34.3
	Flexibility (no. of categories)	238	3.3
	CQ	277	3.9
PRIMARY LEVEL	*Fluency (no of ideas)*	308	3.9
#78	*Product (1+u)*	1926	24.7
	Flexibility (no. of categories)	218	2.8
	CQ	266	3.4

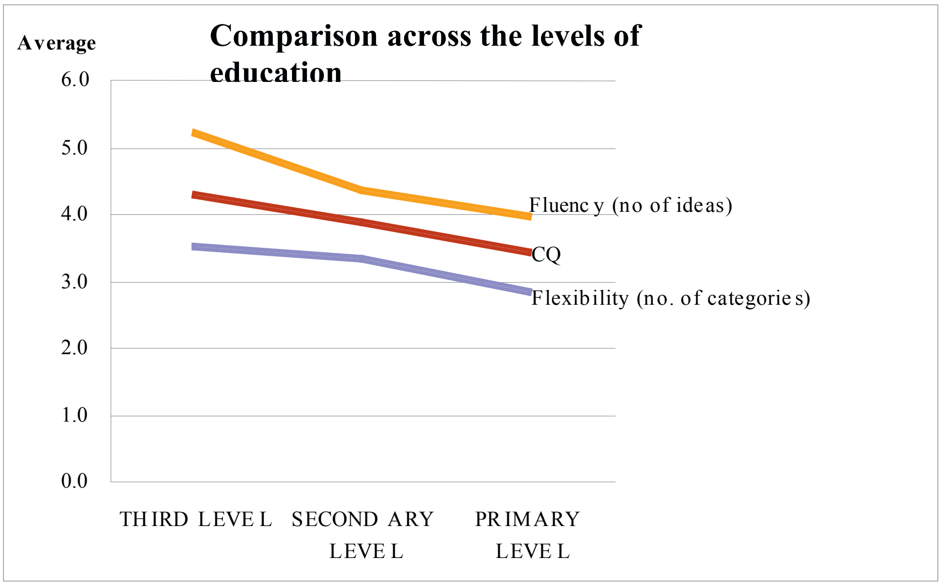

Figure 3: Comparison across the levels of education.

Due to the differing number of students in each level, the comparison of data occurred using mean values (Table 2). Students in third level demonstrated the highest average number of ideas, fluency, at 5.2, in contrast to 4.3 and 3.9 respectively for secondary and primary level. In relation to the number of categories, flexibility, the third level cohort achieved the greatest at 3.5, in contrast to 3.3 and 2.8 respectively for secondary and primary levels. Finally, in terms of CQ the third level cohort was 13% and 11% greater than the secondary and primary level cohorts respectively (Table 2, Figure 3).

Charting the statistical difference in progression

From the comparison across the levels of education in the context of fluency, flexibility and CQ it is evident that further statistical analysis needs to occur to determine the level of differences. A t-test was carried out on all three levels in the context of fluency, flexibility and CQ as evident in Table 3. Two education levels were analysed against each other. From the p-values illustrated, those below 0.05 are generally considered statistically significant, while those of 0.05 or greater indicate no difference between the levels, as illustrated in Table 4.

Table 3: Brick T test statistics (p-values)

Brick T-test			
FLUENCY	Primary level	Second level	Third level
Primary	-	0.0029	0.000447
Second	0.00288	-	0.334144
Third	0.00045	0.3341	-

Brick T-test			
FLEXIBILITY	Primary level	Second level	Third level
Primary	-	0.0386	0.043812
Second	0.03858	-	0.994557
Third	0.04381	0.9946	-

Brick T-test			
CQ	Primary level	Second level	Third level
Primary	-	0.0008	0.000071
Second	0.00081	-	0.255898
Third	0.000071	0.2559	-

Table 4: Statistical difference in fluency, flexibility and CQ across the education levels

	Level	Primary	Secondary	Third
Fluency	Primary	-	*Difference*	*Difference*
	Secondary	*Difference*	-	*No difference*
Flexibility	Primary	-	*Difference*	*Difference*
	Secondary	*Difference*	-	*No difference*
CQ	Primary	-	*Difference*	*Difference*
	Secondary	*Difference*	-	*No difference*

Discussion

The aim of this study was to investigate pupil's creativity capacity, through the creativity quotient, across the three levels of education in the Irish education system. Results have indicated that the mean CQ for third level students is 11% and 13% greater than secondary and primary levels, respectively.

However, on analysis of the p-value between the three levels of education it is evident there is a difference between first and second level; between second and third, there is no difference across fluency, flexibility and CQ. The progressive development from first level to second level could be due to the fact that first level does not have a compulsory technology education subject in the curriculum. Thus, second level increases students' level of creativity with respect to this subject. However, unfortunately this progressive development does not continue to third level for this cohort. A greater study involving a greater sample size is ongoing to investigate these findings further.

Thinking skills in an educational setting provide a social infrastructure to extend and develop organisations in the areas of creativity and innovation. Creating a pedagogical space for developing a model of creative learning which moves away from the 'teacher as a technician' model of educational pedagogy and 'learner as passive containers' towards learners as thinkers (Kansanen, 1991, pg 251) must be promoted. If society, as a body of thinkers, is nurtured and developed, their insights will be acknowledged and valued. In promoting students creative capacities pupils should be encouraged to solve "*practical problems in an innovative and creative manner through the application of appropriate knowledge and skills*" (Department of Education 1991, p.1).

Conclusion

As Pablo Picasso once pointed out, all children are creative; the challenge is to remain creative into adulthood. Unfortunately education systems around the world appear to be crushing creativity in favour of rote learning and examination success. As the years progress from primary to second level education a fear of being wrong takes over from our natural creative tendencies.

This study focused on investigating the level of creativity quotient between the levels of education in Ireland. The overall finding of the study presents two stances; the development from primary to second level in terms of creative capacity is evident, thus pupils are not being educated out of their creative capacities. However, between second and third level, there is no statistical difference, thus students do not progressively develop their creative capacity. At present further studies are on-going across a greater cross section of participants in all three levels and across the STEM disciplines.

Appendix 1

Calculating fluency, flexibility and creativity quotient (CQ)

Flexibility – Category	Fluency - Ideas	u
HOLD SOMETHING	*No response*	
	(u+1)	0
HOLDER	*No response*	
	(u+1)	0
BREAK SOMETHING		
	Break a windscreen	1
	(u+1)	2
BUILD SOMETHING		
	Build a brick bbq	1
	Build a house	1
	Build a stairs / steps	1
	Build a wall	1
	(u+1)	5
KILL	*No response*	
	(u+1)	0
INJURE	*No response*	
	(u+1)	0
MAKE SOMETHING	*No response*	
	(u+1)	0
USES ASSOCIATED WITH A CAR	*No response*	
	(u+1)	0
ALTERNATIVE USES-positive		
	Use it as a wedge	1
	(u+1)	2
USES ASSOCIATED TO BUILDING	*No response*	
	(u+1)	0
ALTERNATIVE USES-negative		
	Use it as a weapon	1
	(u+1)	2
CHANGE IT BY…	No response	
	(u+1)	0
NOT ASSOCIATED TO 'USE'	*No response*	
	(u+1)	0
SPORT ASSOCIATIONS	*No response*	
	(u+1)	0
	Product (1+u)	40
	Fluency (no of ideas)	7
	Flexibility (no. of categories) (u)	4
	Creativity Quotient (CQ)	5

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How do the Interactive White Board and the Radio Frequency IDentification and tracking system work? Exploration of pupils' spontaneous knowledge and didactical proposals for Technology Education

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Keywords: Technology education, systems, spontaneous knowledge, junior high school, literacy

Abstract
This paper reports two exploratory surveys focused on the pupils' spontaneous knowledge about the functioning of technological systems. The qualitative and quantitative data analyse highlights their general unawareness, their reasoning from the material components, their lack of vocabulary to explain how the RFID Pass or the Interactive White Board work. The questionnaires and interviews reveal available cognitive supports in order to develop pupils' understanding. The paper suggests didactical and pedagogical orientations for designing school activities.

1. Introduction

Since its genesis in the 1960s modernity, Technology Education has been legitimated by one of its purposes concerning young pupils' appropriation of their contemporary technical world. Ortega y Gasset (1945) underlined the necessary relationships between school contents and the environment of daily life in a cultural perspective. Léontiev (1972) or Vygostky (1970) in a more psychological point of view argued also the human need of appropriation the new artefacts in order to integrate the progress of thought. But Technology Education such as a basic and general education is confronted at present with two main issues linked. The first issue concerns the necessary understanding of new artefacts or systems with digital technologies. The second issue refers to pupils' possibilities to identify these systems and technologies. This paper contributes to the exploration of pupils' ideas regarding two systems: the Interactive white board and the RFID Automatic identification (used for the checking and tracking in public transports).

2. Research questions and theoretical frame

2.1. Objects, artefacts and systems

Mitcham (1992) or Frederik, Sonneveld and de Vries (2011) note that "Artefacts are probably our most obvious everyday encounter with technology". They underline also their broad spectrum and their different kinds (object, machine, tool, device, mechanism or system) described by the main authors. De Vries (2005, p. 14) also discusses with a same philosophical and epistemological point of view, the meanings of "natural objects, instruments, tools and artefacts" and defines "artefacts" as the generic term. He insists on the function that establishes the relationship between users and designers and then underlines the risks of confusion between applied sciences and technology knowledge.

Within proposals for technological literacy, one characteristics of a technologically literate person is: "understands basic engineering concepts and terms, such as systems, constraints, and trade-offs" (NAE & NCR, 2002; Pearson, 2007). As a result of the evolution, the artefacts are mainly technical systems and are generally intelligent systems. Their main change concerns their integration within information systems with WIFI, WRAP, RFID... technologies. Numerous technical systems work with the same principles: the devices (material objects) only are one terminal, for example a Smartphone or a point-of-sale terminal.

2.2. Technology literacy and artefacts' understanding

A technologically literate person is able to understand these technical systems by distinguishing the material components, their functions and by picturing connected and distant computers with information systems.

The "spontaneous knowledge or naïve ideas" are defined by Lautrey (2008) such as beliefs, notions or concepts learned by children from their experience in daily life and without school teaching. The request of international scholar papers during the last ten years results only in a few researches about pupils' spontaneous knowledge. Svensson and Ingerman (2010) propose five ways for understanding systems: using objects, the function of objects, objects as part of a process, objects as components in one system, objects embedded in systems. The authors suggest three levels: "1) the level of the objects themselves – objects as objects; 2) the micro level inside objects – objects with components as systems; and 3) the macro level outside objects – objects as part of systems, together with human and society" (p. 273).

These researches underline the systems description by pupils. One other research identifies children's initial knowledge (Andreucci & Ginestié, 2002; Ara, Nararajan & Chunawala, 2009). Menger (2010) shows that young pupils use subjective explanations based on experience, objective explanations based on materials or logical explanations with links between motion and functions of the different pieces. This perspective is close to the distinction suggested by Piaget and Garcia (1983) between the "intraobjectal" description (centred on perceptible characters and founded on empirical abstraction) and the "interobjectal" analysis (based on reflexive abstraction) that initiate a "transobjectal" understanding (based on isolation of structures).

2.3. Issues

With this theoretical frame, we suppose that middle-school pupils looking at current technological systems only identify the material or visible pieces without establishing relationships with the other components. This main "intraobjectal" point of view doesn't enable them to explain how these systems work nor the relationships between components that transfer invisible information.

3. Methodology

In this perspective, our main interest was the choice of two different familiar systems: the control system used in Parisian urban transports (Navigo-Pass, figure 1) and the Interactive white board used in classrooms (IWB, figure 2). These two systems are familiar for pupils. Nevertheless they are different in their use, structure and capture, treatment and transmission of information. This choice is founded on the fact that, even though these systems are both software dependent, they have unique and contrasting characteristics. Our hypothesis is that these opposite characteristics will induce distinct levels of understanding of the objects' functioning. The Navigo pass'e appearance as a simple plastic card hides its internal components. This characteristic prevents the user from thinking in intraobjectal terms. By contrast, the IWB was chosen because its components (projector, computer and board) are clearly apparent, thereby enabling components-evidence based thinking.

Figure 1: Navigo Pass

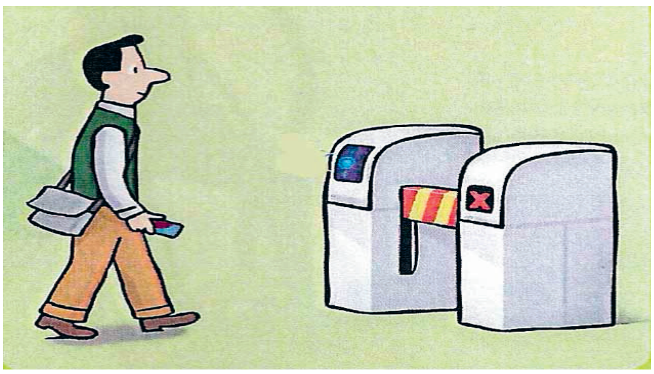
Figure 2: Interactive White Board

Two explorations have been driven with two different Parisian groups during 2010 and 2011. The first survey centred on RFID is based on 368 junior high school pupils (year 9 -10). The second survey centred on IWB concerns 253 pupils (year 7 to 10). Each survey is completed by exploration of adults' ideas: 32 tertiary students and future teachers (RFID) and 23 teachers (IWB). The collection of pupils' or students' and teachers' explanations has been implemented in a first time by questionnaire. In a second time interviews have been organised with couples of pupils (survey 1) and with each teacher (survey 2).

4. First Survey

After different tests, the questionnaire is laid out on one page A4 only is structured with a short introduction and two questions (figure 3).

SURVEY: How does the Navigo Pass works?
You use a Navigo Pass in urban transports. It's very practical and enables you to gain time.



I. Please write With your own words how you think the Navigo Pass works. You may use drawing for explanation.

II. Please indicate if other objects work as the same according to you.

The corpus of answers for each question has been read first and then studied in order to identify the key-expressions i.e. words or ideas-phrases, (cf. Henry & Moscovici, 1968). The quantitative analysis indicated the main pupils' spontaneous knowledge (Table 1; no responds or users' opinions: 17 %). As pupils mentioned several ideas, the cumulative percentage is upper than 100 %.

Smart	Magnetic	Detection	Information	Code	Infrared	Signal
31 %	19 %	17 %	8 %	7 %	4 %	3 %
Validity	Waves	Contact	Radar	Sound	Electromagnetic field	Scanner
3 %	3 %	2 %	2 %	2 %	2 %	1 %

Table 1: Key pupils' spontaneous knowledge

This first distinction enables to define three relevant categories (Table 2).

Categories	Key-words	Examples
Object	Smart, radar, scanner…	It's an electronic smart system
Principle	Magnetic, infrared, wave, contact…	It's the card that does waves with the machine and it opens the gate
Function	Information, validity, detector	We enter if the card is valid.

Table 2: Categories of the content analysis of answers

Unsurprisingly the analysis highlights that the great majority of pupils don't know how the Navigo-Pass works. Only one pupil knew the RFID system and explained it. The general idea (1/3 pupils) is that Navigo-Pass is a smart card which working under the influence of a magnetic field. The data transfer is rarely mentioned. This spontaneous knowledge is underlined within the second answers. Pupils noted that other similar objects were: badges or card-pass (50 %), payment card (12 %), phone card (4 %).

These results were consistent with the concepts and ideas expressed by the interviewees. Indeed, we also found that the questioning enables pupils' discussion that allows they to progress in their conceptualisation and to abandon their spontaneous ideas. They discover progressively that the issue is the remote control. Then they imagine different principles but don't have any elements in order to argument a hypothesis of theirs. The two following extracts were chosen as an example:

Q: How do you think Navigo-Pass works?
Johanna's answer: But, technologically?
Jean's answer: Bah, it's the card which does waves with the machine and it opens the gate.
Johanna's answer: It's magnetic, isn't it?
Jean's answer: Yes, that's what I mean; I didn't mean waves. It's something that bustles when we are near the barrier; that deactivates something.

Q: Why do you think about magnetism?
Johanna's answer: I don't know. It's because we don't press a button. It's not necessary to touch the thing.
Jean's answer: The fact that attracts, that is at distance.
Johanna's answer: Then, it allows going faster.

Q: Do you think if we slide a magnet upon the device it can activate the mechanism?
Jean's answer: If it has the same properties, Yes!

Q: What properties? What is special within the transport card?
Johanna's answer: But, inside the card there is a chip or something like that? Inside a magnet there is no chip, thus it doesn't work. Otherwise everybody could through!

The interviews reveal that the pupils' understanding is mainly limited by the lack of knowledge. They don't know this technology and they can't invent it of course! Nevertheless it seems that there is not any epistemological obstacle for its description and discovering as a specific remote control. Based on the didactical orientation of Giordan & Pellaud (2008) who suggest that learning is in fact moving from an initial conception not very effective to a conception more adapted to the new situation, there are three didactical proposals: 1) implementing school activities based on the comparative analysis of different cards (magnetic cards, smart cards, RFID cards); 2) explaining the induced current in order to understand electric energy of the card without battery; 3) developing documentary surveys of the different technologies. The interviews show that the best pedagogical approach would be to encourage pupils' spontaneous explanations in order to enable them to identify the different issues: the remote control, the automatic device, the role of the card components and the data capture, their transmission and treatment. This last point would allow to understand the tracking that is never identified and nor imagined by pupils. In addition, the questionnaires and the interviews reveal pupils' greatest difficulty: their lack of vocabulary and concepts in order to describe precisely or analyse systems or artefacts and thus move from intra-objectal level to interobjectal level.

5. Second Survey

The exploratory survey is driven with the same procedure. The questionnaire consists of four questions.

SURVEY: How does the IWB work?
A new technology called Interactive White Board is currently introduced in classrooms.

I. According to you what are the necessary devices in the IWB.

II. Please write in your own words how you think it works. You may use drawings for explanation.

III. The WIB is a numerical and interactive board.
– Why is it a numerical board according to you?
– Why is it an interactive board according to you?

IV. Please, indicate if other objects work as the same according to you.

The first question identifies the components (table 3). Surprisingly, numerous pupils forget one or several main components. Only 1/5 pupil mention energy. The internet connection or the software is very rarely mentioned. There is a little difference between year 7 or year 10 pupils. The first component named by the youngest is the video projector while the oldest named the computer first.

Component	Video Projector	Computer	Pointer	Board; Screen	Electricity	Remote control	Internet	Software
%	78	73	63	28	20	8	2	1

Table 3: The components of IWB (n = 251)

The data concerning "how it works" have been analysed with word identification or ideas-phrases. The answers may be classified as four categories according to their meaning:

– The category "connected" focuses on the relationships between the components;
– The category "command by computer" underlines the core component:
– The category "elements" indicates a few components unrelated to one another:
– The category "button" is based on the actions only:

The answers don't explain the functioning but give a partial description of the system only. The youngest pupils' answers are less complete than those of the oldest pupils. The answers focus mainly on the material aspects without analysis of the data transmission and without interaction from board to computer.

The word "numeric" is unknown (only 1/3 pupils answer) and is interpreted in three ways: connexion with a computer, tactile commands, pictures.

The word "interactive" is also unknown. The pupils' answers link it with tactile actions without indicating inputs. Only a few answers (n < 10) associate it to computer or playing action. These spontaneous ideas are close to the information of similar items (question 4). There are either different objects with tactile interface (phones, digital tablets...) or objects of world pictures or world games (TV, video, camera..., game console) or more simply computers.

The questions of the interviews surprised the teachers, even the two technology teachers. Among the 23 teachers, only six of them mentioned the software and its importance. One of the teachers explained that the communication between the electronic pen and the board was established by a "radio signal". Generally users don't question the technological system. But they speak easily of its "interactivity" with a pedagogical point of view only.

Major findings of the second survey show the unawareness of the IWB system and the lack of interrogation of teachers. The IWB is used at school without explanation of the technological and information system. When they are asked pupils or teachers according to their own experience analyse the set by the organisation of its components and visible relationships between them. Then it is only an "intra objectal" analysis founded on the actions of use. One important fact is that pupils' answers show certain sensitivity. When they try to explain the functions they underline the relationships between two components. This partial conception may be a support in teaching-learning and in progressing in the understanding of technological systems.

6. Conclusion

These two surveys of questionnaires and semi-structured interviews are only centred on how these complex objects work and how they are made.

– The qualitative and quantitative data analysis reveals the following:
– The prime identification of each artefact is perceived as an object itself or as a compo-

nent of one set; the RFID Card is seen as a smart card or magnetic card and the Interactive White Board is identified as a computer and video projector;
- This spontaneous approach is both perceptive and material; the immaterial components of the software or the information flows are not mentioned, but appear in interviews only;
- There is no great difference between pupils according to their age or grade in school;
- The scientific and technological vocabulary is poor; pupils don't have the words to describe or explain the artefacts or systems.

But, one of the results shows also the lack of interrogation of pupils. They are surprised by the questions. Use appears more important than the understanding of the functioning of these familiar artefacts. It seems that teachers do not stimulate their curiosity and let them be in the attitude of user or customer. It's a great issue for the development of technological literacy.

Nevertheless pupils' discourses highlight different useful elements in design and implementation of new activities: the necessary consideration of their spontaneous knowledge and confusions, level of their partial approach, possibilities of their extension in a socio-constructive approach. These results enable researchers or policy makers to discuss the contents of Technology Education, their updating according to the contemporary world and the school opportunities in developing young pupils' technology awareness. The future of Technology Education is linked to the ambition of enabling pupils to build concepts and models in order to read and understand the complex technology systems that they mechanically use. Perhaps it would be necessary to establish a relationship between formal and informal technology education and thus define a new curriculum for basic school with some kind of popularization like Demers and Llull (1982) have already suggested it.

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Action Research study with Technology teachers in Limpopo Province of South Africa: an Emancipation recipe for Technology teachers

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Key words: technology education, technology teachers, action research, reconnaissance study, curriculum transformation/reform, emancipation/empowerment

Abstract

The extent of South Africa's (SA) un- and under- qualified teachers amongst technology senior phase teachers has intensified and reinforced that action research (AR) be regarded as a tool for emancipation in the teaching of technology as is apparent from this study. The purpose of the paper is to report DEd inquiry findings from the action research activities that took place in selected schools of Limpopo Province. For technology education – a foreign concept to many teachers and a new learning area in the school curriculum both nationally and internationally – has found its way into the school environment successfully and effectively through engaging informants with the action research approach. In all the spiral activities of planning, observation, action and reflection during the AR cycle contact sessions with participants, the main goal was to address the following research question: *How can an action research intervention be used to improve the teaching practice of senior phase technology teachers who are under qualified?* The presenters argue that inadequate training of technology teachers impacts negatively on their teaching practice. The study did identify the gaps and an appropriate progressive intervention was embarked on.

The research was designed from both a critical theory perspective and a participatory paradigm. The following instruments were used as a means to gather data: observations, interviews, questionnaires, field notes, video recording of lesson plans and logs of meetings. The research findings reveal that most technology teachers were not trained or qualified to teach technology with confidence and every chance of success until an intervention in the form of action research was introduced which has successfully change their situation.

Orientation and motivation for the study

The implementation of Technology Education within the school curriculum has been a hurdle for both teachers and learners (Pudi, 2007). The successful implementation of the technology curriculum is dependent on teachers having a solidly established personal construct of technology equivalent to that of the curriculum (Tholo, Monobe and Lumadi, 2011). Over a decade many countries, South Africa included, have reformed their school curriculum to establish technology as a recognised learning area with a focus on developing students' technological literacy and to prepare students for the new industrial demands (Gumbo, 2010). Jones, Buntting & de Vries (2011) concur that the last two to three decades have seen technology education emerge as a subject in its own right in many countries around the world. It is obvious that if technology education is introduced as a completely new learning area (subject) in the curriculum of any country it will engender the need for extensive in-service teacher training (Potgieter, 2004).

The advent of technology education, nationally and internationally, has posed challenges different from those experienced in regard to other learning areas, contends Rauscher (2010). Amongst the multiple challenges that can be mentioned, teacher development and emancipation becomes prominent as it is the technology teachers that are placed at the forefront to teach students this relatively new subject. Ever since the introduction of technology education, the teachers are still grappling with its pedagogy and didactics. Technology learning area (TLA) needs skilled teachers. It is poignant to disclose that 99% of the teachers teaching technology have no qualification to teach the subject (DoE Gauteng Memo 202, 2004; Nkosi, 2008; Lovington, 2009). The situation seems worse in Limpopo Province which is among provinces known to be underperforming. We therefore chose one circuit in this province to conduct this study.

The study reports on the interventions in technology teaching that has yielded some improvement with the senior phase technology teachers. These emancipation activities of applying action research (AR) cycles help to answer the teachers' training demand that overwhelms the Department of Education (DoE). So many studies have been carried out previously by other scholars concentrated on other aspects of teaching technology. However, little research has been conducted on AR with technology teachers. Therefore we attempt to fill this gap by engaging technology teachers with a critical theory perspective through a participatory paradigm.

Value and application of critical theoretical framework

In the context of this study, critical theory is a social theory oriented towards critiquing and changing technology teachers' circumstances, i.e. their limited technological knowledge and how to teach it. This study would hopefully create enough awareness in these teachers to be able to pass judgment on their didactics of technology and to evaluate their knowledge base of technology with the sole purpose of being emancipated from this situation (Creswell, 1994).

Critical theory indicates that there is a fundamental dialectical relationship which confirms that theory and practice are indivisible (Tooley, 2000), especially in technology. This aligns well with our understanding of technology education, that it is fundamentally a hands-on enterprise. Hands-on in technology must be taken to refer to learning through experiences, that is, through practical engagement in investigating, designing, making, evaluating and communicating ideas and plans (DoE, 2003). Approaching technology theoretically is unfathomable.

Research question

These activities were undertaken to respond to the following research question:

> *How can an action research intervention be used to improve the teaching practice of senior phase technology teachers who are under qualified?*

In responding to the above mentioned question we came with up a research design that is comprehensive. The next section is dedicated to the research design of the AR main study phase 2.

Research design

This is an action research (AR) study. The purpose of AR is to solve classroom problems through the application of a scientific method (Gay, 1987). The AR cycles with technology teachers was undertaken as follows:

The cycles were conducted with the participants as scheduled in table 1.

Table 1: Schedule for action research cycles

Cycle	1-One	2-Two	3-Three	4-Four	5-Five
Date	08 till 12 March 2010	31 January 2011 till 04 February 2011	18 till 22 April 2011	30 May 2011 till 03 June 2011	01 August 2011 till 12 August 2011
Purpose	Reconnaissance study & participants lesson presentations	Feedback & feed-forward of cycle on findings.	Addressing thematic challenges.	Showcasing technology projects.	Wrapping up AR cycles. Participants presented lessons.

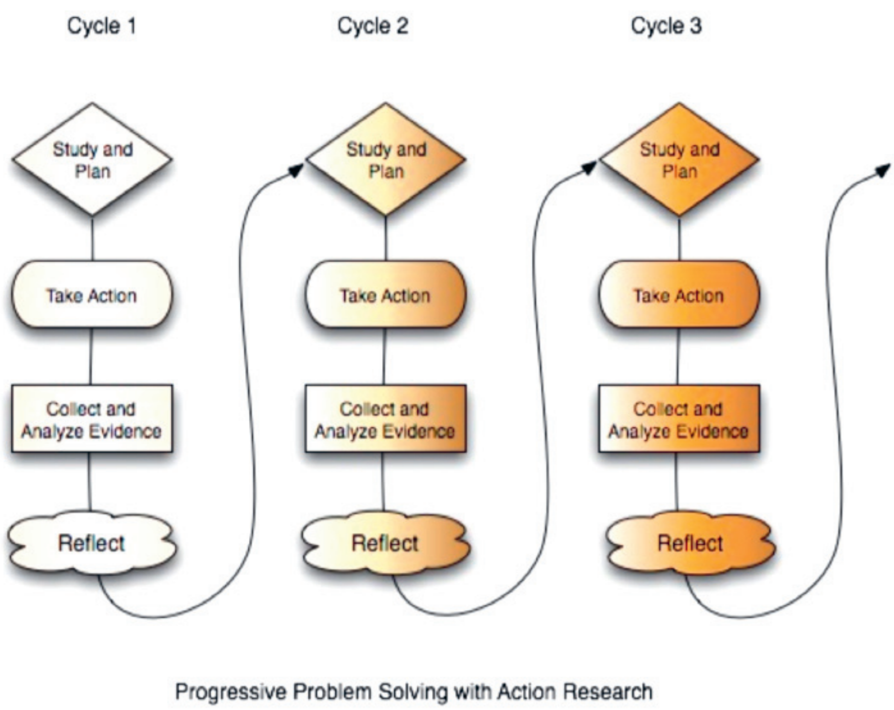

Figure 1: Progressive problem solving with action research

Action Research (AR) is a way of learning from and through one's practice by working through a series of reflective stages that facilitate the development of a form of "adaptive" expertise as displayed in figure 1. Different instruments for data collection were incorporated in line with the nature of activities per each cycle as indicated on the cycles and their findings below. We hoped that both the novice and experienced teachers involved in this AR study would be empowered to teach technology in the General Education and Training (GET) band irrespective of their contextual setting. The study would contribute significantly to action research studies in the field of technology education.

The sample was drawn from Capricorn Region at Mankweng Circuit of Mankweng District in South Africa. The choice of Mankweng Circuit was prompted by the lack of technology knowledge observed previously by one of us as stated above. The aim of delineating the scope of the study was to implement some intervention strategies to a manageable sample of technology teachers teaching these grades. Mankweng Circuit was chosen for a cluster sampling strategy. In this cluster sampling, groups of senior phase technology teachers were randomly selected (Gay, 1987) in terms of their schools.

The total number of the sampled technology teachers is reflected per school in table 1. Some taught Grade 8 only; some taught Grade 9 only while some taught both grades.

Table 2: Sampled schools and technology teachers

School name	**Sampled technology teachers**				**School milieu**
	No. per school	**Grade 8**	**Grade 9**	**Both grades**	
KMK High	7	2	2	3	Rural
VMV High	3	1	2	none	Urban
RMR High	3	1	1	1	Rural
BMB High	3	1	2	none	Rural
WHW High	2	2	2	2	Urban
Total	18	7	9	6	

Cluster sampling was drawn from five high schools (see table 1 in this regard) in Mankweng Circuit. Cluster sampling is characterised by some degree of homogeneity (Maree & Pietersen, 2010). The sampled high schools are located in varied milieus, that is, rural and urban schools. It should also be noted that our focus was on a total of eighteen technology teachers sampled from these schools. Pseudo names were assigned to the schools to conceal their true identity.

A variety of data collection techniques were incorporated; those are non-participative observations, structured interviews, qualitative questionnaires, field notes, logs of meetings, audio and video recordings. Data analysis followed a thematic and narrative form. Themes emerged from the analysis. This process of data analysis focused on understanding the teaching and learning actions and events within the participants' settings and contexts (McNiff, 1988; Ferrance, 2000). According to Wadsworth (in Maree, 2010), multiple methods help the researcher to overtly seek different kinds of views and perspectives from data sources and also helped us to overcome the bias that could result from the use a single method.

A day was spent at each school to observe technology teachers presenting their lessons. A designed observation grid was completed. The observation was followed by interviewing the teachers using the code of responses on a prepared printed schedule. During the observations video recording of participants' lesson presentations were undertaken. Finally, they were given a questionnaire to respond to. On the last day of the contact session the participants and I have a meeting to reflect on the completed session and plan a way forward for the next cycle.

Findings

From participants' biographical information

We start by presenting the findings from technology teachers' biographical information as captured in table 2.

Table 3: Senior phase technology teachers' biographical information

Gender		Technology teaching experience		Technology qualification		School milieu		Can plan technology lesson	
m	f	less than 6 yrs	more than 6 yrs	yes	no	rural	urban	yes	no
9	9	11	7	7	11	13	5	10	8

Participants in total from the five participating high schools, nine males and nine females. Eleven participants had less than six years of technology teaching experience when seven had more than five years of technology teaching experience whereas seven had more than six years technology teaching experience. Eleven participants did not have any technology education qualification; seven had some form of qualification. Thirteen of the participants worked in rural areas whereas five worked in urban areas. Ten participants could plan the technology lessons whereas eight still needed some help.

Integrate data sources for the reflection of findings

The themes were selected to cover aspects of technology teaching from policy interpretation to the classroom practice. These themes include technology-specific teaching experience, technology lesson planning, technology assessment, and level of internal and external support for technology teaching.

Displaying participants' responses of technology learning area (TLA) teachers in two versions, before AR (i.e. cycle 1) and after AR cycles (refers to last day of cycle 5) of contact sessions under the following themes:

Technology-specific teaching experience
How do you find the teaching of TLA? Share some of your technology teaching experience.

Before AR cycles

Bearing in mind the above question, most of technology teachers are generally uncomfortable with the pedagogy of technology as it was observed and revealed from the interviews. Some did not even have any interest in teaching technology as one contended:

> "It just came along while I am already teaching and I didn't develop any interest in the subject"

The response and reaction of the technology teaching experience after the AR cycles sounded different as mentioned below.

After AR cycles

The response to the same question after the AR cycles is really quite opposite to the initial one. It's evident of the impact that the intervention strategies applied from cycle 2 to cycle 4 had on the technology teachers. The impact can be evaluated from the statement below uttered confidently by one teacher during our last AR meeting:

> "I find it to be interesting and practical. Since I started teaching technology I realised that demonstrations make a lesson interesting and realistic".

The situation of technology teachers has serious implications on their level of capacity in terms of planning lessons for technology teaching.

Technology lesson planning
Why are you teaching the learning area (technology)?

Before AR cycles

Many teachers of technology were asked to volunteer to teach technology. As a result many do not have any qualifications in technology education. Some may be qualified and experienced in other subjects, but not specifically in technology education when they were asked to cross over into technology. In responding to the interview one teacher responded by saying:

"It was just allocated to me".

After a consent form was signed by all the participants, a full roll out of AR was undertaken. A teacher response is stated below after the AR cycles which reflect a better insight of technology.

After AR cycles

Given the background before the AR cycles, and the findings from the teachers' biographical information in table 3, technology teachers held reasons for teaching technology which ranged from being coerced into teaching it to basically having the no option than just being assigned to teach it. There was a new mind set for teaching technology after the AR cycles. For instance, the interviews revealed one teacher stating:

> "It makes me to be more interested in teaching the technology field because my mind is now broad".

Technology assessment

What are we assessing and what are forms of assessment are you are using in technology?

Before AR cycles

Assessment should ideally be integrated with planning so that teaching and learning activities are not devoid of it. An interview question sought to establish the assessment methods that technology teachers applied during their teaching. One teacher responded by not really giving the answer that we sought in this regard:

> "We are assessing skills, knowledge, attitude and values. We evaluate learners' performance''

After AR cycles

One of the Mathematics, Science & Technology Head of Department commented during the last cycle after assessing his staff member report that: "The strategy of assessment implemented was appropriate, guided by the gathered information. The assessment tasks relate to Learning Outcomes and Assessment Standards".

Level of internal and external support

The participants have to rate their support from within the school and outside.

Before AR cycles

Technology, being relatively new in the curriculum, may not thrive without a concerted commitment to empowering technology teachers. Teachers were keen to see support both from within and outside their schools to help them develop in the knowledge and teaching of technology. They expressed this need as follows during the interviews:

> "The principal should develop an interest in technology education so that he cannot have a problem in allocating a budget for technology education".

After AR cycles

Based on the internal and external support we will present what one teacher has said on the questionnaire open question: "Could you still be our mentor even next year (2012) since we haven`t specialised in technology. Your presence is making a huge difference in our schools and in our lives. We really understand that now we are the same with other provinces that had technology long before us. Please come back next year to iron out issues that are still problems. Thank you and wish you a wonderful journey in your research project. God bless".

Conclusion

This study set out to emancipate senior phase technology teachers teaching in Grade 8 and 9 at Mankweng Circuit of Limpopo Province in South Africa regarding their knowledge and didactic of technology. The paper report about the next step embarked on after reconnaissance study, which is the main action research study phase 2. The study employed action research spiral cycles to intervene in the challenges that the teachers faced as a way of addressing the research problem. The findings from the study confirm to a great extent that interventions strategies during AR cycles of contact sessions can be employed as a recipe for emancipation in favour of un- and under-qualified technology teachers.

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Values in design and technology education: Past, present and future

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Keywords: Values, curriculum, technology.

Abstract

This paper explore values and design and technology in two ways, Firstly in looking at how the subject is valued by stakeholders and secondly by looking at how pupils can explore values issues through design and technological activity. It does so at a key point in the history of design and technology as a curriculum subject within the statutory curriculum of England.

In exploring values issues in these ways, the paper draws upon the work of David Layton who wrote two important texts on the same issues 20 years ago. Key issues emerging from curriculum development activity in that period are discussed along with a framework of activities to undertake with pupils. The paper concludes by making the case for reinforcing the centrality of values within design and technology education at the present time.

> *Values and value judgements are the 'engine' of design and technology. Judgements about what is possible and worthwhile initiate activity; judgements about how intentions are to be realised shape activity; and judgements about the efficacy and effects of the product influence the next steps to take. Value judgements, reflecting people's beliefs are ubiquitous in design and technology activity.*
>
> Layton 1992a:36

Introduction

The subject of design and technology, as has been understood in England for the last 20 years, is under threat with a government set on reducing the statutory curriculum requirements. Its future is being discussed, as will be seen below, and potentially re-shaped by a number of stakeholders each of which come from particular perspectives.

Discussion about the curriculum tends to focus on the overall aims of the subject and the relative proportions of designing to making activities. In the process of planning for the future, however, it is important that there be a discussion about the extent to which values issues are explored with pupils.

Technology and values

Given that values issue within design and technology education have been written about for the last 20 years it should not perhaps be necessary to provide an explanation of the relationship between technology and values. At the point of writing, however, there is a feeling that the centrality of values has been missed and the ways in which technologies are manifestations of values are not being recognised.

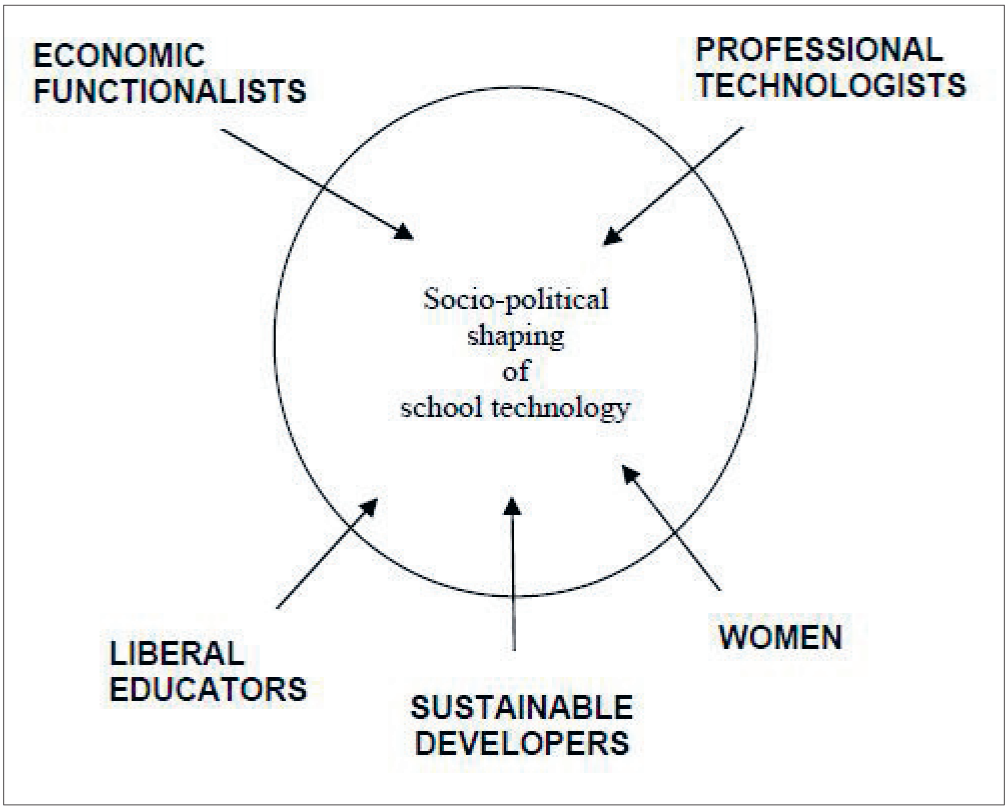
The relationship between humans and technology is long and it can be argued that human development is linked directly to technological development – that we have only developed as result of technological advances. Heidegger (1977) discusses technology as it affects how we see ourselves as human beings and expresses concern about the ways in which technology affects who we are and how we are. This view is reinforced by Pacey (1983) who provides examples of the positive and negative effects of technology transfer.

With the increased use of modern manufacturing technologies it could be argued that we are getting further away from being directly involved in the design and making of products and that our understanding of what is involved in the process has narrowed. Without design and technology as a general part of pupils' education, the knowledge of the means of production will be held by a smaller and smaller portion of humankind. As this happens it is important that we recognise the importance of developing not only informed users, but individuals able to express their views about technology as a whole.

The value of design and technology

1992 a key point in history...

Two works written by David Layton, both with the title of 'values and design and technology' (Layton 1992a, 1992b), reflected the state of the subject at the time. Having been introduced as a statutory subject in 1990 (DES 1990) there was considerable debate about it's role as part of the statutory curriculum. The heavily biased and under-researched report by Smithers and Robinson (1992) said that the technology curriculum was 'in a mess'. Only 2 years after the introduction of the statutory curriculum this was unhelpful and said more about the biased views of the Engineering Council than a critique of the curriculum in practice. Layton (1992a) presented a coherent view of the debate by presenting different categories of stakeholders as can be seen on the diagram below. Each group of stakeholders had specific views about what areas of content should be highlighted and the purpose of the subject.



Layton (1992a: 3)

Between 1992 and 1995 there were many different version of the curriculum produced by those responsible for the curriculum e.g. NCC 1992. Each one of the versions of the curriculum reflected a different pattern of stakeholder influences upon it. Over time these iterations ended in what we recognise as the basis for the subject in England today.

2012 a key point in history…

Currently the subject of design and technology is again under debate and it's future as a statutory part of the curriculum in England is uncertain as the government in England works on reducing the requirements. As was the case 20 years ago, there are different perspectives on the value of the subject and again recognisable stakeholders.

The context is, however, different than that of 20 years ago not least as there are 20 years of history in between! When discussing the future of the subject, stakeholders are able to draw on what they have seen in school whether this be good practice or not. Whilst the debate is still there, it is influenced by the success, or failures, of teachers as deliverers of the unique contribution to pupils' general education.

Have we developed creative individuals who can work both independently and in groups? Do we have a generation of individuals who are comfortable with CADCAM technology and are aware of manufacturing systems? With regard to the issue of values have we been able to develop the personal attributes in young people that enable them to work in our technological world as informed users rather than passive consumers?

One of the strongest voices at the moment is that of professional engineers such as Dyson who when interviewed, said of design and technology:.

> *Without it, it will be even harder to inspire young people to go into the engineering professions and develop new technology.*
>
> Smithers, R (2011)

This is not a surprising perspective given the rise of STEM (Science, Technology, Engineering and Mathematics). Linked to this voice there are those interested in vocational aspects (economic functionalists) and we are now seeing in England the setting up of University technical colleges (www.utcolleges.org).

Another stakeholder group are sustainable developers and this can be seen from the move to include issues about the relation between technology and human need (QCA 2007). Certainly the world of design has moved to include aspects of sustainability and this is likely to become more central in the future.

Layton (1992a) highlighted another group – that of liberal educators. This group of stakeholders were interested in providing young people with access to technological activity as a unique part of their education. It could be argued that in no other area of the curriculum do pupils see in 3 dimensions the result of their own thinking and decision making. Within our increasingly technological society where the link between people the means of production are getting wider and wider, it is important that young people understand how technology comes about and have experience of being involved in the process.

Looking at values issues in design and technology

An important issue in 1992

David Layton was involved in developing the Interim Report for the Technology curriculum (DES/HMSO 1989) which contained the programme of study for design and technology. Whilst the idea of pupils exploring values issues was implied within the curriculum document it was only in 1992 with the publication of Make the Future Work (Budgett-Meakin 1992) that a fuller, coherent, justification for the inclusion of the issues was given by Layton.

Following on from David Layton's keynote address a special interest group was set up within the IDATER conference. The subsequently led to the formation of VALIDATE which was active for a number of years. The effect that this group had on the curriculum is hard to define but it did stimulate debate and a number of papers and resources were produced at the time.

At the turn of the millennium there was a gradual change in emphasis by those who were writing about values in the 1990's. Ethics and sustainability, in particular, were becoming more popular topics and the number of papers written explicitly about values issues in the subject dropped dramatically. This is not to say that the issues disappeared altogether. Literature about sustainability, for example, is written from a values perspective. Take for example the literature developed by Practical Action (www.practicalaction.org). Whilst this focuses on sustainability it is underpinned by a strong values position that promotes positive images of other cultures.

An important issue in 2012

It is recognised within the curriculum that is used within schools at the moment that issues dealing with the relationship between humans and technology are important (refs) Issues of sustainability are to be discussed and support materials are much more widely available than before. Values issues per-se, however, are not explicit within the curriculum and are indeed not included within the debates about the future position of the subject. Could this be that it is taken for granted that they are subsumed within other things? Or have we as a community of practice ignored this fundamental area of the subject.

Of course values are always present, as Layton (1992b) says. It is the extent to which we expose this underlying bedrock through the work that we do with young people. It can be argued that more than ever we are in need of developing a critical view of technology (valuing) and need to be aware of the consequences of technological activity.

The exploration of values issues is much more than just being critical of design and technological activity however. The very personal, perhaps spiritual, nature of products that have been made by individuals is something to be valued. Layton (1992a) talked about different types of values namely: technical, economic, aesthetic, social ,environmental, moral and spiritual / religious.

Exploring values in design and technology

How in the future are we to facilitate the exploration and exposure of values in technological activity by pupils in schools? To answer this question is to draw on the last 20 years of curriculum development and draw out the issues that have been discussed and the ways in which hands-on activities can be developed to support pupils learning.

Looking at existing products

Product evaluation is a way of enabling pupils to look at the values embedded within products. With enough information about the product it is possible for them to get an insight into the motivations of designers and the appropriateness of the product for the users. The information about products has become more accessible in recent times and can take different forms in different media.

In addition, looking at the work of others enable pupils to explore how they personally view products and their personal preferences. The fact that different pupils will have different preferences, or values position, when it comes to looking at a selection of products can be a positive influence on how they themselves design.

Planning and evaluating pupils' work

In addition to looking at the work of other people it is important that pupils look at what they themselves have been doing. At the point of exploring contexts for making, deciding on materials and at key points throughout their designing, values come into play. The underlying values can be exposed through questioning and self-evaluation in order to build an understanding of the significance that such underpinning has on the final outcome. Looking at each other's' work, through carefully structured peer evaluation, can also be valuable.

Understanding technological systems

It could be argued that one of the most important aspects of values in the design and technology curriculum should be in looking at technology outside the classroom. This perspective of technological literacy is a significant, at least on paper, part of the curriculum documents of a number of different countries, notably the USA (ITEA 2000). More recently this is beginning to be discussed in England as a more significant component. Curriculum materials looking at the effects of technology across different cultures have been around as part of the Nuffield materials for the last 20 years (Nuffield 1995). How much they have been used is not known but it one can speculate that they have not been looked at much.

So what technologies or technological systems should pupils study? In the United States the curriculum comes under the heading of technological literacy which is broken down into different areas such as medical technologies; agricultural and related biotechnologies; energy and power technologies; information and communication technologies; transportation technologies; manufacturing technologies and construction technologies. (ITEA 2000). Whilst this is understandable it is a very simplified taxonomy and one that has more to do with different industries than the nature of technology as a whole. A much better way of categorising technological systems is to look at them from the micro to the macro in terms of the relationship they have to pupils.

Designer	User	Context	Complexity
Self	Self	Home	Single element
Other pupil	Other pupils	School	Joined elements
Single designer	Others outside school	Community	Multi-material
Organisation	Organisation	Commercial	System

Martin 2007: 164

One of the more complex things for pupils to learn will be that different people have different views about technology in the wider world. In addition it is important to learn that information about technology written by others as can be found through the internet may not be accurate. It is therefore important that pupils develop their own views and critical faculties.

Whilst the subject of design and technology was focused entirely on developing practical skills there was no need, or no curriculum driver, for teachers to engage in a discussion of values and potentially controversial, issues. The curriculum has evolved from that model and now very much includes the development of attitudes as well as the acquisition of skills. Teachers must therefore begin, if they have not done so already, to discuss values issues with pupils and broaden pupils understanding of the nature of design and technological activity. This is an entitlement of the curriculum.

Exploring contexts

Pupils look at contexts that they are presented through design and make activities. In addition, pupils can explore other contexts within their own culture or indeed the context of those in other cultures. Considering the needs of others is an important part of developing an understanding of how products and technological systems come about. Looking at different cultures does, however, need to be handled with care. Developing empathy with others through an exploration of their context is one thing. To 'solve their problems for them' is quite a different matter and misunderstands the whole purpose of exploring contexts (Siraj-Blatchford 1993)

Conclusion

Margarita Pavlova and James Pitt in their work on sustainability discuss perspectives that people can adopt. One of these is sustainability as a ‘state of mind’ (Pavlova and Pitt 2007: 82) affecting every decision that one makes as a natural process. A recognition of the place of values embedded in design and technological activity would be to adopt a values perspective as a state of mind and as a way of operating in the world.

Design and technological activity undertaken by young people, involving the design and manufacture of products in response to human needs and wants within contexts is valuable for the following reasons;

Firstly as a form of technological literacy it is important in developing pupils understanding of technology and how we value it’s use and are aware of the consequences of its existence through the effects on others and the environment.

Secondly it is important in providing opportunities for young people to work in a practical way, accessing the domain of technological knowledge and working technologically both individually and with others. This could involve the development of practical skills of using hand-tools and machines or the development of skills to operate machine tools through CADCAM systems.

Critical to the future shaping of the subject, and the extent to which values issues are discussed by pupils in schools, are the values and attitudes of teachers. It would be quite easy for any teacher, as they do, to decide not to include areas of learning as defined by the statutory curriculum. It will only be if teachers are persuaded of the value of values that pupils will be exposed to the true nature of designing and making.

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Applied Design Thinking LAB Vienna:
INTERACCT. Interdisciplinary Technology Education in the 21st Century

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Abstract

INTERACCT is a project where two universities in Vienna (University of Applied Arts Vienna: Institute of Art Sciences and Art Education, Department of Design, Architecture and Environment for Education; University of Vienna: Faculty of Informatics, Computer Science Didactics and Learning Research, and Research Group Entertainment Computing), CCRI (Childrens´ Cancer Research Institute), children of an Austrian high school (Schulschiff Bertha von Suttner) and T-systems (a division of Deutsche Telekom, *systems* integration, computing and network services and e-business) have been involved within the Applied Design Thinking LAB Vienna from 2009 until today. Aim of the project is to enhance interdisciplinary and participatory approaches in design and technology education. Case study is design of an interactive web based communication platform for improving quality of life for the patients of the stemcell-lab department (SCT-INTERACT) and to improve medical communication and education in outpatient care after pediatric hematopoietic stem cell transplantation (SCT). Spin-off is design of a serious game where healthy and malignant children are participatory involved as well as the students of different teaching subjects (informatics, art and design education), the caring medical staff and the industry partner.

Interdisciplinarity as teaching competency at universities and schools

The twenty-century academy organized itself firmly around the concepts of diciplinary conceptual structures, problems and methods. Europe is considered to take a second life through the „Bologna process“ in setting intellectual standards for disciplines, scholars are tuning the contours of „the disciplines“ for the twenty-first century (Schneider 2010, xv). In inter/transdisciplinary work, practitioners must be able to cooperate with fellow team members and make referrals and offer educational services (Klein 1990, 150). The National Research Council (NCR) of the USA tracked series of research reports and announced that most significant growth in knowledge production in recent decades was occurring due to Interdisciplinary Design Research (NRC report 1986, 1990). Interdisciplinary Design Research (IDR) tracked developments that were promoting increased collaborations between life sciences and medicine and between physical sciences and engineering (Klein 2010, 17). “Members of interdisciplinary teams are, in effect, translating specialized knowledge into a “synthetic product“, acting as filters for each other, consulting experts, and the ultimative recipients of their work, whether they are students, patients, clients or other scholars“ (Klein 1990, 190). The dialectical framework enables integrate of material from different disciplines and provides in teaching and learning a liberal or horizon-expanding education.

Brenda Bannan-Ritland stressed in her study of professionalization of teacher education (TDR – Teacher Design Research) the importance of learning, “which can prompt teachers to reconsider their core teaching ideas, beliefs, and competencies. (...) the instructional aspects of TDR come not from outside experts”, but, rather from the teachers´ cognitive dissonance experiences as designers in design cycles.” (Bannan-Ritland 2008, 246)

Design thinking is an interdisciplinary method and can be described ”(...) as a discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity” (Brown 2008). Its scientific origins can be found in the radical and social constructivism desiring to change society positively, focused on social or environmental items. The constructivist idea is the empowerment of the people, the participatory research with target groups, interdisciplinary nature, the plurality of diverse constructions, a holistic vision of our world, empowerment of critical questions etc. (Siebert 2005, 20). The process starts with “thinking out loud”, followed by iterating, creating and prototyping by having crazy ideas. In connection with designs for children as target group David Liddle (Liddle 2007, 244-251) proved that different methods have to be used: he suggested to work with the system of three phases (enthusiast, professional, consumer) to be more successful in structuring both the education and the practice of designing interactions. Instead of the formerly used user-centered or human centered design (HCD), in the 1990 participatory design increased to be today’s method (Schuler & Namioka 1993). Participatory design with children in pediatric oncology was applied and proved to be exceptionally successful (Vatne et al. 2008). The role of technology in communication design is discussed in Johannsen (Johansson et al. 2005, 3) from a general point of view and for children with cancer in Moe (Moe et al. 2007).

Keeping these examples in mind it seemed quite natural to start cooperation between art and science education and computer science education. Due to the fact that in both disciplines communication plays a major role it seemed interesting to start the cooperation with this topic. Designing communication systems requires nowadays high expertise in information and communication technology for future art and design teachers and for computer science teachers artistic aspects of communication play a vital role.

As an application case communication between malignant children and medical staff in a hospital was chosen. It should be mentioned that interdisciplinary work is hardly found in Austrian high schools, hence the idea is rather innovative for the Austrian school system.

Communication in Design & Technology: Machines as intermediary objects of communication

In our case we were interested in supporting communication between malignant children and medical staff in a hospital using actual information technology with interfaces, which meet user’s needs and fulfill quality standards of design theory. In a first round the different views of communication design were discussed and a common understanding of the languages in the different disciplines was developed. Art and design focus more on problems, shapes and various solutions, while in computer science main emphasis is on functional aspects of communication using a computing device as intermediary for communication between humans. Although these approaches look at the beginning quite different there exists considerable overlap in the area of interface design. Design theory developed by Alexander and others (Alexander et Al. 1977) is also popular in IT (Tidwell 2006).

Based on this common understanding for both disciplines the communication problem under consideration was analyzed for defining initial requirement specification. The challenges in this project are the complex communication process, involving patients, doctors, psychologists, physiotherapists, teachers, peers, nutrition consultants and social workers, in particular in the time after hospitalization Main requirements for the solution is helping the children in reporting details about health status and social problems. Besides these operational goals the planned (virtual) environment should support communication with friends and offer the children opportunities for leisure activities. An additional problem was the fact that a number of children have different native language than hospital staff.

From the discussions three different approaches evolved emphasizing different communication requirements. One group focused on a solution with mobile devices using as communication metaphor an avatar-mentor. A second group concentrated on a so called house metaphor realized with notebooks, and the third group was mainly interested in using nonstandard haptic interfaces for communication. The joint work of students from art, design and from computer science allowed examination of the three models from artistic and technical point of view over two semesters.

Metaphors of Communication:

(1) "Avatar-Mentor"

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The avatar-mentor should accompany the children as friend and authority, communicate in difficult situation such as not drinking enough or having forgotten to measure the blood etc., disappear when problems are solved and remind when something has to be done. Research was done by students, regarding their own "avatar experiences" in childhood and a fieldwork made with school children. Students proposed to use an "egg" as a basic shape for designing proportions of the avatar-mentor. In order to find out which characteristics influence trust in an avatar a questionnaire was designed asking children about their favorite appearance for the avatar, in particular basic shape, clothes, colors, accessories, hair, profession, age and gender. The survey was done in a research center for tutoring with 52 students (22 male, 30 female) between 8-16 years old. Conclusion: The basic shape "Egg" was accepted by 73% of the research participants. With respect to age and gender the most popular combination was "young woman"; 70% voted for this combination. The selection for cloth seems to be very much influenced by fashion, television and gaming. Fashion colors: red, blue, green, orange also violet and turquoise. In April 2011 a second more elaborated avatar survey was done with two case studies regarding avatar sympathy of 180 children at the age of 11-14 at a public school in Vienna, Austria. Further on existing avatars were tested regarding their evoking sympathy. Girls especially preferred animals as avatars or female avatars.

Participatory Design-Research was used by the means of involving children to design avatars for ill children. The briefing was the same for all: The avatar should accompany children, suffering from cancer and the drawings were interpreted with the methods of art psychology. The signs for evaluation of men (baby, puberty, adult) were assessed as well as specific symbols of age and accessories. Their characters were either differing in age or gender and one was developed as an alien.

Based on these results, a graphic designer developed avatars. These again were tested and evaluated by healthy and sick children. One must assume that sick children may have totally different preferences and this target group has barely been researched.

The interface is supposed to be understood with a "desktop metaphor", graphic symbols (buttons, toolbars) and nonverbal communication because many of the patients do not speak German. They should be motivated through easy handling. Surfaces, colors and forms should be easily personalized, and changeable. The application should work for users of all age. Facility requirements were: self-descriptiveness, simple controls, adjustable to every individual user environment, learning promotion; "drag-and-drop", "quick access"-systems. Some of possible icons were designed. Classic client-server architecture will be suggested and it will be designed in changeable modules for future solutions. The patient should be able to communicate with his medical support team easily by using his or her Smartphone. The patients should keep a diary. The medical mentor-team can have a quick survey of data of the patient and will be alarmed in case of irregularities.

(2) "House"
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Esra Kacar, Andreas Roncat, Anna Hatice Özgan,
Weninger, Desheng Wang, Katharina Weisssteiner

Spatial representation of information by using the metaphor "house" is very close to a virtual reality concept. The research focused on how one can design a virtual reality for the patients and which benefits can be driven, by using "house" as a metaphor. Children with SCT, with a weak immune system, isolated for month from their environment could imagine to obtain "their house" anywhere in the virtual world, which gives an impression of intimacy and protection (Pfister 1998).

Students researched on motivations for movements in virtual realities. The main points were considered as "achieve" and "relax" (Pasch 2008). Also important was the research of virtual environments for motor rehabilitation, which proved no flight from reality (escapism) or behavioral disorders associated with addiction (Holden 2005). Further on different already existing realizations of the metaphor were they evaluated PiNiZoRo: A GPS-based Exercise Game for Families (Stanley et al. 2010)

The first design was a "house" for a target group of 8-14 year old girls in a colorful pleasurable form and similar to MadTV with corridors and doors. Similar to the hospital, doors should lead to the medical team members The final design of the house project ended up in a virtual environment looking more like an estate with a number of building blocks for the different medical attendends, family and friends. The walkways between these buildings represented the different communication channels between the child and his support team. The main idea of the group was that these pathways adapt according to the mood of the patient and offered also a number of games in order to bring a child into good humor. Necessary data collection about health status is done in the different virtual rooms in an interactive way and the system responds to the user by presenting summaries of the status. For support of physiotherapy an interface with a Wii controller is forseen. A typical application scenario looks as follows: The child starts the system and a mood barometer pops up asking about todays temper. A door opens and the child can start a walk through the estate. Depending on the answer to the mood barometer the pathways have different appearance and lead to the doctor's door. Here the child has the opportunity to write a message to the doctor and look for advice. After passing this station the child is guided to the door of the diet assistant and gives a report about last meals. According to the diet plan an answer is given how to plan next meals and a bonus game is offered. The next station is the physiotherapist's world. Here a motion game is offered for improving physical conditions.

This application scenario shows that this proposal offers a conceptual approach for a rather complete solution of the problem and cannot be realized within one course. An interesting feature of the concept is that it allows monitoring of all patient activities and stimulating desired behavior from medical point of view. A prerequisite is development of an appropriate data model for collecting all information and a design strategy supporting all functionalities. It turned out that interaction of computer science students and design student was very fruitful. They made a first concept for the data model and experimented with different programming environments for the interface. SketchUp, Flash and Scratch were used for prototyping.

(3) Haptic Interfaces

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Bettina Hochrinner, Adna Karabeg, Hubert Stadler

This student group focused on a group of children at the age of 13+, having migration background. Contacts to children's peers reduce significantly with illness; after treatment they do not appear "cool" as a matter of skin problems and appearance in general, especially at the time of puberty. Hence, most of the patients fight against their illness as lone warriors and have low social contacts. In case of migration background the situation is worsened many times due to lack of knowledge in German language. Therefore the students decided to work on communication tools with other malignant children using communication devices with non-verbal haptic interfaces. Touch is very rare for them because of infection danger and uncomfortable feeling regarding their skin rash. Moreover the solution should motivate children by fun-factors and awarding communication.

So the students were eager to find something to satisfy their needs. They did research on happiness and motivation as well as how to praise their effort. One of the results was to design something collectable, because children love that. They did workshops to discover preferences of sound and haptic qualities. The collectable objects should be haptic and esthetically interesting, should have a small number, could be redesigned, should have a notional value, exclusive just for patients, and should be identified easily with the hospital. These objects should motivate to build up contacts, could be easily exchanged and should not be related to praise system. The children should enjoy with greatest possible independence. For technical solutions the group studied in detail nontraditional interfaces (Kortum 2008)

As a result ceramic prototypes of egg-like objects with different internal functions were produced and supplied with textures, which could be easily disinfected and cleaned. The egg-like projects have interactive sensors and should be charged by means of magnetic fields, induction. When force is applied on the objects, measured by sensors and signals can be sent and received. Light signals are reproduced, dependent on the force applied. Signal input may be performed through shaking, caress, pulling or pressing. Through the patient's own initiative an abstract language, secret codes can be invented. A primary coil of transformer is installed on the basic unit, secondary coil at the other objects. Iron cores of the transformer are placed next to the coil, transmission of energy possible.

Lessons Learnt

For designing interactions future art and design teachers need expertise in contemporary information technology. Besides the design of mainly functional structures, the superstructure of story lines, avatars, visual effects, motivational aspects had to be designed by the future art & design teachers in interdisciplinary teams. Working together in teams student teachers in design and computer scienece got first experience in interdisciplinary work. Technical basics and possibilities were communicated and the students even switched from their domain disciplines: art & design educators started to design with easy usable programs and IT students started to draw avatars for a research questionnaire. In particular Scratch was completely new for design students and it was impressive to see how one of the design students started to get totally involved with the IT world and started to program with SCRATCH (http://scratch.mit.edu/).

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Design Principles of Instructional Materials for Cultivating Attitude and Ability to Utilize ICT while Considering Ethical Issues and Safety

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Key Words: informatics education, cyber ethics, views and ways of thinking, instructional gaming materials, three types of knowledge for information moral judgment, teacher education

Abstract

Recently, performance standards have been defined in many subject areas in order to maintain the quality of school education. However, the quality of Japanese education is largely managed by controlling its contents through checking and authorizing textbooks based on national curriculum guidelines. In Japan, when teachers focus on educational content, they often expect students to memorize information, and when they focus on performance, they believe it is sufficient to achieve the objectives of the lesson as long as activities that simulate the context of daily life are occasionally offered. We believe that this existing quality management system should be changed to reflect that the objectives of education have shifted from providing knowledge to developing intellectual skills. Accordingly, teachers should consider the model of cognitive process as well as the relationship between this process and knowledge, rules, procedures, values, ethical codes, etc., that students are expected to learn. In this paper, we describe the development of a new e-learning material for Information Studies based on improved design principles derived from our previous studies. Our new e-learning material, "Security Policy" game, asks students to construct security policies for using a computer classroom in a school. In addition to analyzing the findings from experimental lessons, we describe a plan for teacher training that utilizes the game.

Approach to Informatics Education and Cyber Ethics Education

The necessity of informatics education has been highlighted in many countries. For example, the Programme for International Student Assessment (PISA) assesses students' ability to utilize information and communication technology (ICT) in problem solving (OECD 2009), and the Partnership for 21st Century Skills (2009), in participation with the US Department of Education, promotes information, media, and technology skills that students should master in order to succeed in work and life in the 21st century. Though media literacy educators consider informatics education as an extension of the 3Rs, with a focus on the objective of understanding information critically, we believe it should be implemented as a part of technology education. This is because informatics became necessary through the advancement of ICT, and therefore, students should learn how ICT works in order to fully understand its features.

To solve a problem using ICT, one must consider the quality of both the results and the method/process. The latter includes consideration of the ease, cost, safety, and efficiency of the process, which is important in any lesson on cyber safety and ethics. Though similar forms of education are often referred to as "information ethics" (Floridi 1999) or "digital citizenship" (Ribble & Bailey 2007), in Japan, it is known as information moral education (MEXT 1999).

Many types of instructional materials and teacher guidebooks are available for cyber ethics education. However, Hirabayashi et al. (2011) pointed out that most of them focus on negative instructions for students to memorize, such as "Do not..." and "It is dangerous because ...." Einaga and Matsuda (2007) further noted the following three issues regarding the current method of cyber ethics education in Japan: (1) The time allotted to lessons that focus on cyber ethics education is rather limited. (2) The instructional method that instills knowledge using case-based rules does not stimulate ways of thinking about questions such as "Why shouldn't one do....?" Therefore, it does not cultivate the ability to keep up with advances in technology. (3) The current method tends to foster a negative attitude toward ICT.

In order to solve the problems posed by (1) and (2), Tamada and Matsuda (2004) proposed an instructional method aimed at teaching cyber ethics judgment on the basis of a combination of the following three types of knowledge: "ethical code knowledge," "knowledge of ICT," and "knowledge of rational judgment." Then, in order to resolve the problem of (3), Hirabayashi et al. (2011) and Hirabayashi and Matsuda (2011) described an instructional method that integrates 13 items of "informatic and systematic thinking," which Matsuda (2003) proposed for effective use of ICT, with the three types of knowledge listed above. They developed e-learning materials based on this method and verified the positive effects of the materials on students' learning.

Hirabayashi et al. (2011) further pointed out that instructional methods for cyber ethics education in foreign countries also tend to focus on negative instructions. Therefore, their method may be applied toward improving cyber ethics education in other countries as well.

From Instructional Materials Design to Lesson Design

Recently, performance standards have been defined in many subject areas in order to maintain the quality of education. However, in Japan, quality of education is controlled by using national curriculum guidelines, set by the government, to check and authorize textbooks. Thus, quality of education is managed largely through lesson contents, except in subject areas where teachers emphasize practical works and seldom use textbooks. This system of quality management reflects an educational culture in which Japanese teachers tend to teach knowledge; they expect students to memorize important information when the class is focused on content. On the other hand, teachers in practical subject areas tend to consider that it is sufficient to achieve the lesson's objectives as long as activities that simulate the context of daily life are occasionally offered.

In this school culture, informatics education is conducted mainly in compulsory subject areas —"Information Studies" in upper secondary schools and "Industrial Arts and Home Economics" in lower secondary schools. Information Studies teachers emphasize either activities such as computer/software operation, multimedia design, and giving presentations and holding discussions after online research, or those such as memorizing the latest technical knowledge and judgment rules for cyber safety and ethics. This practice has led the Central Council of Education (2008) to point out that the existing instructional method of informatics education in Japan does not cultivate students' problem-solving abilities.

We believe that the national curriculum guidelines and approved textbooks are not enough to manage the quality of school education in Japan. Although the objectives of education have shifted from providing knowledge to developing intellectual skills, teachers lack the pedagogical training necessary to effectively reach this goal. They should strive to base their teaching approaches on consideration of the model of cognitive process as well as the relationship between this process and knowledge, rules, procedures, values, ethical codes, etc., that students are expected to learn.

According to Ishii and Matsuda (2003), teachers must realize three main goals to utilize ICT in lessons or to teach informatics: They should (1) recognize the necessity of developing students' problem-solving abilities, (2) understand features of appropriate lessons that foster problem-solving abilities, and (3) redesign their lesson plans accordingly. We consider that our instructional materials can be used in teacher education courses to achieve goals (2) and (3).

Purpose

In this paper, we describe the development of a new e-learning material for Information Studies based on improved design principles derived from our previous studies. The new e-learning material, "Security Policy," asks students to create security policies for using a computer classroom in a school. In addition, we describe a teacher training method that utilizes this e-learning material, based on findings from an experimental lesson.

Design Principles of Gaming Materials for Information Studies

According to the revised national curriculum guidelines of Japan, as of 2013, students must elect to study one of the following two subjects: "Information Studies for the Global Community" or "Information Studies by Scientific Approach." Because the former is expected to be chosen by more than 80% of students based on the current selection ratios of similar subjects, we had developed instructional games corresponding to the first and the second of the four units in the former subject. In the first unit, students learn about digital technology and utilization of multi-media technology. Therefore, we selected the topic "Designing an Effective Presentation" for the game. In the second unit, because students learn about utilizing the communication network, we developed an "Internet Auction" game.

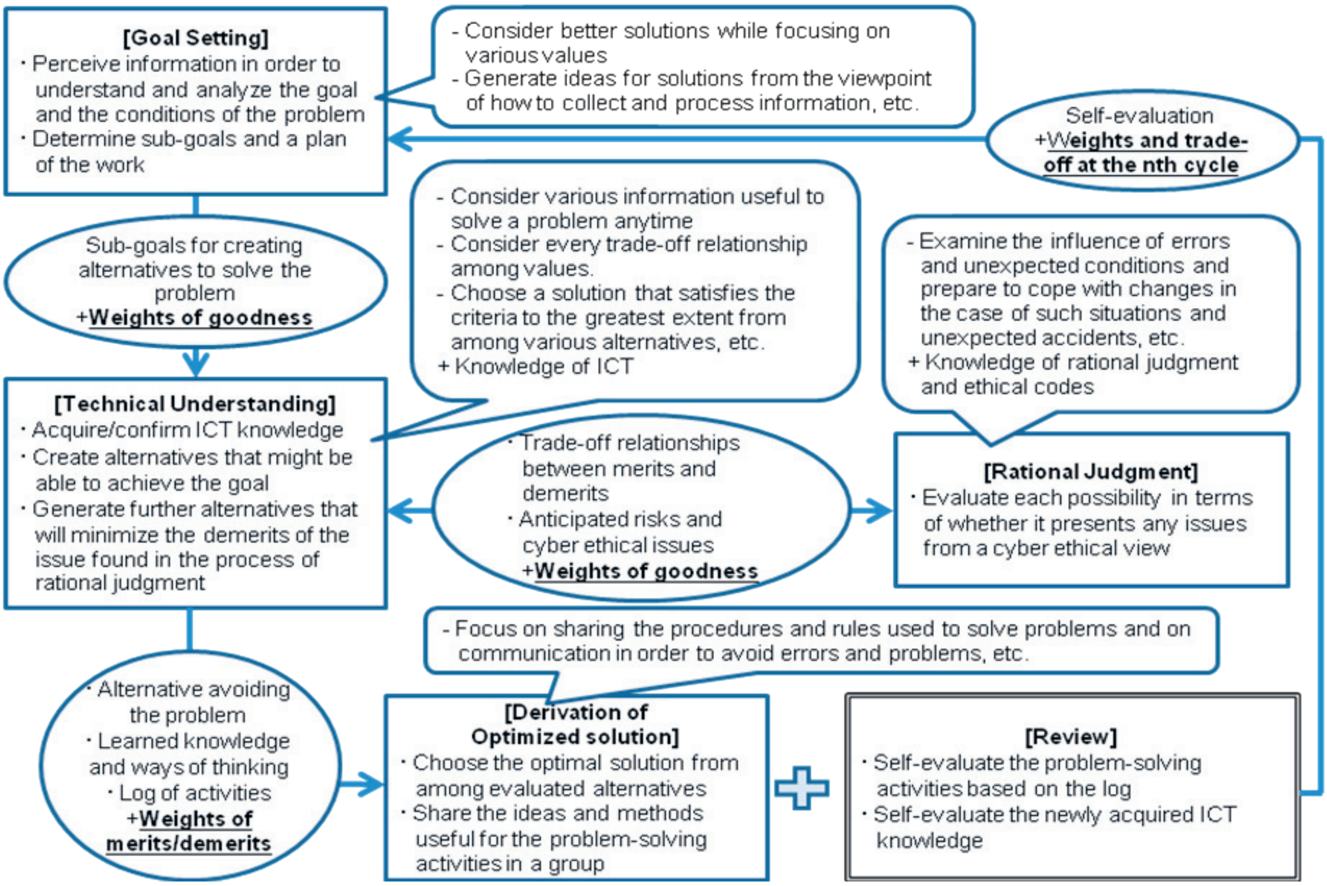

Figure 1 Design principle of the instructional game materials

When we developed the games, we constructed the design framework shown in Figure 1. First, we divided the problem-solving process into four sub-processes, shown in the rectangles: goal setting, technical understanding, rational judgment, and derivation of optimized solution. These categories are based on Savery's (2009) framework of Problem-Based Instruction. The design framework is intended to integrate informatic and systematic thinking with the three types of knowledge mentioned earlier and to clearly show students where each of them should be utilized in the task of problem solving, as shown in the balloons in Figure 1. All three types of knowledge are required for the "technical understanding" and "rational judgment" processes. In the technical understanding process, students generate several possible plans as they learn about ICT. In the rational judgment process, they evaluate each possibility in terms of whether it presents cyber ethics issues, considering knowledge of both ethical codes and rational judgment. If a plan is found to present any issues, the students may disregard it in favor of another plan or return to the process of generating ideas. Each oval in Figure 1 lists the elements that should be determined in each process in order to be used in the next.

Because the game is intended to be used at the end of each lesson unit, it requires students to go through all the sub-processes of problem solving. In addition, as an instructional game, rather than a test, the materials should offer students the opportunity to try again. Therefore, we added a "Review" stage, represented by the double-lined rectangle in Figure 1, as well as referring the manner of gaming simulation: briefing -> game play -> debriefing (Matsuda 2011). This feature of the game design renders the whole process into a cycle, allowing students to solve similar but different problems under various conditions. It also introduces the challenge of flexibly applying their skills to changing circumstances.

From the results of trial lessons conducted with 51 students at a women's university, we confirmed that, after playing "Designing an Effective Presentation," students better recognized the importance of utilizing informatic and systematic thinking in problem solving. For example, they were significantly more likely to agree with the statement "We should study a thinking method for how to apply our ICT knowledge when assessing cyber ethics problems" and significantly less likely to agree that "When problem solving, we should resolve the problem using customary methods." However, regarding agreement with the statement "Considering trade-offs prevents us from solving problems," we found a difference between the responses of those who indicated alternatives to improving the problem in addition to pointing out cyber ethics issues (26 students) and the responses of those who did not (20 students).

This tendency was revealed in the log analysis. However, evaluation in the game must provide immediate feedback on whether students have demonstrated sufficient knowledge of ICT and whether they have utilized informatic and systematic thinking; therefore, we needed to revise Figure 1 to reflect the results of the trial lessons as underlined elements of each oval. Moreover, though we originally created the elements according to the topic, we should add more, such as the merits/demerits that are considered in the problem-solving process as well as their weights and trade-off relations when students evaluate the various possible plans. These elements should examine whether the weights are consistent with the students' evaluation of each idea.

Furthermore, in the review process, although it is important to evaluate the wisdom of students' decisions, it is more important to assess how the students utilize informatic and systematic thinking and the range of merits/demerits they take into consideration. In order to evaluate these points reliably in the game and make students conscious of their own learning, we prepared a common framework of evaluation. That is, we improved Matsuda's (2011) rubric for evaluating student competency to utilize several views and ways of thinking. If discrepancies are found between a student's self-evaluation and the activity recorded in the game, students are asked the reasons for their self-evaluation when they receive feedback about the discrepancy. Moreover, they are asked to explain their newly acquired knowledge of ICT.

Development of New Gaming Material: "Security Policy"

"Security Policy" is the main topic of the third unit of "Information Studies for the Global Community." In this unit, students learn about personal authentication, encryption, rules, and laws related to information security, etc., through examples of familiar situations. Moreover, the unit objectives are not only to acquire knowledge but also to learn methods of building group consensus concerning rules and policies.

"Security Policy" was developed under the same constraints as our previous materials: (1) Students must finish the game in an hour, which includes the time taken by teachers to explain the instructions, and (2) students are asked to accomplish a certain mission by weighing trade-offs between achieving a higher goal and avoiding various problems. Moreover, in order to cultivate the students' competency in making appropriate decisions according to the situation, the game enables them to play multiple times under changing goals and conditions.

In the goal-setting process, a student defines his/her goals for creating an adequate security policy after the teacher describes the current state of information security. A tablet terminal with a wireless LAN connection is assumed to be available to each student in the game. The student is asked to identify the various merits/demerits of the present security system and to list issues to be resolved. He/she is also asked to distinguish constraints from goals according to the analysis of information that he/she will collect individually and to form a plan for creating an adequate security policy that everyone can agree on. When the student evaluate all the potential plans at a later stage, the weights of goodness will be estimated based on his/her goals.

In the technical understanding process, the student is asked to brainstorm alternative ways to manage the computer room more securely, to evaluate each alternative considering trade-off relationships between its merits and demerits, and to estimate the influence of potential security incidents as well as the probability of their occurrence. The goal of this process is to encourage the student to define criteria for choosing the optimal solution from among a set of alternatives. The weights of goodness change according to the number of generated alternatives, their effectiveness/usability/risk, the student's trade-off judgments, and the evaluated severity of incident.

In the rational judgment process, the student considers the issues of the leading alternative using ICT knowledge and rational judgment: "Has the law been broken?" "Are others injured?" "Could I injure myself?" If any problems are found, the student returns to the technical understanding process to generate further alternatives that will minimize the demerits of the issue. The weights of merits/demerits change according to where the issue is found and the features of the improved alternative.

In the derivation of the optimized solution process, each student creates a security policy by choosing the optimal solution from among the alternatives generated and evaluated in the previous processes. Then, he/she moves on to the review process to evaluate both the security policy he/she has adopted and the weight of each merit/demerit evaluated through the previous processes. According to this information, the student checks whether these weights are consistent with the goal. Moreover, each student evaluates his/her own problem solving based on the rubric. If any discrepancies are detected between the self-evaluation and the activity recorded in the game, these are drawn to the student's attention through appropriate feedback. After the self-evaluation, the teacher in the game prompts the students to problem solve in a different situation by stating, "Since the situation has changed, I want you to re-consider the security policy you created."

Experiment and Discussion: Application to Teacher Education

We conducted experimental lessons with 171 students at an upper secondary school. We verified the effectiveness of the lessons according to the log data and a pre- and post-questionnaire. Significant differences in the responses on the pre- and post-questionnaire indicated the game was effective at providing students with confidence to utilize their ICT knowledge as well as informatic and systematic thinking in problem solving. In addition, the students recognized the importance of creating ideas to minimize demerits and avoid anticipated problems. However, we also found that students who lacked confidence tended to generate few and inadequate ideas that were inconsistent with their goals. Therefore, teachers should teach ICT knowledge well before implementing the e-learning games so that students are properly equipped to utilize this knowledge in their problem solving when they play.

Based on this study and our previous ones, we plan to develop a "virtual lesson" game to promote teachers' professional development regarding how to give effective lessons on Information Studies. As Ishii and Matsuda (2003) suggested, firstly, we must prompt teachers to recognize the necessity of promoting students' utilization of informatic and systematic thinking as well as the importance of integrating informatics education and cyber safety/ethics education. Secondly, we should encourage teachers to play "Security Policy" as students; this will fully familiarize them with all aspects of the game and provide them with insights into the student perspective. Finally, we should ask teachers play a "virtual lesson" game that simulates a lesson on "Designing an Effective Presentation" in order to evaluate the adequacy of their decisions and provide feedback to improve their lesson plans based on our design framework.

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The importance of technological activity and designing and making activity, a historical perspective

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Key Words: Technology, designing, making, design and technology, tool use, neuroscience, cultural psychology, constructivism, socio-technological

Abstract

Whilst tool use is by no means an exclusive human trait, the "ability to deliberately manipulate" is central to our development, and it is our ability to "create complex artefacts" (Wolpert, 2003) that sets us apart. Recent archaeological and neuroscience advances have suggested that the activity of designing and making of tools, such as the handaxe, played a crucial role in the development of language. This paper will argue that the technological mindset is a preeminent paradigm in human development.

The paper will work within an interpretive and constructivist paradigm. The standpoint of the author is that of a technologist and literature is used to build and argument for the historic relevance of technological achievement, the trustworthiness of the research will be addressed through critical and reflective review of literature. The conclusion ends with polemic and rhetorical questions, based on the discussion, aimed a generating further debate both within the subject and the wider educational communities.

In the context of curriculum change in the English education system, the aim of this paper is to re-examine the role of designing and making activity and technology education. The findings will be literature from contemporary neuroscience, and revisit the original nature of design and technology and current challenges (Ofsted, 2011), highlighting the historical and social importance of the designing and making activity.

A central assertion of this paper is that core subjects, such as science, in the contemporary English curriculum owe their origins to technological innovation, in terms of solving human needs through design and making. As such, they argue for the case for continued inclusion within a broad curriculum, in whatever form it may take, from a cultural rather than purely a technical or economic perspective.

Introduction

> *"… the evolution of causal thinking was essential for the development of tool use, as it is not possible to make a complex tool without understanding cause and effect. This was a great evolutionary adaptive advantage. The evolution of language may have been linked to the same process.* ***It has been technology that resulted from causal beliefs, not social interaction, that has driven human evolution."*** (Wolpert, 2003, emphasis mine)

Technology, as defined by biologist Lewis Wolpert (2003: 1709), is "the ability to deliberately manipulate the environment", describing the action and intention of human activity (such as making a product), as opposed to the manifestation of technology as artefact (the product itself). In a recent consultation event run by the Design and Technology Association, chief executive Richard Green echoed this concept of technology, describing the intent of D&T to create "thinking manipulators" (DATA, 2012). Wolpert goes on to state that technological activity predates science, which began to influence culture and society in 18th Century as a formal discipline. According to Wolpert, trial and error approaches, which typify early technological activity giving rise to causal belief, which in turn give rise to the development of language and communication (McCormack, Hoerl, and Butterfill, 2011; Csibra and Gergely, 2006; Baber, 2003). In the context of this paper, design and making activity (whether as discrete or as holistic learning experiences) are viewed as functions of technological activity.

In this paper the term technology is used to refer to the human activities related to interaction with and shaping of the material world for human intentions, as opposed to the products of designing and making. Designing and making are considered to be essential functions of this intentionality in the realisation of technological solutions to human needs (and wants).

Over the past twenty years, as Design and Technology (D&T) has developed with the school curriculum in England and Wales, there has been a terminological transition from describing the outcomes of designing and making activity from "artefacts" (NCC, 1990) to "products and systems" (QCA, 2007). This can be viewed as a positive move to clarify and communicate the nature of learning outcomes and delineate between artefacts derived from artistic endeavour as opposed to technological. In this case, one might crudely define the differences in terms of the functionality and use of the created object. A *product* or *system* is recognisable outcome, which might be understood by learners and teachers alike. However, this reduction focusing on outcomes might have some negative effects on the concept of designing and making as a cultural and historical endeavour (NCC, 1990: 23; DfE, 1995, 10; DfEE, 1999: 8, 23-4; QCA, 2004: 10, 25-6; QCA, 2007: 52).

The positioning of the *cultural* statements in design and technology have shifted somewhat in the National Curriculum programme of study. This paper suggests that designing and making activity is essentially a cultural endeavour. Kimbell, Stables and Green (1996: 45-7) locate cultural technology within Key Stage 1 (ages 5-7), reflecting the first programme of study for Technology (NCC, 1990: 23). This emphasis shifts to Key Stage 4 (age 14-16) in the programme of study beginning in 2000 (DfEE, 1999:23-4), although it is also included across the curriculum (pp. 8) and by 2008 (QCA, 2007:52) is specifically mentioned in Key Stage 3 (ages 11-14). However, the role of culture as expressed in the programmes of study relates to the influence of culture *on* designing and making activities, rather than the contribution of design and making *to* culture: influencing, and creating, cultural artefacts. From a perspective that human culture is derived from social and technological activity (Bruner, 2009; de Vries, 2007:20-33), a broadening of the role of cultural learning in the curriculum could be viewed as a positive, though possibly underdeveloped, aspect of D&T. This view of the socio-technological origins of culture has been discussed by biologists (Wolpert, 2003), cultural psychologists (Cole, 1996; Cole and Derry, 2005) and sociologists (Sennett, 2008). However, this view of culture as being mediated by artefacts (Cole, 1996: 116-45) is not universally held. Clifford Geertz quotes Ward Goodenough view that "culture [is located] in the minds and hearts of men" (Geertz, 1973: 10) as contemporary and influential "theoretical muddlement" which he believed was a misconceived dualism between *subjective* and *objective*, or *idealist* and *materialist*. Similarly, Richard Sennett (2008: 124) discusses "the supposed superiority of the head over the hand", where ideas are conceived as "more sustainable than decomposing material": a view that is deep rooted in Western civilization. Although the briefest reading of the history philosophical thought would question the immutability of ideas.

This paper discusses how literature and research in the fields of neuroscience, cultural psychology and sociology inform our understanding of the role and importance of technological activity, as expressed in design and making (i.e. realising products and systems), as aspects of formal learning. The theoretical position adopted views culture and learning as distributed between social and material concerns (Fenwick et al, 2011: 2-6).

Methodology

As an interpretive study, within a broadly constructivist paradigm (Lincoln, Lynham and Guba, 2011: 98-116), this paper seeks to explore the nature of human development in relation to technological activity. In relation to the interaction between mind and body in design and making activity, ontological assumptions are relativist, recognising the multiple realities of individuals in society interpreting technological activity (Guba, 1981: 77). The standpoint adopted in this paper is that of a "situated" technologist and educator (Olesen 2011:130; Lave, 2009). Situated in the context of a standpoint epistemology, not in terms of being the member of an oppressed group, but rather of a contemporaneously misunderstood subject, whose place in the curriculum is under scrutiny (DEF, 2011a: 24; Miller, 2011). Similarly, the epistemological stance adopted is to examine with relationship between technological and social activity (**Figure 1**) in relation to cultural and cognitive evolution; rather than more positivistic concerns regarding the nature of materials or processes.

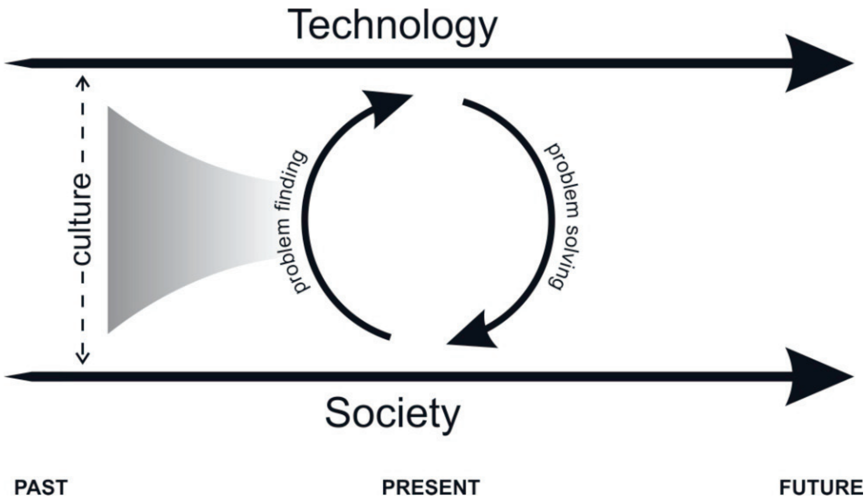

Figure 1 Socio-technological human activity

The methodological approach is to use literature from a variety of sources to discuss the complexity of the object of the study (technological activity, and in particular designing and making). Cultural-historical activity theory has influenced the dialectic analysis of the literature, which links the object of design and making activity as "cultural entities" and that in human development "object-orientedness of action" is central to understanding the mind (Engeström, 2009: 54; **Figure 2**). The nature of objects and their influence human behaviour ,and development, has also been discussed by Graham Harman (2002), who builds on Heidegger's philosophy of tool use, and Bruno Latour (2008).

To ensure a rigorous, credible and trustworthy interpretation of the central elements of this study, literature from a range of sources and disciplines is used to inform the discussion (Lincoln and Guba, 1986; Guba, 1981). However, the paper itself is a starting point, or positioning, aimed at engaging academic debate, initially within the national and international design and technology community. The aim beyond this is to engage with the wider education community, in the United Kingdom, to address the perceptions of the subject's "weaker epistemological roots" (DFE, 2011a: 24). The confirmability of the study will be tested and reviewed through peer review and further discussion. As such, this paper does not purport to stand alone, but rather to contribute to wider discussions in the context of current developments in education policy.

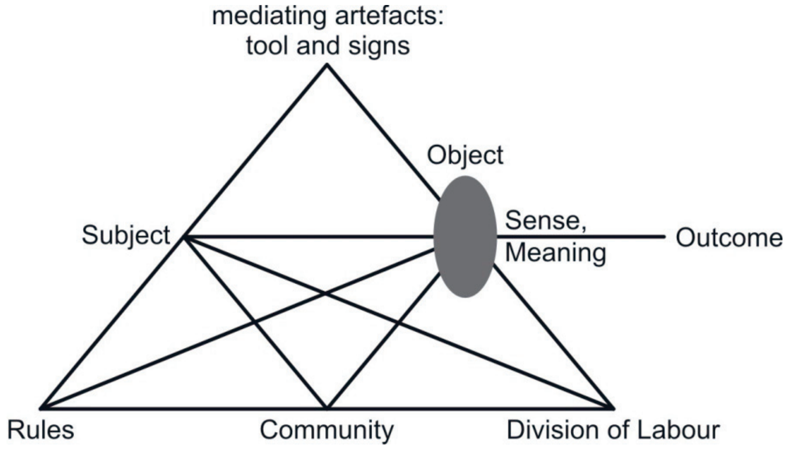

Figure 2 The structure of a human activity system (Engeström, 1987:78)

Literature Review

Three themes emerge from the literature reviewed for this study: aspects of *socio-technological activity*; *cultural learning and evolution*; and the *impact of tool use on cognition*. These themes inform a discussion, culminating in a series of polemic statements intended to trigger debate over the role of design and technology education.

Socio-technological activity: In recent years there has been an increased interesting craft, as described by Richard Sennett (2008) in 'The Craftsman' and Matthew Crawford in 'The case for working with your hands' (2009). Sennett outlines the development of craft skills from ancient times to European guilds, as self-contained units of designing and making, albeit designing and developing over long periods of time. During the Enlightenment of the eighteenth century, science emerges out of the mystical and heuristic practices of alchemy as a force for change. This change, whilst amplifying productivity was accompanied by a division of labour and in turn lead to the role of designer (or engineer) and maker being separated during the industrial revolution. One of Sennett's aims in his book is to "explore what happens when hand and head, technique and science, art and craft are separated" (Sennett, 2008: 20). Sennett discusses the nature of problem finding as a prerequisite to problem-solving, where the craftsman experiences an inner-outer dialogue between practicalities and thinking; reminiscent of Habermas' "everyday praxis". **Figure 1** attempts to interpret Sennett's finding-solving paradigm in relation to socio-technological activity.

> *"... the evolution of the hominid mind is linked to the development of a way of life where reality is represented by a symbolism shared by members of a cultural community in which a technical-social way of life is both organized and construed in terms of that symbolism."*
> (Bruner, 2009)

Cultural learning and evolution: Socially constructivist theories of learning tend to emphasis the multifaceted nature of culture and the relationship between mind and body. The concept of Cartesian Dualism, critiqued as "ghost in the machine" by Gilbert Ryle (1949), which views the mind and body as separate entities, places cognition in authority over the body. However, both seventeenth century contemporary criticism of Descartes (Huet, 2003 cited in Bakker, 2005: 78) and modern scientific investigation of the brain (Greif, 2011: 39; Johnson-Frey, 2004; Greenfield, 1991) challenge this view. Bruner's concept of the "technical-social way of life" centres on embodiment and culture, where body and mind are actively involved cultural and cognitive evolution (Barrett, Henzi and Lusseau, 2011).

Level	Description	Example
Primary	"artefacts… used in the direct production"	Tools (as technological artefacts) and language (as social artefacts).
	"artefacts… used in the preservation and transmission of the acquired skills or modes of action or praxis by which the production is carried out."	Knowledge (knowing that) and skills (knowing how)
Tertiary	"constitute a domain in which there is a free construction in the imagination of rules and operations different from those adopted for ordinary, this worldly praxis."	Creativity and imagination

Table 1 Wartofsky's levels of artefact (1979: 202)

In social constructivism, human cognitive evolution as a product of technological and social drivers, is mediated by artefacts as "objectifications of human needs and intentions" (Daniels, Cole and Wertsch, 2007: 255; Wartofsky, 1979; Vygotsky, 1978). Returning to the earlier discussion of the problematic nature of the term 'artefact' in early D&T, the Wartofsky (1979: 202) describes three levels of artefact (**Table 1**) that place the technological (tools) alongside the social (language) as primary artefacts. This reinforces the assertion that technological and social activities are primary drivers in human development.

The impact of tool use on cognition: The links between intelligence, as expressed in language use and tool use, are explored by John Campbell (2011: 169-182) who identifies common features in both. In fact the term *tools* in constructivist theory can refer to cognitive, or psychological, tools (Vygotsky, 1978). Campbell describes the use of tools as "an extension of the body" (pp.170), although he dismisses a simplistic analogue as not "immediately helpful". Michael Cole (1996: 136) cites an example of a blind man using a stick, asking where the sensation begins – in the hand or in the stick? The effect of technology as a cognitive amplifier are discussed by Raymond Nickerson (2005: 6) "either by facilitating reasoning directly or by reducing the demand that the solution of a problem makes on one's cognitive resources, thereby freeing those resources up for other uses." In other words technology enables human beings to outsource, or distribute, elements of cognitive capacity. For example, the development of written language and methods of recording enabled knowledge to be stored, and the invention of the printing press in Europe in the mid-fifteenth century facilitated the distribution and democratisation of that knowledge, technological advances developing hand-in-hand with social human activity (not to mention the telegraph, telephone, internet and so on). Melvin Bragg, in "the Adventure of English" (2004:238) highlights the link between language and technology in recent times, linking the effect of the industrial revolution on language. This emphasises the symbiotic relationship between language and technology. Rather than technology being the servant of language, or vice versa, they have an integral and cyclic relationship. These technological advances would not have been possible without the facilitation of designing and making activity.

Returning to Campbell's analysis of the similarities between language use and tool use, intelligent application is more than mere demonstration of use, but rather the "sense in which you understand why it works as it does" (2005: 171) and the ability to transfer that understanding into different contexts. Intelligent use implies a "focal awareness" of the target (that which the tool is acting on – i.e. object) with a subsidiary awareness of the tool itself, balancing both the variable properties and standing properties of the target and the tool. An every day example of this might be driving a car, where the learner initial focuses on the front of the vehicle (i.e. the tool), consciously steering it without being able to focus on the road ahead (i.e. the target). Similarly, when using tools in design and technological activity (be it physical/making or cognitive/design – or indeed a combination), the intelligent use of the tool is virtually invisible to the user.

The value of practical learning:

> *"When education, under the influence of a scholastic conception of knowledge which ignores everything but scientifically formulated facts and truths, fails to recognize that primary or initial subject matter always exists as matter of an active doing, involving the use of the body and the handling of material, the subject matter of instruction is isolated from the needs and purposes of the learner, and so becomes just a something to be memorized and reproduced upon demand. Recognition of the natural course of development, on the contrary, always sets out with situations which involve learning by doing."* (Dewey, 1916, 2001: 192)

The value of practical learning (including technological activity – and designing and making) is not confined to economic drivers. Influential linguistic theorist Noam Chomsky quotes John Dewey as stating that the "ultimate aim of production is not production of goods, but the production of free human beings associated with one another on terms of equality" (Chomsky, 2003). Dewey, in common with Vygotsky, attack attempts to reductionist or dualistic divisions within education, adopting a "dynamic holism" (Russell, 1993:173-174) in opposition to influential contemporary philosophy. A, possibly, unconscious expression of this is evident in the popular taxonomy of educational objectives presented by Bloom et al (Bloom, 1956; Krathwohl, Bloom and Masia, 1956) and revised by Andersen and Krathwohl (2001). Bloom had identified three domains of educational objective: *cognitive*, *affective* and *psychomotor*. The most familiar, *cognitive* domain (Bloom, 1956), and *affective* (Krathwohl, Bloom and Masia, 1956) domain were developed first, with the intention to develop the psychomotor domain. However, this division of functions was not without its critique (Marranzo and Kendell, 2007: 17-18) as it "isolates aspects of the same objective". In fact, one of the subsequent texts addressing the psychomotor domain, Elizabeth Simpson, quotes Bloom (1956: 7-8) as having found "so little done about [the psychomotor domain]" and that they "[did] not believe the development of a classification of these objectives would be very useful at present" (1966: 2). Simpson, as principle investigator, drew from expertise in practical subjects at the time (Industrial Arts, Agriculture, Home Economics, Music, Physical Education and Art), and emphasised the link between cognitive and motor control.

In common with other practical subjects, design and making activity can engage the whole person, cognitive, affective and psychomotor domains. However, the focus of this paper is to challenge conceptions of a dualistic self, and the importance of design and making as cultural activities engaging body and mind in socio-technological activity. The body is not merely a vehicle to transport the head to meetings, as Ken Robinson quips (Robinson, 2006), but an integral part of our being. Rather than the body serving the mind, the brain evolved to control movement, with causal belief, tool use and language as by-products (Wolpert, 2003: 1710-11)

Conclusions

Jürgen Habermas (1981: 3-14) echoes some of the sentiments of constructivist 'dynamic holism' and challenges the tendency of post-enlightenment, modernist, thinking to view spheres of culture (science, morality and art) as distinct and separable. This division created by the professionalization of culture helped create the role of the designer as distinct from the craftsman, and Habermas does not denounce the intentions of the Enlightenment, but called for "unconstrained interaction" (p.11). A similar philosophy was envisaged in the beginnings of D&T, where knowledge was conceived as a "resource to be used" (DES and WO, 1988:29) in contrast to the curriculum being comprised of "essential knowledge [and] fundamental operations" (DFE, 2011a: 6). Wolpert discusses the relationship between science and technology, where "reliable scientific knowledge is value-free" and the moral decisions occur when science is applied as technology in the production of products (Wolpert, 2002). Technological activity, as a Habermasian "moral-practical" culture, plays a key role in the *three spheres* (**Figure 3**), which begs the questions: Do we accept and try to fit in with the new order? Or do we challenge the foundations that our definitions of education as a cultural activity?

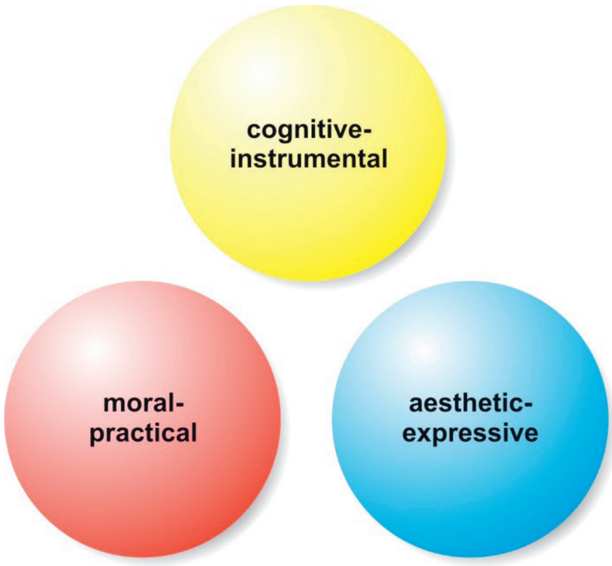

Figure 3 Representation of Habermas' cultural spheres

The literature reviewed for this paper builds an argument for technological activity, from a range of disciplines being viewed as within a constructivist paradigm, as a facet of overarching human activity. Design and making, as discrete elements or functions of technology (and, historically, central to D&T), plays a key role both historically and contemporaneously in cognitive and cultural evolution. It is apparent that the nature of culture is interpreted in different ways, exemplified by the highly cognitive "minds and hearts" of Goodenough (Geertz, 1973: 10), which builds on a dualist tradition in Western philosophy. Contemporary sociological commentator, Richard Sennett (2011) describes the tensions between head and hand, outlining three manifest aspects of practical activity: the interaction between *inner and outer life*, which encourages an iterative interaction reminiscent of the "APU model of the interaction between mind and hand" (Kimbell et al, 1991:20); the concept of *resistance*, in searching for limits and reflexive "use of minimal force": and dealing with *ambiguity*, which characterises Engestrom's activity system (**Figure 2**). All forms of practical learning contribute to either fine motor skills (Art and Design, Design and Technology and Music) or gross motor skills (Physical Education).

So what therefore is the case for Design and Technology, if this kind of learning can be found elsewhere in the curriculum? Part of an answer lies in returning to the concept of cultural artefacts as physical objects. Both Art and Design and Design and Technology have a shared, though underdeveloped, interest in design and craft skills (Ofsted, 2009; de Vries, 2007: 23-27). Where D&T differs is in the focus on combining "practical and technological skills with creative thinking to design and make products and systems that meet human needs" (QCA, 2007:51). The rationale for retaining design and making activities in the curriculum is cultural, rather than economic. Much has been made, in recent times, of the importance of the Science, Technology, Engineering and Mathematics (STEM) agenda, which are valuable expressions of learning in D&T. However, design and making as technological acts (or functions) has more to offer, including a vehicle for cultural awareness and evolution. It is the interaction between social and technological drivers that generate the 'wake' of cultural artefacts (**Figure 1**), be they physical (tools, products, systems or environments) or psychological (language or cognition). In a world where knowledge is prolific and accessible through computers and mobile devices (Internet), and products and building can be design in virtual environments (Sennett, 2008: 39-45), the ability to interact and create with real materials is essential (Dewey, 1916, 2001: 192).

To conclude, I would like to pose a number of polemic and rhetorical questions to challenge the status of technological activity. Each question has convincing arguments both for and against, but the aim is to generate discussion. Whether or not design and technology activity, and designing and making, is weak epistemologically (DFE, 2011a), it is ontologically active.

Questions

If technological activity predates scientific method, why is science perceived as more important?

If language came about as a result of our ancestors' creation and use of tools, why is there an imbalance in society and education between practical and cognitive skill?

How do we measure the social aspects of history or geography, if not through the mediation of technological development?

Can a painter paint without a brush, or a sculptor sculpt without hammer and chisel?

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Examining thinking in primary-level Design and Technology learning activities

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Abstract

Most curriculum documents in Design and Technology make claims about how students will develop and learn as a result of engaging in Design and Technology learning activities. These claims will often include the development of creative and innovative thinking, both of which are regarded as forms of higher order thinking. However, there is little research evidence to support these claims and much of what is available is drawn from small-scale qualitative studies and thus subject to the limitations inherent in such research.

This paper outlines and examines the use of an instrument called the Cognitive Holding Power Questionnaire (CHPQ) (Stevenson, 1986) to measure higher order thinking with primary age students engaging in design and technology learning activities. The CHPQ is a quantitative instrument that elicits responses from students on their perceptions about the influence the learning environment (teacher, materials, activities etc) is having on the kinds of thinking they are using during their learning. The instrument is suitable for large scale studies and provides powerful data to support the learning area. The paper outlines a study in which the instrument was used. However, the primary aim of the paper is to explore the utility and robustness of the instrument to provide a better understanding of the kinds of thinking that occurs in Design and Technology classrooms.

Introduction

Much current research in Design and Technology education employs qualitative methodologies such as interviews, focus groups, stimulated recall and observation to uncover evidence to help explain the nature of the teaching and learning that occurs in Design and Technology classrooms. These have been used extensively from primary years to university teacher education levels. There has been a strong rationale for these methods. The activities students engage in, in Design and Technology classrooms are known to be complex in terms of their requirement for students to engage in both visual and verbal reasoning, the solving of complex, ill-defined problems and the need for the solutions to these problems to be new or creative in some way. Because of these factors, it has been necessary to use methods that are capable of capturing this complexity by allowing in-depth studies of limited numbers of students or classes or learning activities. These studies are important in providing research results to inform the direction of further research and practice.

Qualitative methods do, however, suffer from a number of limitations, with the principal one being generalisability. It has generally been the case that qualitative studies have always been regarded as telling us many important things about a particular individual or small sample but there has been strong reservations about the extent to which the results can be argued to be generalisable to larger groups of people, even when the larger group could be regarded as constituting the population represented by the sample. It is for this reason that there has been a move in some areas of education to employ a combination of qualitative and quantitative methods.

In addition, the results of research are increasingly employed to inform decisions made about educational policy and practice. When this occurs, decision-makers who are developing policy that is designed to be appropriate for an education system, have a tendency to prefer research where there is some confidence that the results and conclusions would be applicable to a policy for the entire system. In these instances, quantitative methods where large samples can be used are preferred, albeit with qualitative methods being used to provide explanatory data. It is for this reason and the argument about its applicability for researching Design and Technology education that this paper has been developed. The following section provides a description of the features of the Cognitive Holding Power Questionnaire (Stevenson & Ryan, ND). This is followed by a brief description of a study where the CHPQ was used with upper primary (elementary) age students. The final section draws some conclusions about our efforts to understand the teaching and learning process in Design and Technology education classrooms.

The Cognitive Holding Power Questionnaire

The Cognitive Holding Power Questionnaire (CHPQ) is an instrument designed to measure the extent to which different learning settings press students into different kinds of cognitive activity. The instrument is administered to students and scored for two dimensions: First Order Cognitive Holding Power (FOCHP) and Second Order Cognitive Holding Power (SOCHP). The concept of Cognitive Holding Power (CHP) is synthesised from theories of settings and theories of cognitive structures.

Cognitive Holding Power is a characteristic of a setting. The tendency for a learning environment to aid or impede individuals in achieving their goals has been called **press** (Murray, 1938). Pace and Stern (1958) have extended this concept to include student perception of the atmosphere of a learning institution. Similar concepts have been used in setting theory (Barker, 1978) where it has been argued that settings elicit behaviour from participants. Moos (1979) attributed the behaviour elicited by settings to the participants' cognitive appraisal of the environment which leads to efforts to adapt to the setting to cope with it. A more powerful term used by Kounin and Sherman (1979) to refer to the demands of a learning setting is **holding power.**

Cognitive Holding Power is measured in terms of two kinds of procedural knowledge elicited by the setting. Ryle (1949) differentiated knowledge into knowledge 'that' and knowledge 'how'. Knowledge 'that' is termed propositional or declarative and knowledge 'how' is termed procedural (Anderson, 1990). Procedural knowledge is the ability to perform an action to secure a particular goal, e.g. Anderson (1990). Cognitive Holding Power measures the extent to which different kinds of procedural knowledge are elicited by the setting.

From the theories of Anderson (1990), Scandura (1980, 1981) and Fischer (1980), three orders of cognitive procedures can be differentiated according to the nature of the goals for which they are applicable (Stevenson, 1986a, 1991). Evans (1991) has proposed a similar differentiation of procedural knowledge based on the kind of control exercised.

The **first order** comprises specific procedures which enable the achievement of goals through the performance of an action. For example, first order procedural knowledge includes knowledge of how to hammer a nail, play a familiar piece of music, apply a particular mathematical algorithm, or perform a particular stroke when playing tennis.

Second order procedures achieve more general purposes by accessing both propositional and procedural knowledge, and operating on specific procedures when immediate action goals cannot be fulfilled. They result in relating, combining, and modifying specific procedures so as to produce new procedures which can handle as yet unfamiliar situations. Examples include designing a plan for a new house to meet a client's requirements, interpreting and playing an unfamiliar piece of music, selecting a strategy for the solution of a new mathematical problem, or developing a strategy for winning a tennis match.

It has been argued (Stevenson, 1986b) that engagement in learning activities which demand the use of second order procedures assists students in achieving **far transfer** (Royer, 1979), that is, transfer where there is no clear similarity between the stimulus elements in the original learning and the transfer tasks. Second order procedures can be likened to Sternberg's meta-components of intelligence (Sternberg & Davidson, 1989) which are involved in 'defining the problem, setting up a strategy to solve the problem and monitoring the consequences of one's problem solving' (p.23).

A **third order** of cognitive procedures is conceived as those procedures which achieve overall control of cognition and switch cognitive activity between orders. This third order is variously called a flow of control (Anderson, 1982), a goal switching mechanism (Scandura, 1981), control through procedures (Fischer, 1980), and executive control (Evans, 1991). In addition to these control functions, propositional knowledge is accessed in the control and monitoring of first order, or specific procedures, and higher order procedures are elicited when task feedback indicates a problem state (Evans, 1991).

Setting characteristics which lead to First Order Cognitive Holding Power are those which are concerned largely with the practice of existing specific procedures or are ones in which the teacher, or the lesson, tends to minimise the need for the student to combine and modify specific procedures. The students' tasks are reduced to copying or to the simplest interpretation of information. It is the teacher who takes the responsibility for the second order procedures. Thus, the student may be largely unaware of the thinking strategies used in the lesson and may not be responsible for controlling them (Rigney, 1980; Derry & Murphy, 1986). Such activities tend to short circuit the students' use of second order procedures and include copying directly from the teacher, being shown a procedure explicitly by the teacher, being told explicitly what to do, and acting on information, ideas, and judgements of the teacher. Such activities may foster the learning of target first order skills, but not second order procedures.

A setting with high Second Order Cognitive Holding Power is defined as one which poses goals unfamiliar to the student, and elicits the execution of second order procedures to interpret the situation and to deal with the associated problems. Such a setting promotes the use of second order procedures and impedes the achievement of goals through only the direct application of specific procedures nominated by the teacher. Second order procedures are used to make links between the features of the setting and existing knowledge, to generate ideas, to try out and test problem-solving strategies, to monitor the effectiveness of approaches, and to check results.

The trialling of novel combinations of specific procedures and the monitoring of strategies for attacking the situational problems would also be accomplished by second order procedures activated as a result of the switching function of third order executive procedures. Such a setting is conceived as possessing a high level Second Order Cognitive Holding Power, which encourages students to confront problems and practise and evaluate the assembly of new sets of specific procedures. The utilisation of second order procedures is transferable to other problematic situations and enables adaptation.

Thus, learning settings can be conceptualised in terms of the Cognitive Holding Power that they possess and Cognitive Holding Power can be differentiated as first or second order in terms of the cognitive procedures which learners utilise in responding to setting demands.

Three aspects of Cognitive Holding Power can be distinguished: the teacher may encourage an activity; the learner may feel impelled or have agency to undertake the activity or the learner may actually undertake the activity (Evans, 1991). If these three aspects are all present in the environment, for example, then Cognitive Holding Power may be different from the situation in which only teacher encouragement is present. Therefore, three basic forms of wording are used for items:

- The teacher encourages students to (undertake an activity)
- I feel I have to (undertake an activity)
- I (undertake an activity)

The research project

The research project employed here to illustrate the use of the CHPQ was funded by the Technical Foundation of America and involved six classes from five primary schools located on the Gold Coast, in Queensland, Australia. The schools were chosen as ones that had adopted the new Queensland state Technology Key Learning Area (KLA) syllabus, developed from the national Technology KLA curriculum (Curriculum Corporation, 1994).

The basis of school selection was that the teachers in these schools were regarded by the state Technology Advisor as having developed and implemented good technology education programs. One issue in administering the CHPQ with primary students was in having confidence that their responses were related to technology and not some other subject, given the more flexible boundaries between subjects within primary schools. To reduce any effect, data were collected at the conclusion of a significant technology project and it was made clear to students that the questions were about the technology activity only.

Design activities

There were a range of design activities across the five schools. One activity that was typical of those used, was based around a design brief to research, design and construct a stand and the associated signage for marketing an Australian product to an Asian country of the student's choice. The stand had to be able to be flat packed for air transport and had a number of other requirements. Students had to select a country and research the kinds of products that might be suitable and how they might be marketed in a culturally appropriate way.

Findings

The research project found that students from these Technology Education classes perceived themselves to be engaging in more higher order thinking than lower order thinking. The results were compared with those from another study by D'Netto (2004) (See Table 1 below) where the CHPQ was used to examine thinking among students involved in a curriculum initiative called New Basics. New Basics had similar aims to the new Technology Curriculum in terms of encouraging higher-order-thinking.

Table 1: Cognitive Holding Power in Different Studies
(Means with Standard Deviations in Brackets)

Study	SOCHP	FOCHP
Primary Technology Education (Current Study) (n =139)	3.51 (0.51)	2.77 (0.53)
Middle School New Basics (D'Netto, 2004) (n = 227)	3.35 (0.48)	3.06 (0.51)
Total (n = 336)	3.41 (0.49)	2.95 (0.54)

Students in the primary Technology study reported that they felt they had to solve problems by themselves, that the teacher encouraged them to solve problems by themselves and that they actually did solve problems by themselves. Conversely, they reported fewer instances where the teacher told them what to do, or feeling that they needed to follow directions. These findings suggest that the learning activities drew on 2nd order CHP (Higher order thinking) more than 1st order CHP (Lower order thinking) and to a statistically significant degree.

Why is the CHPQ is good for examining thinking in Technology/Design and Technology?

There are a number of reasons the CHPQ appears to be useful in researching thinking across primary Technology/Design and Technology education students. The language of the questionnaire is very accessible, unambiguous and of the kind students can relate to their experiences in school. 'The teacher encourages me to solve problems by myself' is clear in its meaning. The questions are also ones the students perceive as relevant to their classroom experience. There is also a good match between the questions and tech learning activities. The nature of problem-solving in some school subjects can be abstract and removed from students' experiences, but relating to the statement: 'I solve problems by myself' in Technology education is something students appear to have little difficulty in doing. Two sources of evidence are advanced for these conclusions. Firstly, there were no requests for clarification of questions in the study and an almost zero rate of unanswered questions. Finally, the CHPQ is useful because it provides quantitative data about what is otherwise anecdotal evidence or evidence from studies that cannot rule out bias.

Conclusions

CHPQ is suggesting that higher order thinking is strongly correlated with student perceptions that they have a strong ownership of their own learning (engagement) and that good Design and Technology learning activities that motivate students engage students in meaningful higher order thinking. Design and Technology teachers have known from observation that their students were engaging in activities that were personally meaningful. The problem has often been in convincing decision-makers, school authorities, and policy makers of the value of the learning area. The ability to provide data from large samples that illuminates a central and as it happens, a positive, element of the complex interactions that comprise Design and Technology learning activities is the important contribution the CHPQ can make to Design and Technology education research, practice and advocacy.

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Parents as teachers: Using parent helpers to guide young children's technological practice

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Abstract

Technology Education is one of eight learning areas of the New Zealand national curriculum. It aims to develop a broad technological literacy through students participating in learning programmes in which they engage in technological practice and through this practice develop capability, knowledge and an understanding of technology as a domain in its own right. Experiencing and exploring contemporary examples of technological practice is recognised as an effective way of developing technological literacy and, in this study, students visited a chocolate factory in order to find out how to make a chocolate gift for Mothers' Day. While the value of learning experiences outside the classroom (LEOTC) is well documented in learning areas such as science, there are few studies which explore LEOTC in Technology and specifically those of junior primary students.

A key element of this process, and the focus of this paper, is the role that parent helpers play in guiding and supporting students during both visits outside the classroom, and construction tasks within the classroom. It also raises the issue of the preparation and scaffolding parents require to enable them to help students effectively carry out these tasks. The role of a parent helper is a crucial one and the data from this study suggests that the status and time given to this preparation is, at times, varied and can have significant impact on children's learning outcomes.

Introduction

The value of students experiencing learning opportunities outside the classroom (LEOTC) is well documented (Anderson, Thomas & Ellenbogen, 2003; Rennie & Mc Clafferty, 1996). Whilst there is research reporting on LEOTC in science (Bolstad, 2000; Dierking, Falk, Rennie, Anderson & Ellenbogen, 2003; Tofield, Coll, Vyle & Bolstad, 2003), we have found no previous studies in technology, nor those which particularly relate to the role that parent helpers play in enabling a visit outside the classroom. LEOTC is defined by the New Zealand Ministry of Education as any learning experience which extends beyond the four walls of the classroom and typically beyond the school grounds (MoE, 2010). The philosophy is that LEOTC programmes need to complement students' in-school learning and provide experiences which could not be made available in the normal school environment (Te Kete Ipurangi [TKI], 2011).

This paper describes two phases of voluntary, unpaid, parental involvement in a Technology Education unit carried out in two New Entrant classrooms (5 year olds) in which the students visited a chocolate factory and used the information gathered there to design and make a chocolate gift for Mothers day. During the factory visit parents assisted the teacher by transporting the students to the site and also supervising small groups during the chocolate making demonstrations and whilst exploring a retail area. The following week, parents again assisted by helping the children make their chocolate gift for Mothers' Day. Both of these episodes were implemented differently, one being the sole responsibility of the researcher and the other organised by the participant teachers. The outcome of each of these episodes varied significantly and the possible reasons for this will be explored in this paper.

Background

An element of the technology curriculum that is pivotal to students' technological practice is access to the practice of experts. The NZ technology curriculum describes students developing outcomes which are "informed, critical and creative" (Ministry of Education, [MoE] 2007. P32). Furthermore the learning associated with the technology education curriculum stresses the need for students to "examine the practice of others and undertake their own" (Ministry of Education, 2007, p32). There are a range of different strategies through which students can access knowledge of their intended product development but the literature review of this study suggests that a novel experience outside the classroom is likely to offer the greatest learning opportunities. The literature offers some useful considerations for the way we should prepare and plan for these types of experiences including consideration of the anticipated engagement of parent helpers.

Planning and Preparation

Dierking, Falk, Rennie, Anderson and Ellenbogen, (2003) argue that learning is extensively influenced by prior knowledge and experience, interest and the motivation that students bring to the task. This suggests that thorough preparation of students for a visit - in the case of this study, the design task ahead - will effectively prepare them for the ensuing learning opportunities during their factory visit. The aim of this preparation is to ensure that teachers, students and parent-helpers all have a clear purpose for their visit and that parent-helpers have at least some understanding of the knowledge and skills necessary to achieve the goals of the teaching unit. Lambert and Balderstone (2000) and more recently Jarvis and Pell (2002) refer to the importance of teachers creating a 'need to know' amongst pupils – arming them with a genuine research purpose to their tasks during a site visit. Anderson (2003) supports this notion and believes that a student's motivation and agenda for visiting a site significantly impact on how, what and how much he/she learns. Armed with a clear purpose, Falk and Balling (1982) suggest that students are less likely to concentrate on non-relevant aspects of the surrounds, and instead focus on obtaining the answers to questions they require in order to complete their technology task.

Anderson (2003) has reported that visitors' memories of a world expo exhibition were significantly influenced by the socio-cultural identity of the sightseer at the time of the visit. Similarly, the socio-cultural identity of five-year old students attending an LEOTC visit would clearly influence what attracts their attention, what they notice as being important, and what they remember. In a paper exploring guided school tours at a museum, Cox-Peterson, Marsh, Kisiel & Melber (2003) reported that focusing questions and activities were seen to help students make connections between the formal (science) curriculum and the artefacts of the exhibition. This suggests that supervising parents can enhance student learning if they mediate and help connect students to aspects of their visit that, because of their age and socio-cultural background, may be ignored. This support of 'a more knowledgeable other' (Vygotsky, 1987) during the visit who is able to direct students' attention to the ingredients, equipment and the different shapes and structures to chose from when making chocolate, is invaluable, as this, along with hands-on experiences, has the potential to inform the students' future design decisions. Employing the help of parents to carry out this role, to interpret factory presentations and to model and encourage the use of language associated with the chocolate making process, will also enhance students' understanding of, and engagement in the visit.

There are inherent difficulties when planning to take five-year-old students out of the classroom on an LEOTC visit. A high priority we believe, is managing the children's physical needs in order to reduce any stress or anxiety that may be experienced by children being away from familiar surroundings. This may include their toilet requirements, refreshments and play opportunities. These types of problems may be alleviated by factoring in time for the children to use rest rooms at regular intervals, providing opportunities to have refreshments and anticipating problems which may emerge as a result of the children being confined in a non-school controlled space for a lengthy period. These ideas are summarised in the table below.

Table 1. Summary of parent helpers' tasks before, during and after the factory visit

PHASES OF THE VISIT	**ROLE OF OTHERS - (***Parent helpers***)**
BEFORE	• Understand both the purpose of the visit and the teaching goals • Understand that the tasks they have been asked to carry out are designed and informed by previous research and the literature of LEOTC Ensure familiarity with the schedule of the visit including time for refreshments, toilet visits and when would be most appropriate to make purchases from the factory retail outlet

DURING	• Supervise and work with a small group of students
	• Follow teacher guidelines, that is
	   ○ talk to the children about learning goals
	   ○ interpret presentations and products being viewed
	   ○ present/reinforce correct names of items and processes as children view the products and demonstrations
	• Draw students' attention to the products and exhibits relevant to their study

AFTER	• Supervise chocolate making using students designs, planning frameworks and • questionnaire information

What we did

The two phases of this study that required the support of parents were (i) during the factory visit and (ii) during the children's chocolate making sessions. The process of preparing parent helpers was a key element of the planning framework. Prior to the commencement of the technology unit, each child's parent or care giver received a letter inviting them to supervise a group of students during the factory visit, and an explanation of the research that was going to track students' progress. Five parents from one school and four from a second school participated in the visit, each person supervising between two and four students. In addition, ethical approval was sought from each child's caregiver which allowed students to participate in the research component of the visit; to have photographs taken, to provide examples of their work and to participate in a series of interviews. The students themselves were also carefully informed about the intention of the research, ensuring they understood that they were free withdraw at any stage if they chose.

On the morning of the visit, the parents who volunteered their help were invited to attend a meeting in which the researcher explained the goals of the visit and the role they were to carry out. They were provided with an information card which listed the learning intentions of the visit and a series of questions to ask the students as they moved through the retail shop, the chocolate-making demonstration and the lollipop-making demonstration. In this way it was hoped to establish clear links between the displays, the demonstrations and the intended outcome of the visit. The information card also listed the language associated with the chocolate making process that parents were encouraged to use during their conversations with the students. The parents were also asked to draw students' attention to items that highlighted aspects of technological practice such as the chocolate moulds, colourings, flavourings and the colourful range of chocolates which were on display. Regularly drawing the students' attention to the purpose of the visit and the possible chocolate designs for their Mothers' day gift were also encouraged. It was anticipated by the researcher that if students participated in the visit with curiosity and desire for information, the degree to which they engaged with exhibits should be heightened (Sandifer, 2003).

To accommodate the physical needs of the students, a 'comfort' stop before and after the visit was timetabled. We anticipated that an interruption to the flow of the visit because of a need to backtrack to a restroom, would create a disturbance for groups following the children and could also result in important 'snippets' of information being missed. 'Hunger pangs' could offer another challenge that would distract students from the learning environment, particularly in this study where they were viewing displays in the chocolate factory shop. To avoid this, time for a sizeable morning tea beforehand was planned. Several studies have found "a positive relationship between increased physical activity and concentration" (Bailey, Armour, Kirk, Jess, Pickup & Sandford, 2009, p. 15), and so, after morning tea, the students were invited to play outside for a short time (Wineman, Piper & Maple, 1996).

Figure 1: Visit to the retail section of the factory

Figure 2: Making a gift for Mothers' Day

Findings

The data reported here consists of teacher interviews and document analysis of the students' drawings and stories about how to make chocolate. The teacher interviews were primarily a review of planning for the visit and the technology unit. Analysis of data suggests that the careful attention to detail in preparing the parent helpers was very successful. The two participating teachers, Rose and Hannah, both recognized the value of parents being fully informed about their role during the visit and understanding the learning goals and expected outcomes of the technology unit. Rose made the following observation:

> *Yes, I think it was made quite clear that it wasn't just entertainment - we were going out there because we were going to do the process. The card you [researcher] gave them made it quite clear what they needed to be pointing out, and actually when we walked through the shop part before we went in I thought they did a really good job - they were really talking to the kids.*

Responses from the children indicated that many of the goals of the visit had been achieved. In the document analysis of their post-visit drawings and stories about how to make chocolate, terms such as moulds, fillings, mixing machines and the cooling tunnel were frequently noted. The stories tended to be single sentences, but the drawings and sequence of drawings under which the teacher scribed their stories indicated a sound understanding of much of the new terminology. For example Roddie explains the chocolate making process described in his drawing:

> *John and Lance (the factory presenters) are showing us the big block of chocolate. They are putting the big block of chocolate into the melting machine to make chocolate fish. The children are getting a spoon and pouring it into the moulds.*

Drawing on similar understandings, Jessica describes it in this way:

> *We looked at the big block of chocolate. We put the melted chocolate into the fish moulds. The fish went into the cooling machine. It made the fish go hard.*

These descriptions compared favourably with the more simplistic descriptions and language of the stories pre-visit. Whilst several of the children knew to use a recipe book to help find out how to make a food product, they were unable to accurately describe elements of the process. Most children attempted to draw on their previous experience of baking and suggested a range of ingredients which mixed together would then be baked in the oven. For example Chrissie explains how she might make a chocolate gift for her mother:

> *Put the brown stuff in a bowl. Melt it in the microwave. Put butter in. Put flour in then baking soda. Put it in the oven.*

On their return to school, the students' models and drawings of their intended gifts were liberally sprinkled with colours, imaginative shapes and sometimes fillings – all design ideas which they observed and discussed during their visit. Some children wanted to make snail shapes for their gift, and curiously, others thought worms would be popular. Many students created stars, fairies and butterfly shapes but no student in either of the groups selected the segmented bar or fish shapes which they would normally have been most familiar with. The focussed walk through the retail area of the factory with the parent helpers, seems to have impacted significantly on the students' designs.

The second phase of the unit which also required parent supervision took place during the construction of the students' chocolate gifts. The gifts were to be based on the clay models they had created the previous day. In addition, the students had taken home a simple questionnaire which included images representing three different flavours of chocolate and a space to include a filling. Alongside each of these were three emoticons to indicate whether 'Mum' loved, liked, or disliked each of the flavours. This information was to guide the students' chocolate making.

It was not anticipated that this phase of the technology unit was likely to attract a different group of parents – parents who had a general idea of what the children were creating but unaware of how the visit, the mother's questionnaire and the making of the chocolate gift were related. All parents had received the same correspondence but the second group did not meet before hand to confirm the expected outcomes of the session or to discuss how best to work with the children. Two of the three parents in the first school had attended the factory visit, so their management of the task was generally directed at creating the chocolate gift for Mothers' Day although attention to the questionnaire varied – some encouraged the children to check their questionnaire results and others didn't.

The four parents helping at the second school had not attended the factory visit. They had missed out on the more focused preparation of helpers prior to the visit and they seemed less aware of the teaching and learning goals and, in fact, altered the chocolate making task. Hannah reported that:

> *I think a couple of mothers have said '"right you're making one for mum and you can make one for yourself".*

The approach of the parent helpers significantly impacted on the task focus of most of the children. They appeared to disregard the questionnaire completed with their mothers and turn their focus to selecting flavours and fillings for themselves. One child ate his chocolates before going home, another ate his when he got home and another was unfortunately 'stolen' at 'After School Care'. Only some of the gifts from this group successfully made it home to 'Mum'. Interviews with these children afterwards indicated that they were not as clear about the purpose of the chocolate making.

Mike sums this up nicely with this response to my questions:

Interviewer	*Did you take yours (chocolate gift) home to Mum?*
Mike	*No.*
Interviewer	*Did you eat yours at school?*
Mike.	*Yes. I had both. I eated both of them.*
Interviewer	*Did you?*
Mike	*Yes cause I was tricking my Mum.*

Concluding remarks

This study was an initial investigation into the influence parent helpers have on student learning during LEOTC and a technology unit. The findings indicate that a significant aspect of preparing for this type of learning experience is committing time to preparing and scaffolding parents so that they can not only effectively support the classroom teacher in managing the learning activities, but also enhance the learning opportunities of the students. These findings inform future planning in these areas, highlight the potentially crucial role of parent helpers, and indicate an area worthy of further research.

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Cultivating Problem-solving Ability by Utilizing Scientific Views and Ways of Thinking: Introducing Science Communication into Earthquake Disasters Game

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Key-words: science technology literacy, instructional materials, views and ways of thinking, science communication

Abstract
In this study, we developed science communication gaming material to cultivate scientific views and ways of thinking about issues concerning daily life. From the perspective of citizens' science communication, learners' roles were set as earthquake supporters/tsunami survivors. These learners constituted people who lived in areas neighboring quake-hit ones or far from quake-hit areas. As supporters, these people considered what the quake/tsunami survivors needed and thought about and how to transport materials to them. This experience was meant to prepare learners for natural disasters of this nature and make them aware of what course of action to adopt to survive in these situations. Each supporter, in isolation, cannot do enough to help survivors; however, when supporters communicate with each other, they can support survivors effectively. Consensus formation is part of this communication and is needed to make decisions. By utilizing scientific views and ways of thinking, we believe that consensus formation can be a rational and reasonable process. This material is to be implemented in e-learning courses.

Introduction

Science Literacy for Problem Solving
Science technology, while benefiting humanity, has also created several problems. Although information abounds on the Internet, sometimes, even information provided by the media or government is not accurate. Therefore, all citizens must think, judge, and decide on their own. For this reason, they must acquire and develop science literacy, especially when linked to problem solving in daily life.

There are several terms related to science technology literacy, such as "science literacy," "scientific literacy," and so on, as used here. Additionally, the terms "science technology" and "science and technology" should be distinguished. Since our purpose in this study is not to discuss this difference, we will roughly assume a containment relationship between them.

As expanded upon later, our theme is "earthquake disaster education," which relates to both science and technology. In essence, school education does not address technology education, except for "industrial arts and home economics" in junior high school and "information study" as a common subject in high school. Hence, we will focus on scientific literacy in problem solving; in other words, we focus on better decision-making based on scientific reasoning as the present educational goal.

The current task involves aspects of thinking, judging, and attitude. The objective of science, as a subject, also consists of thinking, judging, and attitude, combined with knowledge, understanding, and skill. Aspects of thinking, judging, and attitude are related to scientific views and ways of thinking and the attitude involved with how to use them, which should be taught in schools as the objective of science education. However, scientific views and ways of thinking are not as clearly defined as they are in mathematics (Hosonoya, 1999). Moreover, some scholars argue that cientific views and ways of thinking do not bring results (Shibue, Y., & Okada, Koichi., 2011).

To focus on the above aspects, the new National Education Guidelines, presented in 2009 and 2010, emphasize the activities of writing reports and making presentations by increasing opportunities for experimentation and observation (Central Council for Education, 2008). In our opinion, while this is an important improvement, it does not provide sufficient opportunities for activities. The curriculum contains few explicit instructions on scientific views and ways of thinking. The important roles among scientific views and ways of thinking are instruction and facilitation.

Relationship with Science Technology Communication

We believe that science communication should be citizen-centered. However, currently, science communication activities focus on scientists explaining science in a "friendly" and "understandable" way for citizens, with scientists playing the main role. If a citizen is expected to think, judge, and make decisions regarding science technology literacy, then science communication should be citizen-centered, and the target of the research should focus on communication among citizens. To make citizens focus on scientific views and ways of thinking, it is important for them to cultivate related knowledge and critically evaluate how they and others think when problems need to be solved.

Purpose

In the National Education Guidelines, the necessity of scientific views and ways of thinking is acknowledged, and it is set as one of the targets of science education; however, it does not achieve results. According to us, this is because there is "less correlation with daily life" and "few explicit instructions on scientific views and ways of thinking." Therefore, we developed the material for solving these problems. Specifically, by teaching scientific views and ways of thinking, and adapting the material in the syllabus so that it clearly relates to daily life, we can enable learners to adopt this way of thinking for daily problem solving. Since our theme is earthquake disaster prevention education, learners will be given explicit problem-solving questions connected with the situation of earthquake disaster. They must then utilize scientific views and ways of thinking to solve the problem, which cannot be solved directly by research alone.

Scientific Views and Ways of Thinking

The word "science" can be described as "verification, reproducibility, and objectivity." The procedure for examining these conditions is referred to as "scientific ways." However, scientific views and ways of thinking do not merely involve procedures but points of view or a checklist when considering target issues from a scientific perspective.

According to Matsuda (2012), scientific views and ways of thinking can be broken down in the form of a checklist. The items on the checklist below were selected from the Matsuda's checkliset for general problem solving from a scientific perspective to be used as guidelines.

1. Make a hypothesis with cause and effect relationships and determine ways of verification
2. Consider factors when solving the problem
3. Consider the case that does not take into account a certain factor
4. Check through experimentation or observation
5. Consider matters quantitatively
6. Consider consistency with rules or known facts
7. Consider by analogy

"Generating a hypothesis" is important in terms of scientific views and ways of thinking, as indicated by the following two studies: (1) the method for problem solving in developing products and (2) the method in commmon among three scientific inquiry methods. (1) The generation of a hypothesis is already being used as one of the necessary skills for problem solving in order to develop products like the plan-do-check-act (PDCA) cycle, which identifies cause and effect relationships. The implementation of the PDCA cycle is widely recognized in the scientific world as "kaizen" or "improvement" in Japanese (Watanabe, 2011). (2) Watanabe's report (2011) compares three scientific inquiry methods and shows "a hypothesis with cause and effect relationships in common among them." One of three methods is a process for scientific inquiry by R Reiff, Harwood and Phillipson (2002), the second, a process of scientific thinking by Wada (2010), and the other, a process adopted from Klett's textbook.

Instructional Methodology

There are two precedent studies on instructional methodology, and we will now point out the drawbacks of these studies from the viewpoint of instructional methodology for scientific views and ways of thinking.

First, in the study by Magara (1991)—that verifies how to support students by using scientific views and ways of thinking—the author relates a rule of science to a situation in daily life and creates a story, applying the rule to it. He then compares the results with those of a laboratory situation. The results are well verified; however, the application range is limited because the application requires many rules, depending on each case. Tamada and Matsuda (2004) suggest that case studies and rule-based lessons cannot be applied to every situation a student may face and that views and ways of thinking can cover a range of applications, similar to the three types of knowledge for information on moral instruction.

Second, the study "E-portfolio for self-regulated learning" by Sato, Matsuda, and Ishi (2010) develops ideas on teaching views and ways of thinking and successfully supports students' study of views and ways of thinking. However, it does not deal with scientific views and ways of thinking.

Theme: Earthquake Disaster Prevention Education

The primary reason for choosing earthquake disaster prevention education is that the conventional thinking of "experts teach citizens in a way that is easy to understand, and citizens follow this" is not necessarily appropriate. This was based on the so-called Kamaishi Miracle (The Kahoku Shimpo, 2011) at the time of the Tohoku earthquake, and was the impetus for focusing on the cultivation of scientific views and ways of thinking and reconsidering the definition of "science communication."

We therefore defined the issue: "come up with a proposal for better food and a delivery method thereof for delivering food to disaster-stricken areas." As a theme, this satisfies various requirements such as "not greatly dependent on the region where one lives"; "helpful not only at the time of disaster but also in reassessing everyday life"; "considers one's own position by considering other's position"; "the knowledge already acquired by high-school-level students can be used, but it is also necessary to acquire some new knowledge"; and "rather than by oneself, it is necessary to cooperate with others for better problem resolution."

We selected a food-related issue for the following reason also: It was suggested that at the time of the Kobe earthquake, situations could have been improved if citizens had a proper understanding of volunteer activities for disasters and supply shortages in evacuation shelters, and prepared daily for them (Matuda, T. and Morikawa, H., 2008).

When undertaking earthquake disaster prevention education, we must consider how to increase the probability that learners will actually face these situations; this is because learners are apt to lose interest in learning if the time and place of a disaster cannot be specified. In addition, the probability of their falling victim to such disasters is low. There is a higher likelihood that they will serve as supporters of the actual victims. By taking the supporters' role, their motivation can be raised. Moreover through their experience in supporting victims, we expect that they will be able to identify what they themselves would really need if they find themselves in a similar situation.

Design Principle of the Instructional Materials

This study aims to teach the importance of scientific views and ways of thinking. Making decisions that are based on private experience as well as scientific reasoning leads to better problem solving when faced with important decisions. In this study, there are no right answers, but learners are required to think using logic and reasoning.

Subject

The subject for this material is an undergraduate student for preparatory experience, though the supposed learner is a high school student. The reason for this is that this study aims to cultivate the ability of science literacy for citizens through school education.

Considering the percentage of junior high school students moving to high school at present in Japan, it is not necessary to limit the target to junior high students on the compulsory education stage, as fixed by PISA.

It is suitable to target high school students at present because logical thinking training is important for them, and scientific knowledge related to nutrition and cooking is taught in high school.

Situation for Learning

Learners' roles are set as supporters for earthquake/tsunami survivors. They might live in neighboring areas or far from the earthquake-hit area (Fig. 1).

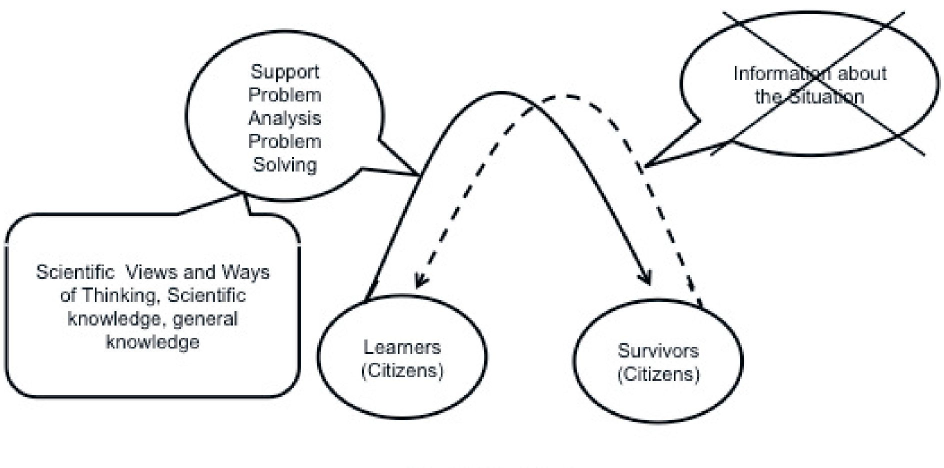

Fig. 1 Role of the Learner

As the possibility of being supporters is much higher than that of being survivors, it motivates learners.

We also propose that it is useful to make them consider how to prepare for such eventualities in their daily lives and how to survive in such situations, like earthquakes, by themselves.

In order to support them effectively, it is necessary for citizens to cooperate and build consensus. At this time, they will be required to utilize scientific views and ways of thinking to arrive at more persuasive suggestions (Fig. 2).

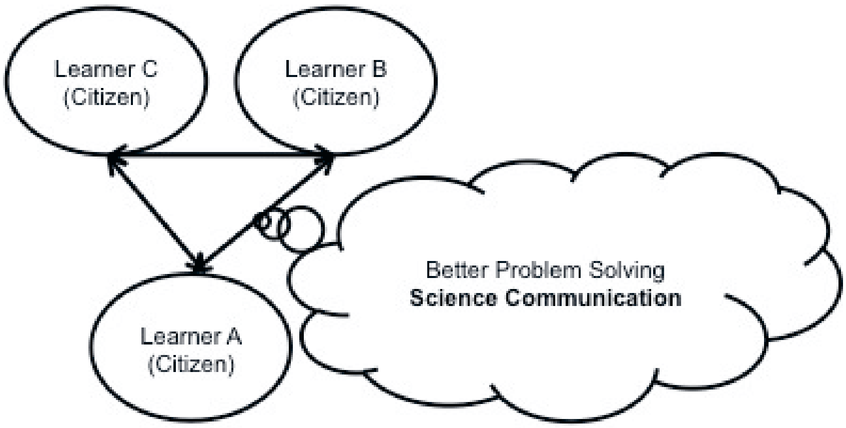

Fig. 2 Science Communication among Citizens

Framework of the Material

The framework of the material is based on the gaming material for information education (Matsuda, Hirabayashi, & Tamada, 2012). This framework responds to that of problem-based instruction (Savery, 2009). Further, Matsuda (2012) suggests that this framework can be used as the basic framework for all gaming material. There are several steps involved in this framework. Each step consists of explicit problem-solving questions that are connected with the situation of an earthquake disaster. Scientific views and ways of thinking are used as the viewpoints for problem solving. An evaluation list with four grades was also prepared to check the level in the debriefing step.

The framework comprises the following five steps.

1. Goal setting
2. Technical understanding
3. Rational judgment
4. Derivation of optimized solutions
5. Debriefing

Outline of Material

1. Goal Setting: In this stage, the task is presented (Figs. 3 and 4), and a situation with explicit problem-solving questions is given, considering the factor of "best support." Learners are encouraged to use scientific views and ways of thinking in the form of analogical thinking and reasoning to solve the problem.

2. Technical Understanding: The learner is given a situation whereby he/she has to consider the task based on quantification and data. Learners are encouraged to use scientific views and ways of thinking. There are only two food selections—rice and cup noodles—and learners are required to compare them from a quantitative point of view.

3. Rational Judgment: The learners are given a situation and asked to evaluate several possibilities in terms of "beyond imagination" or "the risks of making errors," and consider how to respond to and deal with this situation. Learners are encouraged to consider the issues critically.

4. Derivation of Optimized Solutions: Through the above steps, learners are asked to use reasoning and arrive at a consensus about the final answer.

5. Debriefing: The learners have to self-evaluate the problem-solving activities based on their written records of the activities. They are also asked to evaluate others' activities. In this way, the learners are able to reflect upon, consider how they can best be prepared for, and survive in this situation in their daily lives.

Task

You will consider how to support survivors when the earthquake occurs.

Please read the following situation and consider how to deliver the food to the quake-hit area.

A big earthquake has occurred with an intensity of 7 on the Japanese seismic scale* in area A. You want to send the food to the survivors for support. At this moment, there is no information about the quake-hit area, so you do not know what they need or what they have.

Fig. 3 Task Description

Lesson 1

You will determine the goal: "what is the better* solution". It is important to consider by focusing on various "goodness" when solving the problem.

First, consider "what is the better support" for better decision.

Please write down "the better support" in order to attain the goal of "delivering food as support" as much as possible.

* you are seeking for the better for improvement not necessary to be the best.

1. Ex. To keep well (Better preservation)

____

Fig. 4 Description of Lesson 1

Preparatory Experiment: Results and Considerations

Dialogical. 1 facilitator, two participants (college students). Time required: 30 minutes.

Results

1. Although learners were able to come up with many factors for "best support" using reasoning with analogical thinking and brainstorming, these factors were not comprehensive without the use of scientific views and ways of thinking.
2. Facilitation is needed for learners when making quantitative comparisons.
   The aim of the task was to quantitatively compare the merits between rice and cup noodles. However, learners concentrated on "the lack of water" and focused on a solution wherein water was in short supply. They did not focus on a quantitative comparison. Therefore, this task needed to be facilitated so that students would consider a hypothesis both with water and without it.

3. “Unexpected issues” like the garbage generated after eating the food selected in the rational judgment part of the task brought about other viewpoints, enabling the learners to consider the problem and its solution.
4. This experiment ends with rational judgment; however, we were unable to complete the last step, “debriefing”, due to time constraints.

Considerations

Learners were able to use analogical thinking or reasoning naturally, without reference to scientific views and ways of thinking. They were familiar with brainstorming and critical thinking and tended to enjoy brushing up on their thinking abilities.

Facilitation was required for quantification and rational judgment. The evaluation standard was then changed based on these findings.

In this study, the number of subjects was small, and it is necessary to increase this number in order to check when and how to introduce scientific views and ways of thinking in each of the abovementioned steps.

Conclusions and Future Work

In order to encourage learners to think, judge, and make decisions in a given situation with the information offered—which is not always accurate—we designed and developed instructional material to encourage learners to use scientific views and ways of thinking to solve problems.

By way of future work, we will make this material available online, on the instructional activities game (IAG) system. This will be developed based on our gaming material on information education, the framework of which works on the same design principles. We also plan to conduct trial sessions at both the high school affiliated with the Tokyo Institute of Technology and a public lower secondary school.

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Design teaching and industrial enterprises: a relevant relationship? An exploratory study of two didactic situations of design

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Abstract

This article presents an exploratory study concerning the "initial training / enterprises" relationship in the field of industrial design education. This study aims to characterize the intervention of an industrial enterprise (a sponsor) in a situation of design teaching and specifically its impact on the students' design activity.

We based our exploratory research on the clinical analysis of concrete cases. We want to analyze the design activity of students confronted with the same design task (an industrial "order"), but in two different teaching situations. In one of the studied training situation, students have met the "industrial sponsor. In the other training situation, students only had the "industrial order". At the end of the exercise, students of both situations have been interviewed about the tracks (notes, drawings, plans, models or CAD) that they have produced in order to accomplish the prescribed design task. The analysis of the students' design activity has been realized through the verbalizations collected during these interviews.

The processing and analysis of six students' verbalizations, allow us to highlight the influence of the presence of an industrial sponsor in a situation of design teaching. On the one hand this influence appears in the assimilation and processing of requirements contained in the specifications (the prescribed task), on the other hand, in the development of assumptions about the artifact to be designed. This study helps to show not only the importance of the teaching situation constructed by the teachers and their mediating role, but also the impact of the representations that the students have of the situation itself (didactic, operational, both). The presence of an industrial sponsor – invisible in one of the situations or physically present in the other one - engages all the students in researching a technical "credibility" (feasibility) of their artifact assumptions. Encouraged by their teachers, the students who have not been in direct contact with the industrial sponsor

have privileged training objectives and, for this purpose, they have "falsified" the requirements proposed by the industrial enterprise. The students in contact with the industrial enterprise have strictly complied with the requirements, denying any didactic objective.

One of the teaching situations can be described as a simulation, and the other as a re-creation, of the "complex of interactions" (Lebahar, 2007) inherent to every situation of design, The analysis of these two teaching situations raises questions about the relevance of a "situated design learning" based on "hybrid" design situations, neither completely operational, nor totally simulated.

Introduction

The industrial design practice and generally applied arts practice, in opposition of fine arts practice, cannot be conceived without a sponsor (issued from the industry or crafts). Industrial enterprises appear thus as "natural" partners when it comes to train industrial design students. Also, a lot of collaborations between "design schools" and industry, often in form of orders, have mapped out the design education history since the beginning of the 20th century.

What characterizes a teaching design situation integrating an industrial sponsor? The aim of this exploratory study is to try to characterize the intervention of an additional actor (an industrial sponsor) in a design teaching situation and specifically its influence on the design activity of future designers.

We can consider several theoretical approaches of the product design activity: an activity of resolution of ill-defined problems (Simon, 1969), a construction activity of representations allowing the control and management of uncertainty (Lebahar, 2007). The concepts of "*situation*" (Dewey, 1938; Vergnaud, 1991), of "*didactic situation*" (Brousseau, 1988), and of "*situated action*" (Lave, 1988; Suchman, 1987; cited by Beguin & Clot, 2004) allow Lebahar to define the design situation as a "*complex of interactions*", represented on figure 1. At the center of this "*complex of interactions*" is the professional *"designer"*, (Lebahar, 2007, 2008), and around the "*elements of* [the] *operative environment*" (Lebahar, 2001) of the designer: the design task, the design competences of the designer himself, external knowledge sources, communication media and representation media and, at last, the other subjects (Lebahar, 2001, 2007).

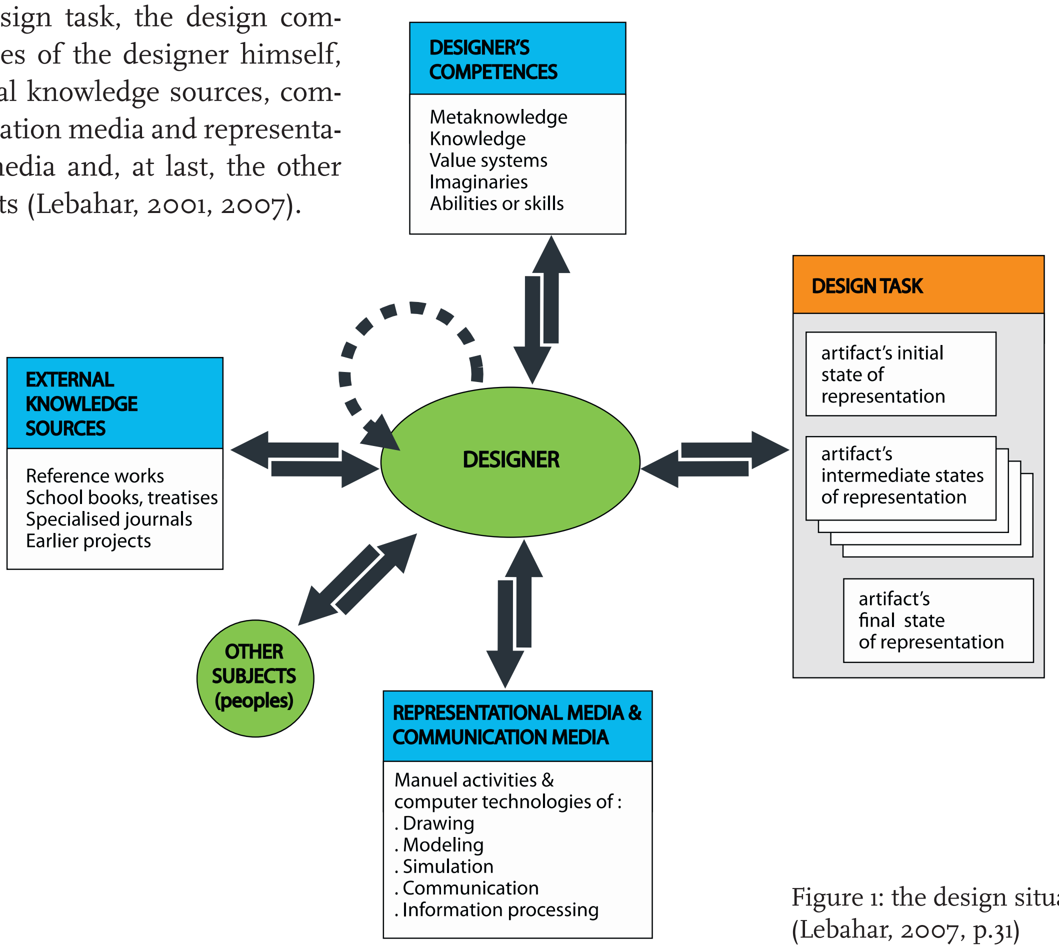

Figure 1: the design situation (Lebahar, 2007, p.31)

Taking as a basis these different approaches concerning professional design situations we are interested in design teaching situations. We can try to sketch the outlines of an artifact design didactic by grounding it in "the *project of professional didactic*" (Rogalski, 2004). This didactics could be theoretically based "*at the crossroad of cognitive ergonomics and didactics area*" (Rogalski, 2004, Samurçay & Pastré, 1998). The concepts of "*didactic situation*" (Joshua & Dupin, 1993, Brousseau, 1988), of "*didactic transposition*" (Chevallard, 1985), of "*relevant professional reference knowledge*" versus "*legitimated (scientific and cultural) knowledge*" (Rogalski & Samurçay, 1994) and of "*social practices of reference*" (Martinand, 1981), show the difficulty to produce a model of a such complex activity as product design activity. These concepts raise two questions: on the one hand, about the nature of the necessary transposition to work out a "relevant" didactic situation of design (Rogalski & Samurçay, 1994; Tortochot & Lebahar, 2008), on the other hand, about the practices of reference this transposition should be grounded on. "Design schools" often answer these questions by "working" with industrial enterprises within the framework of design exercises. In these cases, the subject of the exercise usually takes more or less the form of a sponsor's order. Our objective was to observe and analyze the introduction of an operational sponsor into a teaching design situation in order to characterize its influence on the activity of the apprentice industrial designers. We have also tried to characterize the competences and knowledge the students have acquired at the end of this activity.

According to Lebahar:

> "*The analysis of the apprentice designer's activity, during his training, reveals, not only design competences, but much more, one building episode of its design competence. As a future professional designer, he's preparing to adapt to the constraints of certain tasks and to the constraints which condition the relations of exchange and co-operation between the various actors of the labor division*" *(Lebahar, 2007, p. 243)*.

However, the question of the training of the "*relations of exchange and co-operation between the various actors*" is not tackled in the studies carried by Lebahar.

Research Methodology

Built on the work of Lebahar (Lebahar, 2001, 2007, 2008) our investigation - a clinical analysis of specific cases - is based on the analysis of the design activity (Lebahar, 2007) of product design students in the context of two different teaching design situations.

The survey takes for frameworks the department of applied arts of the University of Nîmes (situation A) and the design product BTS (Brevet de Technicien Supérieur) section of the High school Jean Perrin of Marseilles (situation B).

The same design exercise, grounded on a sponsor's request was proposed to two groups of students with comparable design competences (two years of applied arts training after high school diploma).

In order to select the sponsor, the teachers have used the following criteria: the wish of the enterprise to participate in the students' training and the acceptance of planning constraints stipulated by teachers. The enterprise has engaged itself to give the students a counterpart in the event of industrialization of a model designed within the exercise framework. The choice of the enterprise also has been conducted by the technical simplicity of the products to be designed and by the fact that these products are domestic products, familiar to students (i.e. kitchen utensils, laundry utensils or drying racks, little garden tools or flower pots).

The same design task was presented in writing in a similar form to all students. The task was also orally presented by the teachers in the situation B and by the industrial sponsor in situation A. The planning of the exercise is set out in figure 2.

All students were asked to elaborate an individual logbook all along the design exercises. This logbook had to present, in an exhaustive and chronological way, all the tracks (notes, drawings, plans, models or CAD) produced in order to accomplish the prescribed design task.

To achieve the design task, students have worked in two different contexts. In situation A the students were in direct contact with the sponsor. In the situation B, the students received the instructions only by the teachers and had never been in direct contact with the sponsor. Thus, the students involved in situation A had met the leaders of the enterprise three times while the students involved in situation B had never met them.

In both teaching situations, the exercise was performed over comparable periods of times in the two education establishments, in Spring 2010. Students worked for approximately 35 hours at school with their teachers and approximately 35 hours on their own, in their residence.

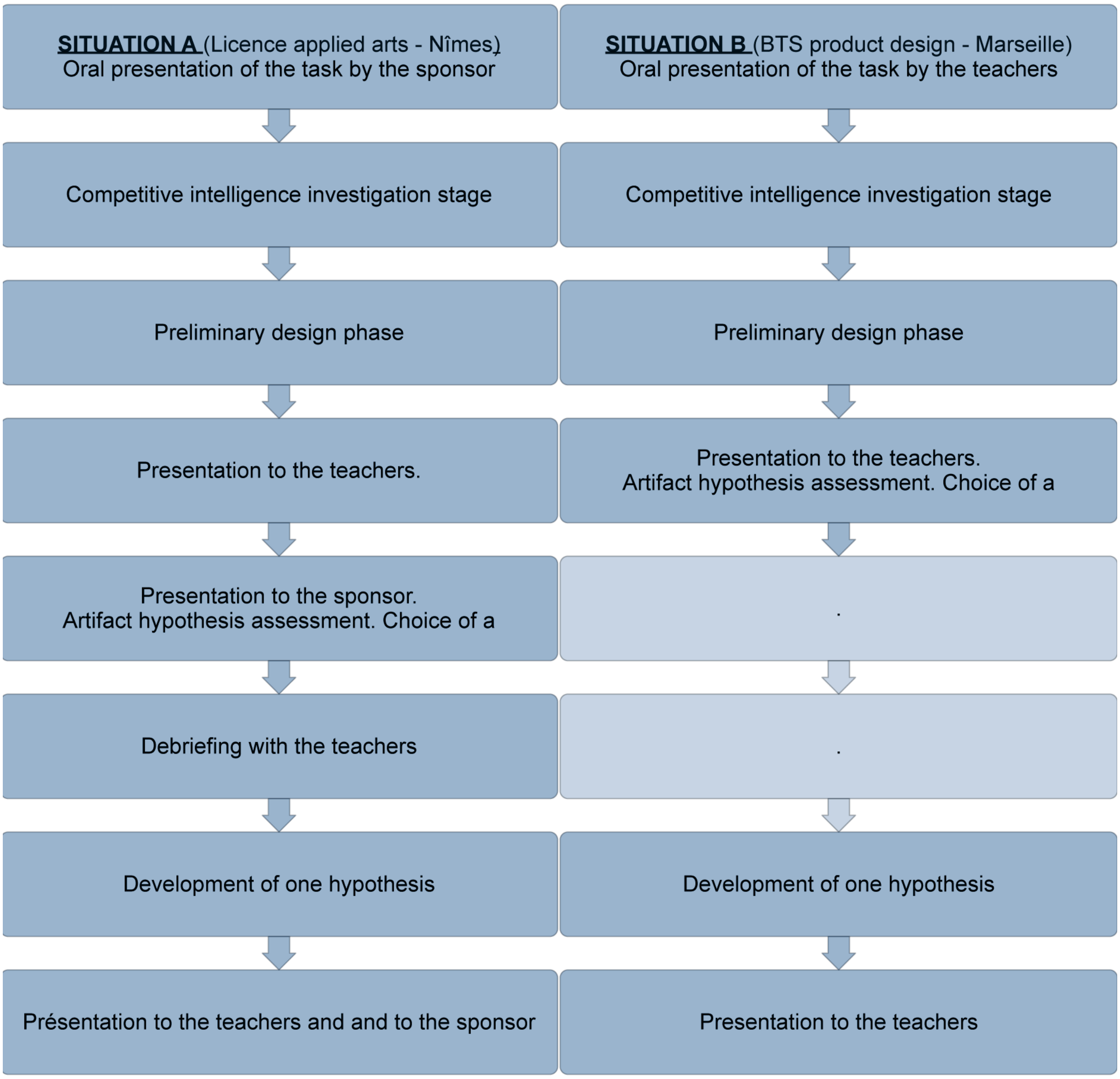

Figure 2: Workflow within the framework of the two situations

Collection of the data

At the end of the exercise, the students handed in their “logbooks”: notes, references, elements of the competitive intelligence investigation, sketch, drawings or annotated plans, which are *“successive states of representation”* of the artifact hypothesis (Lebahar, 2008).

We have used six students’ “logbooks” as support to perform semi-directive interviews of six voluntary students. Three interviewed students had taken part in the teaching situation A and the three other students had followed the teaching situation B.

The students’ verbalizations have been literally transcribed and then segmented into elementary sentences and lastly into elementary proposals. Thus, we obtained a "*linguistic corpus*" (Lebahar, 2007, p.67), which we have analyze "*with the semantic models provided by linguistics* [...] *and semiology* [...]." (idem).

Results

The analysis of data collected trough the semi-directive interviews based on the students "log-books" highlights the knowledge or competences used or acquired during the exercise but also the "*reasoning*" and the "*dialogue strategies*" (Lebahar, 2007) with the teachers, the sponsor and the other actors of the situation. Lebahar shows that the produced representations allow an analysis of the various successive design states that correspond with various *"states of the representation"* that the designer has of the artifact to design.

This study also shows the direct or indirect links between the students' activity and the industrial sponsor, physically present (situation A) or "invisible" (situation B): through the consideration of the prescribed task, through the activity organization, through used strategies and through the situation representations.

We will present here three results found in the students' verbalizations analysis.

The first result is that the existence of a sponsor ("*the teachers have not found the subject*" said a situation B student) has forced or encouraged all the students to refine their artifact assumptions from a technical point of view, *("more definite", "more real", "that really works", "that can be made", "all must be feasible"*, and so on). This constraint, which is not specified in the subject of the exercise, is deducted from the training situation they experienced and more generally from the design situations: it is the "*principle of reality*" (Lebahar, 2007). All the students involved in both situations have mentioned this *"principle of reality"* and they justified its respect by the existence of a sponsor. Thus, the students of situation B confer to the absent sponsor a symbolic function (Piaget, 1945) of "guarantor" of a "technical reality". In order to respect technical constraints, all the students make use of their own technical competences, acquired during their formation, or use their teachers' technical expertise. A student in situation B also has developed collaborations with an external actor to the teaching situation, expert in 3D modeling and in the resistance of materials.

This particular point enables us to present a second result about the students' targets in both situations. The students involved in situation B have sought to apply and to consolidate technical knowledge or representation skills (CAD) already acquired. To this end, they free themselves from the sponsor's specifications. For the students involved in situation A, technical feasibility is an essential precondition to achieve the industrial development of their assumption, which is their main objective. So they perceive the situation as an operational situation rather than a teaching situation. The execution of design tasks, in operational framework, *"requires a performance and the product (here a model of artifact) have to be accepted by the sponsor within the timetable.*" (Lebahar, 2008, p. 238). Therefore the students in situation A have selected quickly among their assumptions and then have focused on the "technical feasibility" of their model of artifact but also on an attentive respect of the sponsor's requirements (simplicity, distribution networks, marketing targets...). Lebahar notes: "*a performance based approach does not systematically correspond with an approach of building of competences* (Idem). However, the implementation of a sponsor's requirements is not limited to the respect of an "uncontextualized" technical feasibility. The requirements (including specifications), contain, other parameters such as the market requirements, the know-how constraints, the numbers of products to be manufactured or the company's production tools.

We can extract a third result regarding acquired competences. The students involved in situation A have expressed themselves on the stages of their activity of design and on their direct or indirect interactions with the sponsor, but haven't expressed themselves on acquired competences. This fact is consistent because, for them, it was not about a didactic situation. Therefore, they don't place themselves in a learning situation. About the students in situation A, we can hypothetically say that they acquired a "complex skill" of the operational situation. Even if this competence cannot easily be subdivided into "under-competences", we can deem the acquisition of competences related to the assimilation of requirements and skills related to the "dialog" with a sponsor, in all its forms (verbal, boards of presentation, artifact assumptions and so on). The purpose for these students was always to see their artifact assumption industrially achieved, not to acquire competences.

For their part, the students involved in situation B are able to make a reflexive return on the acquired competences (technical competences and knowledge, representation skills). However, they are aware that they have not complied with the initial requirements ("I have not worked for the enterprise" says a student involved in situation B). Encouraged by their teachers, they focused on the acquisition of the above-mentioned competences.

Discussion

Our case studies can be compared to the design activity analysis conducted by Lebahar within didactic or operational situations (Lebahar, 2001, 2007, 2008). The question remains of the transposition or of the recreation of a complex "situation of reference". Do the teaching situations that we observed allow *a "training of the situations rather than the acquisition of knowledge"* or "*know-how*" (Mayen, 1999, Pastré, 1999 and 2000, cited by Leblanc and coll., 2008)? Does the complexity of the situation of reference (Raisky, 1999) have to be preserved? Tortochot notes: "*Taking into consideration complex and multiple practices of reference, the acquired competences and their difficult evaluation highlight the* [essential?] *complexity of the learning situation of artifact design*" (Tortochot, 2007). Is a didactic transposition by "*decomposition (cutting, decoupling and focusing)*" (Rogalski, 1998, cited by Leblanc and coll., 2008) preferable? This last solution also simplifies the assessment of the students' work.

We can also analyze the form and the nature of the prescribed task. The formulation of the prescribed task (subject of pedagogical exercise, operational order) and the "status" of the "prescriber(s)" (sponsor, teachers) are central in the operational design situations and didactic situations (Leplat & Hoc, 1983, Lebahar, 2007, Quarante, 1994). It appears that the representation of the role and "status" of the "prescriber(s)" (teachers, sponsor, both) conditions the representations the students have of the situation itself. These representations allow us to consider several natures of situations: "*didactic*" (Brousseau, 1998, 2003), "*operational*" (Lebahar, 2007), "*situated learning*" (Wenger & Lave, 1991), *"simulated operational situation*" (Mayen, 1999, Pastré, 2005, Pastré, 1999 and 2000, cited by Leblanc and coll., 2008), "*sufficiently similar to the real situation*" (Caens-Martin, Specogna, Delépine & Girerd 2004 cited by Leblanc and coll., 2008). The representations of the nature of the situation (operational within a "school" or only pedagogic), expressed by the students, also determine his purpose (teaching on the one hand, industrial and commercial of the other), as shown in figures 3 and 4.

Our analysis shows that the two situations (sit. A. and sit. B) experienced by students can be described as a superposition of two different situations: a didactic situation and an operational situation. It could be described as an "hybrid situation" (figure 5). This complex situation "overlays" two goals (operational and pedagogical) and students seem to have difficulties to accept this duality. Thus, when the sponsor is not physically present (sit. B), the students choose, encouraged by their teachers, to perform their design activity within a didactic situation and "falsify" the initial requirements and specifications. For their part, students of situation A have denied any didactic status to the situation, despite the presence of their teachers.

This complexity has to be regulated by the teachers according to the students' level of "design competence". We can speak about "*a reduced participation* [of the students] *in the practice of an expert*" (Rogalski, 2004). The teachers' role and their competence of mediation at the time of the situation construction and at the time of the elaboration of the prescribe task - at the same pedagogical exercise and operational order - remains a key element of the relevance of this kind of training situation. This mediation ensures the didactic nature of the situation.

At last, we will specify a limitation of our study. Indeed, important methodological biases were introduced into our observations by the fact that the exercise was prescribed to students of two different teaching establishments, by different teachers and within different teaching programs.

Through an identical prescribed task, one can't neutralize the institution's influence and its actors' influence on the training situation of design. Within the situation B, the teachers have "arranged" the prescription, during the exercise, in order to make it "coincide" with their training targets and with the program of the "BTS". The objective of these teachers is also to evaluate the assimilation of pedagogical contents provided during the year. The design activity is here reduced to the execution of the design task, disconnected from the "*complex of interactions*" described by Lebahar (Lebahar, 2007). Lebahar described this kind of design situation as "robinsonnic" situations (idem). There is a simplification of the "*complex of interactions*" by simulating or removing the major part of the interactions.

The primary goal is therefore different in the two observed situations. In one case (sit. A), the teachers consider a necessarily situated learning of the operational design situation. In the other case (sit. B), the teachers target a synthesis of the teachings and the preparation of the "BTS" exam.

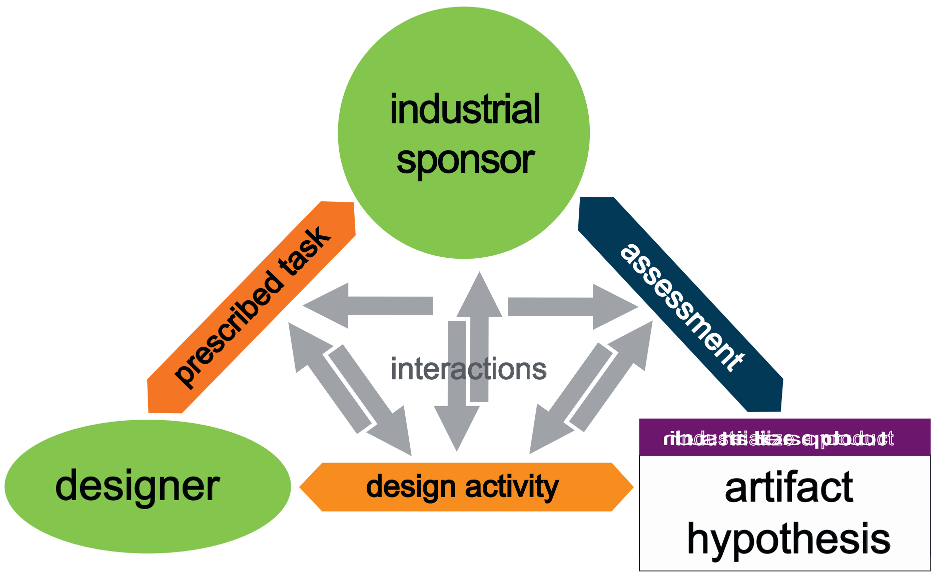

Figure 3: the operational design situation and its objective

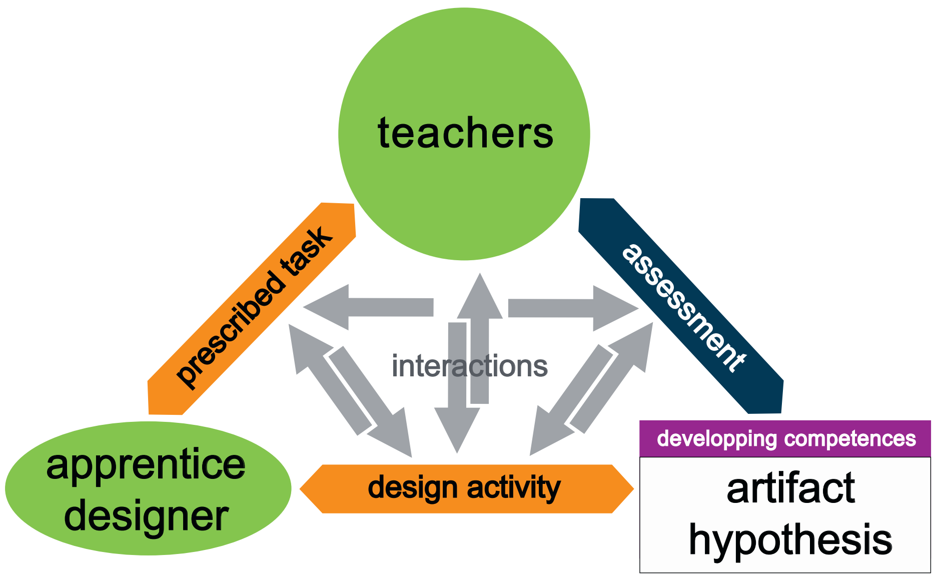

Figure 4: the didactic design situation and its objective

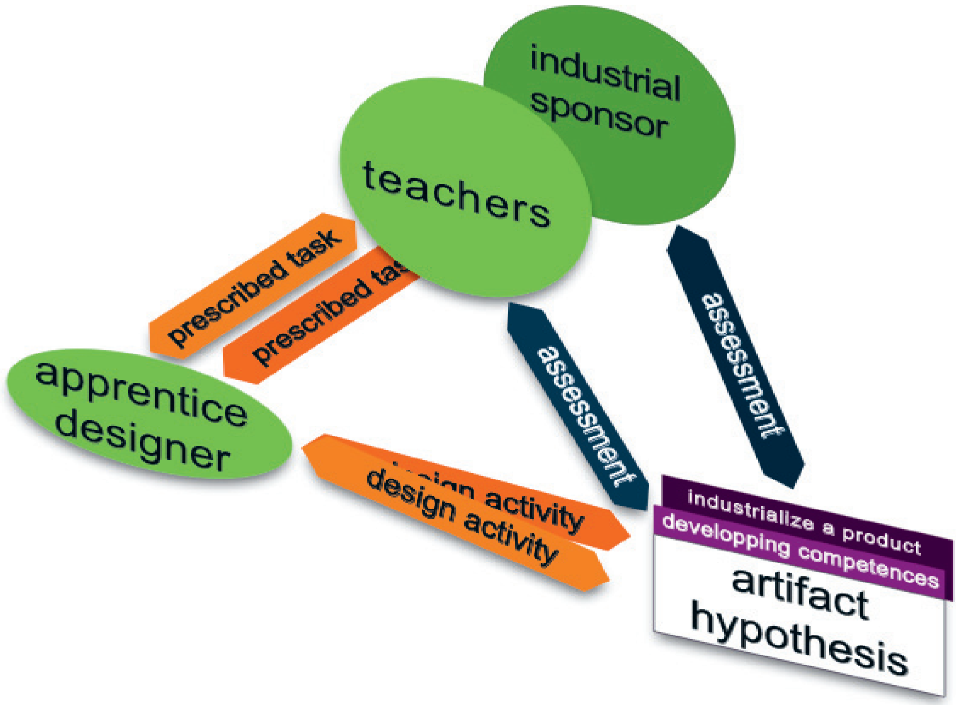

Figure 5: the “hybrid” design situation and its objectives

Conclusion

This exploratory study based on case studies, enabled us to analyze the activity developed by students to achieve the same prescribed task of product design within two different learning situations. We have, through students’ verbalizations, analyzed the representations they have, first, of the nature of the prescribed task (pedagogical exercise/operational order), secondly, the representations they have of the design situation (didactic, operational, “hybrid”), and lastly, the representations they have of the roles of the various actors of the situation (teachers, sponsor, technical experts). The question of the census, of the nature and of the evaluation of the design competences acquired within each situation remains to be refined (competence of assimilation of a prescribed task, analytical competence, communication skills, representation skills, project management skills, “intelligence of the situation”).

However, we have highlighted the fact that the representation that the students have of the situation strongly conditions their activity and especially the assimilation of the specifications included in the subject of the exercise. Thus, the presence of a sponsor engages all the students in research of a technical “credibility” of their artifact assumptions. But only the students who have been in contact (in interaction) with the sponsor have complied with the requirements. These students have had an experience of the “*design situation*”, of its environment and of a non-simulated “*complex of interactions*” (Lebahar, 2007).

What kind of pedagogical device would one implement in order to make the students understand the concept of the “*design situation*”? Does this concept have to remain a theoretical object or can it be used as a ‘tool” for the development of a “situated training” in a relevant environment?

At last, this study presents two French situations that we considered representative of a widespread typology of cooperation between “design schools” and industrial enterprises. A thorough investigation of this kind of practices in France and in Europe would allow us to draw up a more precise cartography. We could also extend our research to the entire design teaching situation described by Lebahar (Lebahar, 2007), in order to clarify the pedagogical challenges but also the political or even financial challenges which encourage the “design schools” to develop such partnerships with industrial enterprises.

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Learning to teach design and technology in university or in school: is emerging teacher identity shaped by where you study?

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Introduction

'We teach who we are' (Stenberg 2010: 343).

This paper describes the preliminary stage of a research project that will investigate whether the course that students take to become teachers of design and technology makes any difference to the professional identity of the teacher they become.

Design and technology (D&T) student teachers come from a wide range of backgrounds, some are young undergraduates straight from school who are acquiring subject knowledge whilst also learning to teach it. Others begin their postgraduate training having achieved subject expertise via their first degree and subsequently gained a wealth of industrial and commercial experience. Whichever route is taken, learning to teach involves not only learning the knowledge and skills required but also the formation of a professional identity as a teacher (Carter and Doyle 1996).

Like Stenberg (2010) we believe that who we are as teachers (our professional identity) is an important aspect not only of our own selves but also informs our classroom practice. According to Sachs (2005: 15) teachers' professional identity 'stands at the core of the teaching profession. It provides a framework for teachers to construct their own ideas of 'how to be', 'how to act' and 'how to understand' their work and their place in society'. Teachers' professional identity is shaped by historical and political influences as well as social and cultural ones, including the student teacher experience and context of learning to teach. It is, therefore, important to understand the impact that the teacher preparation course has on the development of student teachers' emerging professional identity and how this might influence how (student) teachers are, act, and understand.

Our research is being undertaken in England, where teacher preparation is currently undergoing upheaval, with increasing numbers of school-based routes to qualification being proposed. We are investigating two types of teacher preparation courses, one university-based and one school-based, to find out whether these two courses have different outcomes in terms of the professional identities of the design and technology teachers and the types of teachers they are in the classroom. This may give some insight into the teachers we can expect in the future, given the Government's change in emphasis from university-based to school-based preparation. This will have relevance for those investigating D&T student teachers' professional identity and for those concerned with the role of the university and the role of the school in the preparation of teachers.

Definitions Of Teachers' Professional Identity

The concepts of 'identity' (Erikson 1968, Lloyd 2005) and being a 'professional' (Jackson 2010) have been researched for decades. It is outside the scope of this paper to explore these concepts in depth but the research on teachers' professional identity has grown out of these earlier studies.

The literature acknowledges the multi-faceted and complex nature of teachers' professional identity and the difficulty of providing a concise and precise definition. Beijaard et al (2004), in a meta-analysis of the literature, concluded that there was a lack of clarity, with reports defining professional identity differently, or not at all. However, they determined that teachers' professional identity can be characterised as not fixed, consisting of sub-identities, involving both personal and contextual factors and agency, the individual's active involvement. Sub-identities are complex for student teachers, comprising not only the personal and professional but within the professional are identities of subject expert (as graduates), student (particularly for those in university-based programmes) and student teacher. Personal factors include what the student teacher brings to the course and the social interactions experienced during it and contextual factors include the location of training. Other researchers also describe teacher identity as fluid (Olsen 2008) and not fixed (MacGregor 2009, Chong, Low and Goh 2011). Connelly and Clandinin (1999) found that teachers were more concerned about who they were than about what they knew, they referred to professional identity as 'stories to live by'.

Day and Kington (2008) suggested three dimensions to teacher identity: professional identity, situated located identity and personal identity. Lauriala and Kukkonen (2005) and Stenberg (2010) consider identity and self-concept as the same thing, a notion which is contested (see Rodgers and Scott 2008). However, Rodgers and Scott also suggest that identity and self are related, 'If our identities are stories, then our selves might be the storytellers' (2008: 738). Accepting the relationship between identity and self, Lauriala and Kukkonen suggest that there are three dimensions: the actual self, the ought self, and the ideal self.

The context of teacher education in England led us to use the definition of professional identity suggested by Lauriala and Kukkonen (2005). In this we see the actual self as being the identity which the student teacher currently holds about him/herself, and which we will be investigating in later stages. We regard the ought self, which Lauriala & Kukkonen (2005) describe as represented by 'one's own, and significant others' hopes, wishes and aspirations' as being represented in official documents and research reports, for example Qualified Teacher Status Standards and reports on teacher effectiveness (Hay McBer 2000). The ideal self we consider to be the self promoted through the teacher preparation programme undertaken by the student. This paper reports our preliminary findings on the ideal self suggested by pre-service courses which are university-based and those which are school-based, at this stage using only data on the taught programme.

Initial Teacher Education And Student Teachers' Professional Identity

It has been recognised that students begin their teacher education programmes with preconceived notions of what it means to be a teacher (Lortie 1975, Flores 2001, Gratch 2001), and that these notions can be difficult to change (Korthagen 2004, Alsup 2006). One of the purposes of teacher education, therefore, is to engage students in reflecting on their preconceptions and how these might influence them as teachers.

Student teachers' professional identity develops as they progress through their training programme (MacGregor 2009). Battey and Franke (2008:129) believe that 'The process of learning to teach is a social process of identity transformation' and MacGregor (2009:3) that how identity develops depends, to some extent, on 'the social and cultural constructs of others in specific contexts'. This implies that the context for student teachers' learning is an important contributor to their professional identity. If social interaction with others is a factor then who those others are, their views of teaching and what it is to be a teacher and their perception of the individual student will all be influential.

It has also been shown that the school context is important in shaping teachers' professional identity (Beauchamp and Thomas 2009, MacGregor 2009). This suggests that students on teacher preparation programmes that are based in schools are likely to be influenced by the school environment in which they are based, the culture of the department and the individual teachers with whom they work. As these are all located within one environment the influences on the student teacher, we suggest, may be convergent. Students on university-based programmes, although influenced by the school context during the time spent on practicum, will have this influence mediated by their experience in another school, by university tutors and the experiences of other student teachers.

We believe there are additional factors to consider which are specific to D&T student teachers. Many D&T student teachers have previously had successful careers, for example in a design studio, manufacturing company or self-employment which will influence their approach to the subject and what they consider important. MacGregor (2009:3) studied the extent to which the professional identities of D&T teachers are informed by their work backgrounds and found that student teachers identified 'the professional experience as the most significant factor in shaping their professional identity'.

In many countries, D&T is perceived as a low-status subject, often also as a less-academic subject, and this is likely to have some influence on the student teacher's emerging professional identity. However, D&T is a subject that is dynamic, continually changing and popular in schools with pupils, and this subject culture is also likely to impact on the development of professional identity. The changing nature of D&T means that it is also important to consider the preconceived notions that student teachers bring to their pre-service course.

As the influences on teacher professional identity include preconceptions and the social and cultural context of learning to teach, this research investigates two different types of teacher preparation course, one university-based and school-based, to find out whether the type of course undertaken influenced the formation of the student teachers' professional identity and the types of classroom teacher they become. Although teacher, and student teacher, professional identity is increasingly being researched (Stenberg 2010) we found little research on D&T teachers and no research on pre-service teachers undertaking different types of teacher preparation courses.

Teacher Preparation Courses In England

Teacher education in the UK, as in many other countries, has developed from the 'apprenticeship' model, through teacher training colleges to become a university-based degree course. However, since its election in May 2010, the UK government has introduced many changes to education provision in England, including changes to pre-service teacher preparation. One of the changes will result in teacher preparation once more being the responsibility of schools, rather than universities. The issue of who is the leading partner in teacher education is, we believe, an important one and the UK is not the only country where this is topical as other countries also face expansion of the available routes into teaching (Cochran-Smith et al 2008). Many teacher educators are concerned about the consequences this will have for the content and teaching in teacher preparation courses and the nature of the professional teacher emerging from such training.

Currently, there are several programmes available in the UK for those wanting to become secondary school teachers of D&T once they have completed their first degree; the two most popular are the university-based Post Graduate Certificate of Education (PGCE) and the school-based Graduate Teacher Programme (GTP). In 2009-10 (the latest year for which figures are available) 75% of new teachers qualified through a PGCE programme and just less than 25% through a GTP programme.

The PGCE and GTP courses are similar in some ways, in that they are both aimed at those who have a first degree in a relevant subject and both take one academic year to complete. In other ways, the two courses are very different.

The PGCE course is a university course which includes academic study of aspects of teaching and teaching experience, the practicum, in two different schools. The schools are in partnership with the university, in that there is a contractual relationship and roles and responsibilities of university teaching staff and school staff are formally agreed. Students spend a total of 12 weeks in the university, which is spread over the academic year, and 24 weeks in total in the two schools. University staff have responsibility for auditing and developing student teachers' subject knowledge and teaching them the knowledge required for classroom practice. They also visit the student in school to observe and monitor their classroom practice. The university conducts academic assessment, which is through a mixture of written assignments and school-based activities. The university awards the academic qualification and recommends the student (to the government department responsible for registering teachers) for professional accreditation. School staff have responsibility for supervising the student during the practicum, undertaking regular observations and providing feedback. One member of staff will be named as the student's mentor and will have the major responsibility for the practicum and meet regularly with the student. The mentor usually provides the university with assessment of the student against the Standards for the professional accreditation.

In contrast, the GTP course is located in school and the GTP teacher is employed by the school as an unqualified teacher during the period of training. As this course may be the responsibility of a local authority, consultant organisation, university or school there is little consistency on content and structure. Many GTP programmes have links with a university and the GTP teacher may attend the university for an agreed number of days during the academic year, but required attendance can vary between 35-60 days and for some attendance is during the evening, at the end of the school day. Some GTP courses provide training 'in-house' with consultants or school staff running training sessions. There will be a designated mentor who will have major responsibility for the GTP teacher and who will meet regularly to discuss progress. The GTP teacher will be expected to teach timetabled lessons, if not immediately on starting then within 10 weeks, although this is usually limited to 50% of a standard timetable in order to allow time for learning activities. There is also a legal requirement for GTP teachers to undertake a placement in a different school, the length of this placement varies between 15-30 days. Teachers taking this course gain only the professional accreditation of Qualified Teacher Status.

Whilst there are many similarities between the two programmes, the differences are marked. On the PGCE programme, the student teacher's main identity is as a student of a higher education institution working towards an academic qualification and professional accreditation. By contrast, on the GTP programme the student's main identity is as an unqualified teacher working towards professional accreditation. It is this difference that we want to investigate, does it lead to a difference in the professional identity of the teacher and/or the type of teacher they become.

Methodology

This on-going, small-scale study looks at the preparation of teachers for secondary school (11-18 years) design & technology on university-based PGCE programmes and on school-based GTP programmes. The longer term aim is to find out whether these two programmes produce teachers with different professional identities. We have undertaken analysis of official documents to look for the ‘ought self’ (Lauriala and Kukkonen 2005) portrayed in these, but limitations of space mean that this is not reported in this paper. Here we present the work in which we have looked at the content and structure of the two teacher preparation programmes to look for the ‘ideal self’ (Lauriala and Kukkonen 2005) they portray.

In this first stage of the research, a survey was issued to providers of teacher training for secondary school D&T, via an online closed conference group. The survey listed 52 aspects of teacher training, drawn from the researchers’ own experiences and research reports on teacher effectiveness (Hay McBer 2000). Respondents were asked to indicate, for each aspect of training, the approximate number of allocated hours and where the training took place. Responses were uploaded into a spreadsheet and ranked in order of most to least hours allocated, as this was thought to be an indicator of importance given to that aspect. We also analysed where the allocated hours were located, university or school.

From a community of 91 members we received 17 returns, eight of these referred to PGCE programmes and four to GTP programmes. Two respondents combined their data from both programmes so were discounted, as were data from one institution in Scotland and one programme which was of a different kind. Although returns were low, we believe that the data are broadly representative of national provision for two reasons: one is that teacher education is closely monitored by government, through inspection and the requirement for student teachers to meet national Standards, the other is that the sample is random and represents all geographical areas of England.

This represents just the first stage of a longer study, in later stages we will interview and observe student teachers in order to gather more qualitative data on why one course is chosen in preference to the other and whether or not the type of course taken influences the professional identity of the teacher.

Findings

The survey asked course leaders to indicate how much time they spent teaching each of the aspects of teacher education previously identified as relevant to design and technology secondary teacher education.

The main finding from this analysis is that there appears to be little difference in the course content of the two different programmes. However, the university-based providers (PGCE) were more able to provide specific teaching time allocations for each of the topics listed as the university teaching is timetabled for the students and it is easy to identify specific time allocations for each topic. This meant that a rank order could be easily identified.

On GTP programmes, although there are some formally timetabled sessions, much of the teaching of specific topics takes place less formally in the school setting so GTP course providers were less able to give specific timings for the teaching of each topic. As a result, many of the topics are clustered together and no rank order is clearly discernible.

Given the importance of subject knowledge to effective teaching, and the fact that both of these courses lasts just one academic year, it was not surprising that in both types of courses the auditing and development of subject knowledge was ranked highly. In the UK, D&T teachers are required to teach in two material areas yet many begin their training with knowledge and skills in just one area. This means that in their year of teacher preparation they not only have to learn all the knowledge and skills required to teach but also the subject and pedagogical knowledge of a second area.

The other topics which ranked high on the list for both programmes were those that attend to the fundamental aspects of teaching, although it was surprising to see *Lesson Evaluation* so low down the ranking given the importance attached to reflective writing in teacher development (Zeichner 1987, Pollard 2008, Beachamp and Thomas 2010). It was also surprising that *Health and Safety in D&T* was not ranked higher given the critical importance of this in D&T classrooms, the need for students to gain health and safety accreditation and the requirements placed on schools in this regard.

Surprisingly, some of the lower order topics were those which we would expect student teachers to be concerned about as they feature in the professional standards that they are required to obtain, for example *Statutory Duties of Teachers, D&T and Literacy and Numeracy* and *Progression in D&T Learning*. Cross curricular aspects were also low in the rankings: *PSHE in D&T, Citizenship in D&T and Thinking Skills in D&T*.

Those aspects at the bottom of the rank order include some of the more theoretical aspects of teacher learning, such as *Learning Theories, Motivation in Learning, The Nature and Purpose of D&T* and *Research in D&T*. This is surprising for the PGCE university-based courses given that the student teachers are working towards an academic qualification, in many cases at master's level. Although schools have been funded and encouraged by government to engage in research (Furlong and Sainsbury: 2005) this appears to have had little impact in the GTP training provision.

As the PGCE university programmes worked jointly with partner schools, where students undertook their practicum work, and as some GTP programmes require their students to attend university for some training sessions, we asked who had the major responsibility for teaching each of the identified course elements.

In the PGCE courses, the university covered all the topics and most schools also covered similar topics. There were some topics not covered by some schools and these tended to be those of a more 'theoretical' nature, such as the Nature and Purpose of D&T and Research in D&T. However, we would argue that an agreed understanding of the subject, at least by its subject community, should be at the foundation of both teaching and learning and so should be fundamental to a teacher preparation programme. Furthermore, a shared understanding of the subject should contribute to the notion of the 'ideal self' suggested by Lauriala & Kukkonen (2005) as it promotes a vision of what a D&T teacher should be concerned with.

Aspects most covered by schools were those considered more relevant to the practical work of teaching, such as subject knowledge, planning and preparing lessons, assessing pupils and teachers' pastoral work. Although interestingly, all the universities taught students about *The National Curriculum* but only 33% of schools addressed this, yet it is imperative that teachers know the requirements of the National Curriculum.

The GTP programme showed a similar analysis, with the schools relying on the universities to provide the 'academic' input and the schools focusing on the 'practical' aspects of teaching.

Discussion And Conclusion

This study aims to investigate whether there are any differences in the professional identities of D&T teachers who take a university-based course and those who train 'on the job' in school. Using the Lauriala and Kukkonen (2005) typology of professional identity we looked at the content of each type of course to try and identify the 'ideal self' each promotes. It became clear that, although time spent on different aspects of teaching may vary, content on both courses is essentially the same.

Neither of the courses appeared to address the preconceptions that student teachers bring to the course and there is no consideration in the course content of what they think it means to be a teacher. The teacher self we identified through these two types of course is one who is a skilled technician, as the emphasis in both courses was on the knowledge and skills that teachers need in order to run their day-to-day classrooms. Wider concerns, such as the historical development of D&T and the nature and purpose of it on the school curriculum, were low down in the rank order of time allocation on both courses. These findings indicate that both courses may be leading to similar outcomes in terms of the emerging professional identity of the (student) teachers. However, we have so far only gained the 'official' version of these courses, the authentic experience of the students may provide different observations and gathering this data will form the next stage of the study.

Professional identity is also informed by the social and cultural context of learning so we will be interviewing student teachers to ask about their reasons for choosing a particular course, their learning experiences and to try and determine how the student teacher's professional identity is shaping. We will then observe them in the classroom to see whether there are any differences in how they act, are and understand (Sachs 2005).

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Aspiring to be the Best: The impact of research on the teaching of technology

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Key Words: Subject Matter Knowledge (SMK), Pedagogical Content Knowledge (PCK), Professional Development, primary technology teaching and learning programmes

Abstract

In this paper we report on our experience of working collaboratively as part of the *Technological Literacy: Implications for teaching and learning* national research project in New Zealand (Compton, Compton & Patterson, 2011). Moira is the researcher 'on the ground' in the Auckland/Northland region and Jude is the principal of an urban full primary school (year 1-8 or age 5-12) participating in the research project.

Jude responded positively to the initial invitation in 2010 to be a part of this research, with a clear statement of intent that she wanted her school to be 'the best technology primary school in New Zealand'. Realising the challenge in this, Moira and Jude have worked with a core group of staff to develop their subject matter knowledge (SMK) and pedagogical content knowledge (PCK).

The key focus of this paper is on the shifting of teacher understanding related to technology subject knowledge as outlined in the New Zealand Curriculum (Ministry of Education, 2007) and the subsequent development of PCK. The impact of these shifts on the delivery and impact of technology programmes to date are also discussed in terms of student learning.

Introduction

Teaching informed by research has always been encouraged in education. Providing teachers with a sound theoretical background to base their teaching is viewed as an essential factor to support learners in technology (Compton & Jones, 1998). Shifting teacher's theoretical understandings in technology education therefore became a prime focus for teachers involved as part of the *Technological Literacy: Implications for teaching and learning* (*TL: Imps*) research project. This research, led by Dr. Vicki Compton with Ange Compton and Moira Patterson as co-researchers, began in July 2010. The research is in response to the New Zealand Ministry of Education's request for an answer to the following question 'How will the three strands of the technology curriculum work together to develop students' technological literacy'?

The primary aim of this research is to explore and document how technological literacy can be supported through programmes based on the integration of the three strands of the technology learning area in the New Zealand Curriculum (Ministry of Education, 2007). It is specifically focused on exploring how the strands and components of technology work together to support the development of a deep, broad and critical technological literacy as students move from year 1-13 (Compton, Compton & Patterson, 2011). The classroom-based research currently being undertaken involves 92 teachers from throughout New Zealand. Moira is the researcher responsible for providing professional development support to and collecting data from four schools in the Auckland and Northland regions.

This paper reports on one of the schools she is currently working with in Auckland, providing insights from both Moira's and Jude's (the principal of the school) perspective.

Moira recognised early on that teachers needed to use content knowledge confidently to support and enhance children's learning (Farquhar, 2003). To achieve a shift in teachers' understandings both Moira and Jude have worked collaboratively to start the teachers at this primary school on a professional learning journey. A professional development programme, influenced by the Model of Domain Learning (MDL) (Alexander, 2003), was instigated to bridge the gap between teachers' current understandings and contemporary views of educational practice in technology education. With the many changes to expected content in technology in the NZC (Ministry of Education, 2007), it was important to also ensure teachers were well informed about the required subject matter they would need to be teaching. Research indicates (for example Compton & Jones, 1998; Ginns, Norton, McRobbie, & Davies, 2000; Jones & Moreland, 2004) when teachers are introduced to a new curriculum they benefit from professional development focused on developing specific subject matter knowledge (SMK). SMK refers to teacher's understandings of subject matter (Rohann, 2009; Rohann, Taconis, & Jochems, 2010). A summary of literature reviewing the relationships between teachers' knowledge and primary pupils' attitudes towards technology states that teachers' SMK is shaped by their own constructions of knowledge (Rohann et al., 2010). Teachers' understanding of technology have also been seen to influence teachers attitudes to teaching technology, and the pedagogical strategies they employ when teaching it, that is their PCK (Jones & Moreland, 2004). These factors, alongside the teachers self-identified needs, were considered as teachers at this school started on their professional learning journey about technology education as part of the *TL: Imps* project.

Best Technology Primary School

When Jude was approached at the end of 2010, she was very enthusiastic about being part of this research study. An opportunity to up skill her teachers in an area of education she was passionate about meant her commitment; professional leadership and motivation had the potential to positively affect teachers' understandings (Ginns, Norton, McRobbie, & Davies, 2000). The School's technology journey had begun in 2007 when a review of their delivery of the learning area of technology revealed barriers to teaching and learning that included: a lack of teacher confidence in teaching technology, teacher unfamiliarity with technology as represented in the NZC (Ministry of Education, 2007), insufficient resources and equipment, and a lack of a purpose-built space. This review led the school to take steps to begin to address these barriers, beginning with the building in 2008 of a multi-purpose Technology Room adjacent to the existing ICT Room and Information Centre.

An old shabby adjacent classroom was joined to the Information Centre and Library by cutting through walls, to enhance this area as the learning hub of the school. The room was completely modernised with the addition of an expanse of three walls of windows and floor-to-ceiling doors to let in light and provide safety monitoring of the activities out on the new large covered deck. Internal and external storerooms were added. The room was designed to be a multi-purpose room. The kitchen, with stoves, microwaves, sinks and benches, was set in an area featuring red linoleum to signal to children that only food and some bio-technology activities may be conducted there. All other activities are restricted to the remainder of the room or the deck. The room is fully equipped with cooking apparatus, sewing machines, overlockers, tools, etc., to enable the majority of children to be involved in group work at any one time.

The Tech Room proved to be a huge impetus for change. The considerable cost of this asset and the large investment of time and energy by Jude, the Board and Community to raise funds for the outfitting of the room, was a significant incentive to ensure that the room would be well-used for the benefit of children.

At this stage in the school's journey, the aim was simply to ensure that the learning area of technology was on a par with all other learning areas in the school, and delivered as competently. This aim was also perceived by Jude as a strategic way of counter-balancing the increasing pressure of funding ever-changing Information Curriculum Technologies, as she considered much could be achieved within a comparatively modest budget if technology was taught in a more holistic style, and the quality of teaching was high.

Most importantly, what the school gained along the way was a vision and moral purpose to the teaching of technology in the school and this placed technology as learning area in the forefront of their strategic thinking.

Jude by chance read an article by Sir Paul Callaghan (2010) titled 'High Tech is High Dollars' and went on to read his *Wool to Weta: Transforming New Zealand's Culture & Economy (2009)*. New Zealander of the Year twice, internationally renowned scientist, and the brains behind a successful High Tech business, Sir Paul argues that if New Zealand is to have a sound economic future it has to stop thinking of itself as primarily an agricultural country and acknowledge that its past prosperity stemmed from being a world leader in agricultural technology. Sir Paul claims that New Zealand's future prospects of prosperity lie with making High Tech a nation-wide priority. Sir Paul's view that such industry could be environmentally sustainable and not compromise New Zealand's national beauty struck a chord with Jude, as her School is an Enviro School (for details please see http://www.enviroschools.org.nz/Enviroschools-programme-overview).

However what caught Jude's attention most was Sir Paul's claim that there were currently Ten NZ world-leading High Tech businesses that were bringing four billion dollars into the NZ economy. If we had 100 such businesses, we would be on a par with Australia's GDP and its associated economic benefits. Jude's epiphany was that if NZ had 101 such businesses, we would *exceed* our Tasman neighbour's economy. Jude instantly saw the benefits for the pupils going through her school if they were the people to start up, lead, or work in those businesses or design those future products. To achieve such a vision would mean that her school would have to strive to be educational leaders in technology and science education. Together, the Senior Management Team and Board of Trustees decided they owed it to their students to lead - and to succeed.

PD approach

At the beginning of 2011 Jude asked teachers to self-select into one of three professional development projects they wished to be involved in for the next two years. It would be fair to state that for some who ended up in the Tech Team this may have been a choice by default. However, all staff were consulted about the three-option approach and consensus had been obtained before this was embarked on. Jude had a vision of trying to get representation from as many of the teaching teams in the school as was possible and this strategy produced coverage across four out of the five teams. The fifth team still taught technology in-school, but their students (year 7 and 8) were also receiving technology lessons at the neighbouring high school.

After the Tech Team had been established, Moira started working with Jude and this core team of seven teachers. The teachers committed to participating in the TL: Imps research for two years and taught classes that ranged from new entrant/year 1 to year 6. Two teachers taught new entrant/ year 1 classes. One teacher taught a year 2 class One teacher taught a year 3 class. One teacher taught a year 3/ 4 composite class. Two teachers taught a year 5/ 6 composite class. Some of these teachers had participated in previous technology education professional development and were experienced in teaching technology as outlined in the previous technology curriculum (Ministry of Education, 1995). However only one teacher had a more comprehensive understanding of technology particularly as it is now described in the NZC (Ministry of Education, 2007). Consequently this teacher was given a leadership role. Some of the teachers had also worked in the new technology room.

Moira's main focus as researcher in the *TL: Imps* project was to work with teachers to ensure coverage of the three technology strands through the inclusion of the eight components described in the NZC (Ministry of Education, 2007). Explanatory papers for each component (Compton, 2010) are available for teachers to access on a Ministry of Education supported site Techlink (see www.techklink.org.nz). This unique site has been developed for teachers to access curriculum and other material related to technology education. For research purposes it was important that the teachers covered all eight components in their teaching programme during the two-year research study. Current educational directives also recommend teaching the eight components over two years (Compton & Harwood, 2007). Because New Zealand has four terms a year, this model allows for greater focus in teaching for teachers and for students to gain literacy that is of a broad, deep and critical nature (Compton, Compton & Patterson, 2011). This overall programme model for planning was used to guide unit development with teachers involved in the research. Selected units were taught term-by-term in 2011and linked to school themes. As with many schools in New Zealand in 2011, the Rugby World Cup was one such school theme. A major and minor focus was selected for assessment purposes. Components new to technology since the revision of the New Zealand curriculum in 2007, and therefore new to the teachers, were given a major focus. These included components in the Technological Knowledge strand, (technological modeling (TM), technological products (TP) and technological systems (TS) and components in the Nature of Technology strand, (characteristics of technology (CoT) and characteristics of technological outcomes (CoTO).

An overview to guide individual unit planning was developed by the core group of teachers at the beginning of 2011 and revisited at the beginning of 2012 in light of the experiences of all involved during 2011. At the beginning of 2012, the teachers confirmed the major components already selected, and they decided any teacher could select an additional component from the technological practice strand to include as a minor focus. At this time, the group also discussed an issue identified by Moira that related to CoT. This was the first component taught by teachers when the research project started and they were new to understanding technology. Initial impressions of early data collected indicated revisiting understandings associated with this component would benefit all students as many were still unable to identify the defining characteristics technology as a human endeavor or exactly what a technological outcome was. CoT was therefore included twice in the programme overview. The table below provides an outline of what teachers covered in 2011 and what they expect to cover 2012.

Table 1: School 2-year Overview

Term	Year 2011	Context	Major Focus (Assessed)	Minor Focus
1	Unit 1 2011	Containers/Water	CoT	BD
3	Unit 2 2011	Rugby World Cup	TP	PfP
	Year 2012			
T1	Unit 3 2012	Food preparation	TS	TP Master Chief
T3	Unit 4 2012	Jewelry	TM	ODE
T4	Unit 5 2012	Biotechnology, herbal health products	CoTO/CoT	

The Professional Development Programme

Moira's understanding that limited theoretical knowledge prevented teachers from teaching effectively (Ginns, Norton, McRobbie & Davies, 2007) lead to her early decision that the teachers required support to ensure they knew more about what they were teaching. It has been well documented that assistance from external expertise can support and extend teachers' theoretical knowledge, which can then translate into practice (Timperley, Wilson, Barrar & Fung, 2007). Sense making is a complex process involving not only interactions with others but also includes an individual's beliefs, attitude and knowledge (Timperley, Wilson, Barrar & Fung, 2007). Moira therefore saw the development of SMK in a collegial environment as a crucial pre-requisite to enhance teacher's attitudes to and ability in teaching technology. That is, their PCK (Rohaan et al., 2010). After consulting with Jude and considering comments from the core group of teachers involved in the study, a professional development programme influenced by the MDL model (Alexander, 2003) was developed. When developing domain or specific content knowledge, Alexander (2003) describes three stages in the MDL model. Acclimation is the initial stage. Learners at this stage have limited and fragmented understandings. They exhibit little personal interest and require ongoing support to give value to what they are learning (Alexander, 2003). At the second stage, competent learners have greater foundational domain knowledge, their understandings are more cohesive and their personal interest in the area of learning increases (Alexander, 2003). At the third level, proficient learners become experts and domain knowledge becomes broad and deep while interest in specific content knowledge becomes very high (Alexander, 2003). At the beginning of 2010 most teachers exhibited characteristics associated with the acclimation stage.

To achieve a shift in understanding, the professional development initially focused on each teacher's understanding of each component as a whole (Compton & Compton, 2010) and what they needed to know to feel confident to teach their classes. That is their subject matter knowledge (SMK). After this, discussions moved to the interpretation of achievement objectives in the NZC (Ministry of Education, 2007) and the associated indicators of progression at appropriate levels as developed from previous research (Compton & Compton, 2010; Compton & Harwood, 2005). Progression diagrams have also been developed to further support the indicators of progression as described elsewhere (Compton, Compton & Patterson, 2011). The use of the diagrams, showing learning progressions within and across each level of learning in relationship to curriculum achievement objectives, enabled teachers to understand the requirements for teaching to ensure learning in technology was able to be progressed.

Teachers met at the beginning and end of each term to discuss and review their own understandings, and to plan and evaluate learning and assessment experiences. Prior to these meetings Moira asked the teachers to read the explanatory papers for each component. For example, prior to teaching the technological products (TP) component, teachers were asked to read the related explanatory paper. Understandings and or issues as a result of this reading were discussed. Sometimes this engendered debate. For example defining the differences between forming, transformation, and manipulation of materials resulted in the need for a number of examples and these were then linked to proposed units of work. How materials were manipulated to make mascots was discussed in depth. As interest increased and relevance became embedded in practice all teachers increasingly saw the value of content knowledge showing a clear movement of the teachers from the acclimation stage to increasing competence (Alexander, 2003). Periodic follow-up meetings with clusters of teachers working with the same year group also helped to reinforce teacher's pedagogical content knowledge (PCK) and these were run on a more needs basis. Making sense of material became for teachers a journey rather than orderly events (Timperley, Wilson, Barrar & Fung, 2007)

Shifts in Teacher Understanding and Practice

Moira observed that most teachers at the beginning of their journey were a bit fearful of technology. However as the year progressed she noted an increasing interest and confidence amongst teachers resulting in most teachers shifting from the acclimation stage to a position of competence. They were becoming increasingly more familiar with the content knowledge associated with technology. Integrating theory with practice was also noticeably easier for the teachers. For example, by the end of the year when themes were suggested for classroom practice teachers were quickly able to link content knowledge to possible teaching experiences. As teachers planned for their classrooms they successfully interpreted given achievement objectives as guided by the indicators of progression and progression diagrams at different levels.

One teacher's enthusiasm for technology increased hugely to the point she was seen as an expert in the group. Another teacher commented she wanted the core group to continue after the research. Moira photographed Rugby World Cup mascots and students confidently discussed why they chose the materials used. Teachers would proudly share their students work and confidently share their developing understandings with Moira on a regular basis. Many discussions were had about the use of 'difficult' technology terminology with young children and the benefits and problems associated with this were debated amongst the group. After one such conversation with teachers, Moira realised that teachers needed to be more explicit with the students that what they were learning was technology.

On another occasion, a new entrant teacher commented that children didn't even know the word 'materials'. Consequently it was decided that she needed to introduce vocabulary associated with materials first before further technological concepts could be developed.

As the year progressed many teachers commented that technology wasn't that difficult to teach. It had not become a 'teaching extra' but instead they began to integrate it more easily, viewing technology as part of their teaching programme. The teachers enjoyed discussing their successes and difficulties with each other and Moira, and numerous lovely stories started to appear. This supports the view that collegiality among participating teachers appears to be an important factor in successful models of professional development (Timperley, Wilson, Barrar & Fung, 2007).

Impact as Result on Student Learning

Research indicates increased teacher understandings enable greater engagement and improved PCK (Rohaan, 2009) and that this affects teaching and in turn children's understandings of technology (Rohaan et al., 2010). This would certainly appear to be true in this case. Interim interview data collected at the end of 2011 indicated a shift in understandings for the components taught over 2011.

A total of 120 students are participating in the research from seven classes (Two new entrant/ year 1 classes, one year 2, year 3 class, year 3/ 4 and two year 5/ 6 classes.)

As part of the research, 26 of these students were interviewed and judgments made about their understanding of characteristics of technology (CoT) and technological products (TP). Six students from year 1, five from year 2, five from year 3, three from year 4, four from year 5, and three from year 6.

At the beginning of the year, the majority of these students (19 or 76%) exhibited pre-level 1 understandings of CoT and six students (24%) showed level 1 understanding. By the end of the year these figures had changed to 10 students showing pre-level 1 (40%), 14 students showing level 1 (56%) and one student was working at level 2 (4%).

At the beginning of the year, the majority of these students (17 or 68%) exhibited pre-level 1 understandings of TP with eight students (32%) showing level 1 understanding. By the end of the year these figures had changed to four students showing pre-level 1 (16%), 13 students showing level 1 (52%) and eight students were now working at level 2 (32%). This is very good progress for students of this age.

This initial data indicates this cohort of students have shown an improvement in their understanding of these components, albeit a greater shift in learner's understandings regarding TP than CoT. This is consistent with the development of teacher's understandings, where the teacher's knowledge of TP was greater than their knowledge of CoT at the time they were teaching each component.

Jude has also acknowledged there is wide-spread agreement by teachers that students now know that technology helps create the 'made' world and can offer opinions on what technology entails, which is a big shift from the start of the project. School middle managers also reported a consensus that students are becoming more confident using the language of technology... such as talking about brief development and knowing what that means. Students now undertake technological practice in a more 'connected' manner, recognising the importance of the brief and its relevance to the product they are making. One teacher said that even with new terminology students were about to learn, such as 'inputs/outputs', the students were now more confident and able to work out the meaning for themselves. One senior teacher who has been away for a year was astounded when she returned and checked students' prior knowledge and found they knew concepts and terms that she had not expected them to know – and that she now has to come up to speed with herself! Technology teachers at the adjacent high school where the year 7 and 8 student go for additional technology classes have also reported that these students are now standing out in relation to their peer group.

While the increase in technological understandings and skills are impressive, the bigger picture of the gains from a more informed use of the Tech Room should not be overlooked. One Year 3/4 teacher summed up the level of excitement by the students when the room first opened. "You mean we can go in there! We can touch the stuff!'" She said, "their eyes are on stalks. They love being able to produce things themselves." Jude and her team believe that wonderment and awe, and a love of technology as a subject, are the foundations upon which excellence and engagement in learning is built.

2012 the Way Forward...

Regular ongoing in-depth professional development is considered to be the most effective way to change teacher practice. The PD at this school, informed by the MDL model (Alexander, 2003) and a focus on SMK and PCK, appears to have not only successfully shifted teacher theoretical understandings and informed teachers teaching but to have also resulted in measurable changes in *student* understanding.

In 2012 additional teachers have joined the Tech Team of teachers from 2011. A similar format for professional development has been agreed on and it is hoped the original core group will work alongside Moira to support the new teachers with their understandings about technology. In this way, we believe the professional learning of these teachers has the potential to become self-sustaining, meaning when the research input moves out, the school will continue to move on... towards Jude's goal of being the best technology primary school in the country!

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Perception of Sustainable development and Education for Sustainable Development by African technology education academics

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Key words: Education for sustainable development, academics' perceptions, African context, nature of sustainable development, value change

Abstract

Sustainable development (SD) in technology education is considered to be among the important areas for research by the technology education (TE) community. International experts who took part in Martin and Ritz's Delphi study illustrated this point. TE teachers' perceptions of SD and their readiness to address these issues through their teaching are essential for effective learning. Research conducted by Elshof (2005), Pitt and Luben (2009) and Pavlova (2009a) highlight the differences in teachers' perceptions within the context of three countries. Although different methodologies were used in these studies, conclusions were similar: teachers' perceptions of what were important and readiness to address these issues were reflected in classroom practices.

This paper extends these earlier studies by examining the results of a study of African technology education academics' perception of SD and education for sustainable development (ESD). The paper is based on a survey conducted in January 2012. The paper highlights issues that are viewed as important by the African technology education academic community and that are relevant to a specific context. It uses a two-challenge framework (developed – developing countries SD challenges, UNDP, 2011) to interpret the results.

Introduction

University academics serve a critical role in developing a worldview that is sensitive towards the sustainable development agenda. More and more universities are signing Tailors Declaration to include a SD vision within their policies and practice. Education of future technology education teachers within a SD paradigm increases the probability of ESD implementation in school classrooms. These links between teaching and learning at different levels (including universities and schools) are well established in research. Rohaan, Taconis and Jochems (2008, 2009), for example, identified the links between teachers' understandings of technology and learners' concept of and attitude towards technology. Therefore, it is important for university academics to be aware of their own interpretations and beliefs about SD and the ways SD could be addressed through technology education.

Differences between teachers' perceptions of ESD are visible through research conducted across different contexts. Research conducted by Elshof (2005) Hill and Elshof (2007), Pitt and Luben (2009), Pavlova (2009a) highlight the differences in teachers' perceptions of ESD and in the level of readiness to address these issues through their teaching in the context of three countries (Canada, UK and Russia). Through the use of different methodologies these studies concluded that teachers' perceptions of what were important and their readiness to address these issues were reflected in classroom practices. These differences are important to understand to support academics in developing their reflective practices that are aimed at the introduction and/or reinforcement of ESD in technology education.

This paper examines the results of research of African technology education academics' perception of SD and ESD. Academics' perceptions are examined through a framework of the ethics of weak anthropocentrism and the ways SD could be achieved argued elsewhere (e.g. Pavlova, 2009b). The second part of the paper focuses on interpreting the results obtained through a two-challenge framework (UNDP, 2011) that highlights the differences between developed and developing countries in addressing SD.

A framework and research design

A framework for this study is based on previous research (Pavlova, 2009a) on the nature of SD and the ways in which SD could be achieved. I have argued elsewhere (Pavlova, 2009a, b, 2011) that the differences in views about SD are based partly in different philosophical and moral conceptions of appropriate ways to conceive of the relationship between humanity and nature. On the opposite side of the debate are ecocentric environmental ethics (that attribute intrinsic value to nature and suggest that humans should live according to nature), and anthropocentric or technocratic environmental ethics (that attribute instrumental value to nature and suggest that humans should use and manage nature wisely). I have argued that a more balanced position based on the ethics of weak anthropocentrism/noosphere wisdom / 'frame of mind' paradigm (Pavlova, 2009a,b) provides a more appropriate basis for conceptualising SD within technology education for the development of approaches for ESD. This position promotes the mutual flourishing of human and non-human nature. It is well expressed through the principle of: *Respect and care for the community of life, meaning duty to care for other people and other forms of life now and in the future,* formulated as the basis for the ''Caring for the Earth'' strategy by the International Union for Conservation of Nature and Natural Resources and the World Wide Fund for Nature (IUCN, UNEP, WWF, 1991).

Other important categories used in this study are 'technical fix' and 'value change' as two major approaches for achieving sustainable development (Robinson, 2004). The importance of value change, in particular, the prioritising of 'moral values', and a conscious attitude towards the 'technical fix' as the major way of achieving SD have been argued elsewhere (e.g., Pavlova, 2006a, 2006b). A 'technical fix' approach analysed through the prism of a philosophy of technology that assumes that technological development is a subject of profitability: ''Enterprises invest not in order to benefit humanity or to protect it from problematic side-effects, but rather to open up markets and areas of expansion with promise to the future'' (Beck, 1997, p. 117). Technology might treat the symptoms not the disease. To achieve changes towards sustainability, a 'value change' is required. A fundamental transformation in underlying values and attitudes that would characterise a radical shift in our thinking is a condition for achieving sustainability.

These two arguments about the ethics of SD and the ways it could be achieved framed the approach used in this study that was aimed at examining academics' beliefs about SD and ESD and their attitude towards 'technical fix' and 'value change'.

Methodology

This study is a qualitative analysis of 4 surveys used with African technology educators during a workshop on *How to Re-Orient technology teacher training programs towards ESD* that took place prior to the international conference of the South African Association for Research in Mathematics, Science and Technology Education (SAARMSTE) 12-19 January 2012. The workshop attracted the attention of mathematics and science educators as well as technology educators, therefore out of 12 surveys only 4 were analysed for this study (although these other surveys provided valuable data). Three participants were from South Africa and one person from Malawi. Participants had between 15 and 22 years experience in education. There was one female and three males.

The survey used for this study was developed on the basis of the framework presented above. 15 concepts that describe SD (that were drawn from UNESCO/UN interpretations of SD) and a number of statements that describe eco-centric, anthropocentric and a balanced position, as well as a 'technical' fix and a value change belief were used in a survey. Previously this survey was used for another large scale study in China with more than 6000 respondents and was found to be reliable and valid.

For example, an eco-centric position was assessed through statements such as *Rather than seeking a balance across the economic, social and environmental areas, the crucial factor is the ecological integrity of the biosphere; Plans and animals have as much right as humans to live; Nature is very delicate and easily harmed*. An anthropocentric – 'humans as rulers over nature' – view were examined through such statements as *Rather than seeking a balance across the economic, social and environmental areas, the crucial aim is* to *alleviate human suffering and provide basic material well-being for all humankind; Nature is strong enough to handle the bad effects of modern developed countries; Humans were meant to rule over the rest of nature*.

The survey consists of four parts and an introductory section on personal data:

- Level of familiarity with the concept; what SD issues are important and what is addressed through teaching (part A)?
- Interpretation of SD (part B);
- Interpretations of ESD in technology education (part C);
- NEP scale (the "New Ecological Paradigm" to investigate the ecological worldviews, Dunlap & Van Liere, 1978; Dunlap et al, 2000) (part D).

The scale has a six-point Likert-type scale, scaled as: strongly agree (6), agree (5), slightly agree (4), slightly disagree 93), disagree (2) and strongly disagree (1). This scale was used for parts B, C and D. Part A includes open ended questions, and free questions that use a percentage range from 0% (not at all important) to 50% (medium important) and 100% (most important). Informal conversations with participants were conducted during the course of four-days after the workshop to clarify any issues.

The qualitative analysis of the results presented in this paper is focused on a limited number of questions:

1. Level of familiarity with the concept.
2. What are the emphases (on economic, environment, social, cultural aspects)?
3. What issues are important for technology education academics in terms of ESD in TE?
4. Composition of SD interpretation (eco-centric, anthropocentric, balanced).
5. What are the beliefs in terms of technological fix – value change?

Results

The responses reveal that participants are well aware of the SD agenda. Two of them heard for the first time about SD more than 10 years ago, and they perceive their level of familiarity with the concept as 4 out 5 (5 was max). The other two participants judged their level of familiarity as 3 out of 5 and they had heard about SD in 2008 and thus less than 10 years ago. They all heard about SD for the first time from different sources: institution where they worked, media, a conference and the State of the Nation address. These results highlight the importance of using different means to increase awareness of SD issues in society.

Aspects of SD that were most familiar for the participants include such areas as food; health, clean water; education; sustainable livelihoods, care for the environment; consideration of impact on society and environment; teaching how to use locally available resources and how to continuously apply survival skills using knowledge as a commodity. Aspects of SD that the participants would like to explore more included: the ways technological skills could be used to solve problems and address poverty; impact and biases of technology on the environment; education for SD, issues related to food technologies.

They all viewed SD as an issue important for them and their students, as well as for the provinces where they live. In responding to the open-ended question two participants expressed wishes to learn two opposite aspects of SD in relation to technology – one is how to use technology to address poverty (social aspects of SD), another – how to learn and understand environmental impacts of technology (environmental aspects of SD), highlighting that for TE academics learning needs are diverse.

Their descriptions of what SD is included:

- "Addressing any need or want of my community for a longer time with assessment and improvement after a certain periods in between"
- "Being critical of one's actions in a particular environment and keen to develop long-lasting solutions cooperatively"
- "Using the available resources without disadvantaging the coming generation"
- "Using knowledge and skills to survive"

These definitions present the goals for action in a different timeframe: from immediate goal to survive now to considering the rights of the future generations and long term planning. They also believe in the need for cooperation and of constant monitoring of community developments.

When participants identified the issues that need to be addressed in their provinces now, they strongly agree that the three below are the priorities:

- Poverty alleviation;
- Renewable energy;
- Sustainable use of natural resources.

The next set of issues in terms of their importance was: Biodiversity loss; Clean water and sanitation; Infectious diseases; Illiteracy; Wasteful consumption; Population growth, and Health (air and water pollution, exposure to toxic and hazardous materials, HIV/AIDs). Other issues, added by participants were indigenous contexts and the need to attend to all issues above (Malawi).

In relation to teaching, the three key issues that participants are addressing **now** through the courses they teach were:

- Sustainable use of natural resources;
- Health (air and water pollution, exposure to toxic and hazardous materials, HIV/AIDs);
- Illiteracy.

To a smaller extent the participants also address rural development and renewable energy issues followed by **clean water and sanitation**, poverty alleviation, human rights; gender inequality, and then wasteful consumption and **infectious diseases** (they wanted to expand on two highlighted issues). One participant also addresses indigenous technologies through teaching.

In answering the question on 'what issues could be possible to address through the courses you teach', the participants prioritised the following:

- illiteracy,
- poverty alleviation, and
- renewable energy,

followed by clean water and sanitation, infectious diseases, biodiversity loss, and sustainable use of natural resources. They see a role for technology education in addressing the above issues through development of sensitivity towards nature and developing an understanding that technological growth should be balanced; through applying design principles, critical and creative thinking skills to bring a human aspect to technology; through utilisation of locally available resources in a way that would not disadvantaging the incoming generations; and through the use of technological knowledge and skills.

All participants agreed that SD should be addressed through TE and a majority of them believe that the 'Economic aspect of SD should be addressed more than other aspects of SD (social and environmental) through TE". They do not agree that social, cultural or ecological aspects should be addressed more than other aspects of SD through TE. Two participants strongly agree that all aspects of SD should be addressed equally in TE. They also agreed that there is a need to support and promote cultural diversity through TE as a component of ESD.

Participants agree or slightly agree that development of social responsibility is an important aim for TE. They also believe (agree and strongly agree) that the following principles should be addressed through ESD in technology education:

- improve the quality of human life (enable people to realize their potential, lead lives of dignity and fulfilment)
- conserve the earth's vitality and diversity; minimize depletion of non renewable resources (use less, re-use, recycle, switch to renewables where possible);
- keep within the earth's carrying capacity (including human population and level of consumption).

They agree (although with different levels of enthusiasm) that a balanced view of the relationships between human-centred and nature-centred worldviews should be the basis for ESD in TE. They believe that extreme views of eco-centric and anthropocentric beliefs should not underpin ESD in TE.

Their perception of the nature of SD varies. Two participants, C and D have a balanced view of SD. Participant A has a very strong eco-centric view, although she agrees with some balanced view statements:

- SD should seek the balance across the economic, social and environmental issues
- SD should improve the quality of human life while living within the carrying capacity of the eco-system
- There is a need for humans and non-humans to co-exist through a process of co-development.

Participant B does not have strong views about either eco-centric or anthropocentric underpinnings of SD, his position is undecided.

In terms of the ways SD could be achieved, two participants, C and D believe that value change is the main means for achieving sustainability. Participants A and B believe that a mixture of responses was required that include both value change and technical fix.

Analysis

As argued by Pavlova (2011), while the rationale for technology education for all countries needs to be framed by concern for the human condition, due to contextual differences the emphasis of technology education activities will vary. In a simplified way, for developed countries the major area of attention is related to environmental aspect of sustainable design. For developing countries, the social aspects of sustainable design need to be emphasised. These approaches are justified by the analysis conducted by UNEP (2011) that used each country's natural and human capital and its relative level of development as indicators to identify specific challenges. Two dimensions of this analysis are *Ecological footprint* as an instrument to measure the impact of our lifestyle on the environment and the *Human Development Index* (HDI) as an indicator of health, education, and standard of living. Some countries have attained high levels of human development, although at the expense of the quality of their environment. Other countries, while maintaining relatively low per capita ecological footprints, need to improve levels of services and the material well-being to their citizens. Therefore these two groups of countries have different challenges. The first one needs to reduce their per capita ecological footprint without impairing their quality of life; the second one needs to improve the well-being of their citizens without drastically increasing their ecological footprints.

Do the results of this study support the above conclusions?

The relative emphasis that participants put on the issues that need to be addressed in their society, *poverty alleviation* (and survival skills) is strongly emphasised together with the need for renewable energy and sustainable use of natural resources. Together with illiteracy, clean water and sanitation, poverty alleviation is prioritised as a theme to be included in TE courses. Support and promotion of cultural diversity and addressing the issue of infectious diseases are also included. Therefore, a challenge to improve the human development index through TE is strongly presented in participants' views. However, participants have a high level of environmental awareness, understanding that social development could not be achieved without conserving the earth's vitality and diversity and without keeping development within earth's carrying capacity. Therefore such issues as renewable energy; sustainable use of natural resources; biodiversity loss are also viewed as important to be addressed through TE.

The results of this study demonstrate that African technology education academics understand the need to address SD through technology education, putting an emphasis on social development issues framed by environmental challenges. Participants believe that value change is the most important way to address SD issues followed by technical fix. They have different beliefs that underpin their interpretations of SD.

Conclusions

This paper examines the results of research of African technology education academics' perception of SD and ESD, based on a survey. The results highlights that all participants believe in the importance of addressing SD through technology education, and that the social aspects of sustainability have been prioritised by participants, although it was acknowledged that social development needs to be framed by environmental concerns. This confirms the applicability of a two-challenge framework (developed – developing countries SD challenges, UNDP, 2011) for the context of technology education. Participants also prioritised a value-change approach to SD, although acknowledged the appropriateness of a technical fix approach for the technology education classroom. In terms of individual interpretations of SD, responses varied, including an eco-centric, balanced and undecided views. This study highlights the role of technology education as perceived by university academics in terms of involving students in learning through designing and making products and systems within the framework of sustainable development.

These results should be interpreted within the limitations of this study which is small scale and it is possible the participants of the workshop where the study was conducted were more informed, interested and enthusiastic about SD that an 'average' technology education academic.

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Issues Confronting Technology Education: An International Perspective

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Key Words: Technology Education, Issues, Country Programs

Abstract

As technology education progresses, professionals encounter problems that are unique to this school subject and their localized educational and cultural environments. This paper will review issues related to implementing technology education identified through contacts with international professional leaders over a three year period. The research will cite issues affecting the progression of technology education in different countries as identified by professional educators who work in these countries. The researcher will attempt to categorize these issues to provide perspective to the profession.

Introduction

In preparing future leaders and classroom technology education teachers, it is important to transfer knowledge of changes that are occurring and will occur in this school subject. In order to prepare effective teachers for teaching technology education, professors and teacher mentors attempt to pass on the knowledge and skills needed to teach this school subject. This knowledge includes the content and skills that makes one technologically literate. It includes knowledge about the nature of technology, the products of technology, how to design, make, and use these products, and the impacts that technology has on individuals, society, and the environment. The educational community must also teach technology teachers about the operation of our programs within schools and have them experience a school environment including actual teaching and interacting with pupils, teachers, administrators, and the public. All of this knowledge is fine and much needed.

However, what are the other issues future technology education leaders need to know so they may work effectively as practicing professionals? This researcher believes they need to know the problems that the community of technology educators currently face and will face in the future. What issues do professors in other nations face as they position this school subject within the schools of their countries? These issues are part of a graduate level course that this faculty member teaches each year. It is conducted in this way to show students what technology education is like in other countries and to better prepare them to face issues they may encounter in their professional careers.

For the past five years, the author have has as part of a graduate course he teaches (for both masters and Ph.D. students) designed where students learn about technology education in other countries. This includes the basics of the educational system of the country, what content is included in the technology education programs of that country, and how technology teachers are prepared in that country. The PATT proceeding, Sense Publishing books, *International Journal of*

Technology and Design Education, *Journal of Technology Education*, and the Council on Technology Teacher Education Yearbook, *International Technology Teacher Education* (Williams, 2006), provide excellence reference materials for students to begin this process. After the graduate students learn the basics of technology education for a particular country, they then contact a professor from that country and determine a major issue that is impacting technology education in that country. Students must develop a paper and make a class presentation on both the country and the issue that is being faced. Students have to report from their international contact how they are addressing the issue and then reflect on how the student might approach the issue themselves.

Methodologies

The researcher has been tracking data from student's experiences in interacting with international scholars for the past three years and would like to report what the students have found in their interactions on issues in technology education from across the globe. Many participants from PATT Conferences have served as contacts for these young researchers. This correspondence has also been a major learning experience for them in their development to find more detail about technology education from a worldview, but also as important, having students interact with scholars from other parts of the world. All too often we do not teach a world view but are rather monistic in our approach to technology education.

The requirements of this assignment are presented in the course syllabus for students to follow. The professor gives several reviews of how the project should progress, even showing recordings of presentations developed by class members in earlier years. I then contact professors in other countries and ask them if they will assist students in this project. Students are then allowed to select their country and scholar to contact and discuss the assignment. No contact is made until the student first reviews the literature on the country's technology program (requirement for another class project). With today's communication technology, most communicate by email, some students have Skype™ discussions, while others chat using the telephone. In the future Adobe Connect™ might be used to let the international scholar speak directly to the class. For the assignment students were to ask the international scholar a major issue they were trying to solve related to technology education in their country, how the scholar was addressing the problem, and then the student was to reflect how they might address the same problem.

Findings

The data reported comes from 38 student contacts from 16 countries over a three year period, 2009-2011. It involved 31 different scholars. The researcher tries to rotate scholar contacts within countries annually. This is done for two reasons. First it is an attempt to not over burden any one person. Second, the contacts rely heavily upon individuals that the researcher knows from interactions at PATT Conferences or International Technology and Engineering Educators Association Conferences or people the author has communicated about their research and writings. Some scholars have been contacted more than once. This paper will report what was found each year, plus provide an analysis of what the researcher believes is projected through the overall findings.

Fall 2009

During this semester 14 international scholars were contacted. They included contacts from Australia, Belgium, Canada, England, Finland, Germany, Ireland, Israel, Japan, The Netherlands, New Zealand, Scotland, and South Africa. It should be noted that scholars have numerous issues they could discuss with the student researchers. Respective scholars were asked to only report on one issue. One student contacted a scholar without permission, resulting in the same scholar being contacted twice during this year; two separate issues were reported by the scholar. Issues reported in 2009 were on the subject's image, curriculum, teacher preparation, and professional development of teachers. Subject image issues included: perceived value of technology education and female participation in technology education. Curriculum issues included impacts of STEM on technology education programs (how will it be assessed), integrating technology into the school curriculum (a trans-disciplinary approach), implementation of technology education into the secondary school course cycle, and integration of information technology into the technology education curriculum. Teacher preparation issues included: technology education teacher shortage (2) and recruitment of teachers from science and engineering to teach technology education (2). A major professional development issue was implementation of the national curriculum (4). See Table 1 for a listing of these issues.

Table 1

Issues Impacting Technology Education, 2009

Country	Issue
Australia	Implementation of national curriculum Technology education teacher shortage
Belgium	Perceived value of technology education
Canada	Implementation of technology education curriculum
England	Impacts of STEM on programs (how will it be assessed)
Finland	Female participation in technology education
Germany	Integrating technology into the school curriculum (trans-disciplinary)
Ireland	Implementation of senior cycle new national curriculum
Israel	Recruitment of teachers (science and technology/engineering)
Japan	Integration of information technology into the curriculum
The Netherlands	Lack of teaching technology knowledge and skills by science teachers
New Zealand	Curriculum change (new national framework)
Scotland	Curriculum implementation (teacher professional development)
South Africa	Shortage of qualified technology education teachers

Fall 2010

During this academic term, 13 international scholars were contacted. Countries represented by these contacts included Australia, Canada, Denmark, England, Finland, France, Ireland, Israel, The Netherlands, New Zealand, Scotland, South Africa, and Sweden. These scholars were asked to report a major issue they were confronting with the implementation of technology education in their country. Issues reported for 2010 were in four theoretical categories including the subject's image, the curriculum, teacher preparation, and teacher professional development. Subject image issues reported included the stigma associated with technology education of the past (industrial arts), shortage of females in STEM professions (careers), and lack of student appeal for technology education (4 people reported this issue with 2 citing lack of female appeal). Curriculum issues focused on implementation of the country's new national curriculum and unification in delivering the same curriculum throughout the country. Teacher preparation issues focused on training science teachers to deliver technology education in schools, training teachers to implement the new national curriculum, and training teachers how to deliver technology content in secondary schools. This last issue was directed toward teaching technology for general outcomes (technological) vs. vocational purposes. The last set of issues appeared to be closely related to teacher preparation issues, but it was approached from a professional development prospective and included strengthening the countries technology education professional organization, while the other country had limited professional development opportunities for its teachers to learn more about and how to implement technology education in primary and secondary schools grades. Table 2 lists the major issues cited by the individual country scholars in 2010.

Table 2
Issues Impacting Technology Education, 2010

Country	Issue
Australia	Strengthening professional organizations for technology education
Canada	The stigma associated with technology education of the past
Denmark	Limited professional development
England	Shortage of females in STEM professions
Finland	Female interests in crafts/technology education
France	Lack of appeal for technology education, particularly by females
Ireland	Implementation of the new national curriculum
Israel	Low quality of technology education programs
The Netherlands	Teacher training (science teachers delivering technology education)
New Zealand	Training teachers to implement the new nationalcurriculum
Scotland	Content delivered in secondary schools (technological or vocational)
South Africa	Implementation of a unified curriculum
Sweden	Lack of student interest in technology and engineering careers

Fall 2011

The final year reported in this study was 2011. Eleven scholars were contacted for the country project during this time span. It included scholars from Australia, England, Finland, France, Ireland, Israel, The Netherlands, New Zealand, Scotland, South Africa, and Sweden. The issues reported for 2011 were placed into five categories. These included the subject's image, curriculum, teacher preparation, professional development, and political change and financial issues. Image issues included the gender gap in enrollment in technology education programs, increasing college enrollments of STEM majors, and changing the focus of what technology education programs should become. Curriculum issues included revamping the country's curriculum and including technology education content and activities in the basic education curriculum. Teacher preparation issues concentrated on the opposition to the new national technology education curriculum and implementing technology education as a school subject. Teacher professional development issues identified through the study included teacher professional development for using the new national curriculum, enabling science teachers to use project-based learning strategies, and finally to develop quality technology education teachers. A new category was added this year to the issues cited previously, political change and its associated funding issues. See Table 3 for a summary of the issues reported in 2011.

Table 3
Issues Impacting Technology Education, 2011

Country	Issue
Australia	Revamping of national curriculum
England	Political change and program funding
Finland	Including technology education content and activities in basic education
France	Gender enrollment gap in technology education programs
Ireland	Teacher professional development for the new national curriculum
Israel	Teacher training in project-based learning practices
The Netherlands	Increasing college enrollment in STEM majors
New Zealand	Opposition to the new national technology education curriculum
Scotland	Changing the meaning of what technology education should be
South Africa	Developing qualified technology education teachers
Sweden	Implementing technology education as a school subject

Discussion

Design and technology education scholars continually work on refining their delivery of this school subject within their countries. It appears that all have problems or issues to overcome to better deliver technology education to the youth of their countries. Over a three year period, issues related to the image of this school subject, its related curriculum, teacher preparation, teacher professional development, and political change and its related funding issue were shown to be of major concern. However, there can be a fine line between when a curriculum issue becomes a teacher preparation issue, a teacher professional development issue, or a political change issue. Image issues can also be related to teacher preparation and the national curriculum.

For this study, image issues were defined as an opinion on a concept of something that is held by others. Curriculum was defined as a program for the preparation of learners; a group of related courses, often in a special field of study. Teacher preparation was defined as the process of preparing teachers. Professional development implies an intensive approach to improving people to more effectively prepare those they teach or supervise. Political change is when the government, in this case, ministry of education, changes the requirements for schooling and the funding associated with the education of its population. While using established meanings for these terms, the classifications may remain cloudy when trying to categorize information.

Overall, if the definitions the researcher established were followed and categorizations used were accurate, scholars consume time trying to correct issues resulting from a tarnished image of technology education (11), lack of professional development of teachers (9), shortcomings in teacher preparation (9), curriculum design issues (8), and positioning for our school subject during political change and its funding ramifications (1). See Table 4 which displays how these issues were reported by year.

Table 4
Issues Confronting Technology Education

Issues	2009	2010	2011	Totals
Image	2	6	3	11
Curriculum	4	2	2	8
Teacher Preparation	4	3	2	9
Teacher Professional Development	4	2	3	9
Political Change and Funding			1	1

One might argue that all issues are spinoffs of images associated with technology education. Are these images conceptualized from our roots in practical education or the past and current relationships we might have with vocational (career and technical) education? Does it come from the hands-on nature of our practice? Have we not continued to align our practices to the needs of students we should be serving or the needs of external populations, particularly the political and economic world (Ritz & Bevins, 2011)? One can see that countries of the European Union have worked together to improve the image of technology education to better attract females and other students to our school subject (Fadjukoff, 2010). Do we need to re-brand and create a new image for technology education?

Can the image of technology education be transformed with an improved curriculum design? New Zealand (Fox-Turnbull & O'Sullivan, 2011; Compton & Compton, 2010) has a new national curriculum that is based on an excellent foundation. Getting teachers to accept the new curriculum is a current quest. Australia (Middleton, 2011) is currently working on a new national curriculum design. Is it doomed to fail due to the ability to get a large enough mass of teachers to learn to implement the curriculum through professional development? Ireland (Seery, Lynch, & Dunbar, 2011) is experiencing problems with implementing its new national curriculum design.

However, if we did not have a curriculum issue, would the issue stem from ones initial teacher preparation program or shortcomings in continued professional development? The Netherlands (Koski & de Vries, 2011) and Israel (Barak, 2011) are experiencing problems because their policy makers have chosen to have science teachers deliver the content of technology education through science classes. Do these issues again relate to curriculum design for delivering our school subject? How will the economic crisis and demise of governments further erode the foundations of our school subject?

Conclusions

This study was the result of an analysis of issues identified by scholars who work with technology education in various countries throughout the world. Graduate students contacted these experts and asked them to identify a major issue they were encountering with implementing technology education in their country. The study involved three classes over a three year period. Thirty-one scholars from 16 countries were contacted by 38 students. The issues identified were on the image of technology, its curriculum, its teacher preparation, its professional development, and the effects of government changes.

This project contributes to the education of graduate students in three particular ways. First, it provides a global perspective on technology education. Second, it allows graduate students to communicate with scholars from another country. Third, it allows students to reflect on issues that others are encountering and better educate them to deal with these issues in their professional careers.

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Current classroom practice in the teaching of food technology: is it fit for purpose in the 21st Century?

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Key words: food technology, conceptual framework, schemes of work (SoW), Key stage 3 (pupils aged 11-14); modernised curriculum

Abstract

This paper builds on a research project exploring what secondary school pupils in England should learn in a modern food technology curriculum. The early stages of the research investigated the views of a range of professionals interested in teaching food technology and suggested a framework for a modern food technology curriculum, which would include:

- Designing and making food products;
- Underpinned by an understanding of the science of food, cooking and nutrition;
- Incorporating an exploration of both existing and new and emerging food technologies;
- In the context of sustainable development of food supplies locally, nationally and globally;
- Including an appreciation of the roles of the consumer, the food industry and government agencies in influencing, monitoring, regulating and developing the food we eat. (Rutland, 2009, p5).

The next stages of the project explored the views of a number of stakeholders of the framework. These included initial teacher educators, teachers, providers of professional development courses for design and technology teachers, higher education lecturers, examining bodies concerned with the General Certificate of Secondary Education (GCSE) food technology courses for pupils aged 16 years and the General Certificate of Education (GCE) for pupils aged 18 years and researchers working for the food industry.

This paper presents the findings of an analysis of a small sample of Key Stage 3 (pupils aged 11-14 years) English secondary schools' food technology schemes of work (SoW), against the suggested food technology framework. The framework was elaborated to give more details of the potential content and used to critique the schemes of work based on current practice in the classroom.

The key findings were that to ensure a modern technologically challenging food technology curriculum fit for the 21st Century, Key Stage 3 pupils need a broader and more challenging cur-

riculum. It should teach pupils a wider range of appropriate designing strategies aimed at making design decisions other than aesthetic, such conceptual, technical, constructional or marketing. There should be more attention given to progression and continuity from the primary Key Stage 2 (children aged 7-11 years) in the products the pupils design and make and the scientific and nutritional knowledge and understanding that underpins their work. The pupils should learn about new and existing food technologies, issues related to food sources and sustainability and gain more understanding of themselves as consumers and the role of the food industry and government agencies in their lives.

Introduction

Food science and food technology are important aspects of Britain's economy; the food and drink industry is the largest sector of manufacturing activity, employing 400,000 workers, 16% of the manufacturing workforce. The role of food science and food technology is, therefore, an important issue as if pupils do not study food science and technology in school they are unlikely to study it at higher education levels leading to too few graduates to meet industry demands. One representative of the food industry noted that 'Since it [chilled food] is technically demanding it is most likely to suffer from the shortage of food science-relevant graduates' (Monks, 2012, p.17). This is not the only reason, however, for considering the importance of food in the school curriculum. Two other key issues are:

1. The importance of pupils learning to cook as a life skill (Rutland, 2008).
2. The study of food technology, within design and technology (D&T), as an academic study of worth.

Cooking as a life skill is an important contributor to pupils developing healthy lifestyles, whilst studying food as an academic subject can provide motivation and challenge, support the development of higher order thinking skills and develop pupils' understanding of scientific concepts.

However, HMI have commented that 'there has been confusion about food technology's basic aims (Ofsted, 2006, p.5) and 'a lack of clarity about the relationship between the teaching of food as a life skill and the use of food as a medium for teaching D&T' (ibid, p.2). It was recommended that the nature of food technology should be clarified (2006) and recently that learning concerned with food technology should be more intellectually challenging and include 'designing, product development, empirical testing and applying maths and science' (Ofsted, 2008, p.5).

A research project (Rutland, 2009) investigated what secondary school pupils in England should learn, understand and be able to do in a modern food technology curriculum. Data was gathered from two conferences on nanotechnology and interviews with five informants specifically interested in food teaching in schools. The outcome was a conceptual framework to modernise the food technology curriculum which consisted of:

I. Designing and making food products
II. Underpinned by an understanding of the science of food and cooking and nutrition
III. Incorporating an exploration of both existing and new and emerging food technologies
IV. In the context of the sustainable development of food supplies locally, nationally and globally
V. Incorporating an appreciation of the roles of the consumer, the food industry and government agencies in influencing, monitoring, regulating and developing the food we eat.

The conceptual framework was used as a basis for interviews in phases one, two and three of a further research project (Rutland, 2010a; Rutland 2010b; Rutland 2011). Data was collected from a range of stakeholders, including teacher trainers; D&T and science inset providers; teachers; external examiners; higher education lecturers and people involved in food researcher for industry. The key findings of the earlier research:

- Designing with food is a complex process involving a wide range of skills and knowledge of how ingredients interact.
- Food technology teaching and learning should be underpinned with an understanding of the relevant scientific principles of food science, as well as nutrition.
- Food technology can play an important role in supporting the development of pupils' scientific understanding within the science, technology, engineering and maths (STEM) school agenda.
- Progression in food technology across the age phases is essential
- Pupils should learn about existing and emerging food technologies used in the food industry and the implications for their future lives
- Food sustainability is an important issue both at a national and international level.
- Pupils should become informed consumers so that they can make knowledgeable choices and decisions about what they eat (Rutland, 2011)

The paper recommended that a group of interested people should work together to research and develop resources to support food technology teachers in the classroom.

The current paper presents the findings from a critical analysis of a range of current secondary schools' food technology schemes of work against the suggested food technology framework. It was considered important to evaluate examples of existing practice as HMI have indicate that schools are facing a considerable challenge modernising the D&T curriculum, including food technology, so that it keeps pace with technological developmental (Ofsted, 2011). The framework was developed to give more details of the potential curriculum content and used to critic the schemes of work based current practice in the classroom. The findings will be discussed to help identify areas of a modern food technology curriculum that should be included if pupils are to become confident and capable members of a technologically advanced society' (ibid, p.4).

Methodology

The data collected in this study came from schemes of work (SoW) from a total of nine schools across England in the, West Midlands, London Region and one from Oxfordshire. Seven schools provided seven Year 7 SoW, nine schools Year 8 SoW and six schools Year 9 SoW. The SoW came from teachers within the schools through their Initial Teacher Education (ITE) colleagues and with the permission of the teacher/student teacher in the schools. Each of the SoW was analysed against the framework for a modernised food technology curriculum and the results for each year group are presented in a table (Table 1).

	Year 7 Schools = 7	Year 8 Schools = 9	Year 9 Schools = 6
<u>**Designing and making food products**</u>			
A Designing			
Design strategies			
1 Product evaluation	2	3	1
2 Attribute analysis		1	
3 Image Boards		1	
4 User trips			
5 Sensory Analysis	6	7	3
6 Nutritional Analysis	2	1	
7 Modifying recipes - changing flavour, texture, shape and finish, way it is cooked and nutritional content	5	7	3
B Making			
Ways of combining food materials			
1 Rubbing in	3	7	3
2 Creaming	4	4	2
3 Blending	1	2	1
4 Folding			
5 Whisking		1	2
6 Kneading	1	1	
7 Mixing	3	3	1
Stages in Product development			
1 Understanding the market - initial ideas	2		
2 Writing a specification	2	2	1
3 Product development		1	
4 Product testing	1	1	
5 Packaging	2	3	1
Making design decisions			
1 Conceptual			
2 technical			
3 Aesthetic	2		
4 Constructional			
5 Marketing			

Food choices			
1 Guidelines for a healthy diet	7	7	3
2 Understanding needs needs of target markets		1	2
<u>Underpinned by an understanding of the science of food, cooking and nutrition;</u>			
The properties of food			
1 physical		1	2
2 appearance			1
3 taste	1		
Understanding what ingredients do		(bread)	
1 Colloids			1
2 Raising agents - mechanical, chemical and biological	1	3	
3 Thickening liquids - gelatinisation			1
protein coagulation			1
Cooking food			
1 Different methods of cooking	3	1	2
2 What happens when food is cooked			1
3 Changes that take place when food is cooked			1
4 Finishing touches	1		
Nutrition			
1 Nutrients, carbohydrates, proteins, fats, vitamins and minerals (and fibre)	1	2	3
2 Nutritional intake - reference nutrient intake (RNI)			1
3 Nutritional content of foods	2	2	2
<u>Incorporating an exploration of both existing and new and emerging food technologies;</u>			
1 Ways of preserving food - prolonging shelf life, preserving food			2
2 Manufacturing processes used by the food industry		1	1
3 Emerging food technologies - GM foods, nanotechnology			
5 New approaches to food packaging			
4 Impact and implications of eating highly processed foods			

The context of sustainable development of food supplies locally, nationally and globally:			
1 Food sources - where they come from		3	1
2 How they are grown		1	
3 How they are transported			
4 Air miles		1	1
5 Food waste			
6 National and global issues of food sustainability		1	
An appreciation of the roles of the consumer, the food industry and government agencies			
in influencing, monitoring, regulating and developing the food we eat.			
1 How to become informed consumers		2	1
2 To be able to make informed decisions on the foods eaten			
3 The structure of the food industry and its impact on how we live.			
4 The role and support of the government agencies			
5 Food health and safety issues			Eggs

Table 1 Analysis of SoW

Analysis of results

The focus for this analysis was Key Stage 3 (pupils aged 11-14 years) SoW in England, as Key Stage 4 (pupils aged 14-16 years) food technology teaching will match external examination specification requirements. An analysis of Key Stage 4 SoW has been down but is not reported in this paper. At Key Stage 3, there is variety in the time allocated to food technology and the topics covered, so it was thought worthwhile to try and discover what is being taught.

The SoW were obtained from a small number of schools (9 schools) across diverse locations in England. Although the number of SoW analysed is small this was a random sample and is likely to represent teaching across schools in England. As the SoW were produced by each school independently there was no common template for presentation, although most contained similar information the level of detail varied. The SoW were analysed against the framework suggested by the earlier research. Analysis was undertaken by reading through each scheme of work and, where a match was found, assigning content to the pre-designated terms on the 21st century framework.

It should be noted that, although this analysis is based on the Key Stage 3 curriculum, three of the schools had started their Year 9 pupils on General Certificate Examination (GCSE) courses, so the curriculum in these schools would be based on the Key stage 4 examination specifications. The examinations being followed were GCSE Food Technology, GCSE Food & Nutrition and Catering.

Designing and making food products

The analysis shows that schools are attempting to engage pupils in 'designing' food products, but the strategies used to do this are limited. Five schools used evaluation of existing products, although this seemed to be at a superficial level of appearance and sensory evaluation and were conducted on only one or two occasions rather than being a regular feature of product development. Sensory analysis was also a common strategy (6 cases), sometimes of commercial products and sometimes of pupils own products. Modification of existing recipes was the most common strategy for developing new ideas, used by all schools.

Two schools required pupils to consider the market when developing new ideas, and three schools required pupils to write specifications, one school used specifications with pupils in Year 7 and Year 8, one with Year 7 and Year 9 and one with Year 8 only. When making design decisions pupils focused on aesthetic considerations, there was no evidence that consideration was given to other aspects, such as conceptual, technical, constructional or marketing.

There was also evidence that pupils are being asked to draw food design ideas, examples were seen of requests for drawings of pizza topping designs, using the 4x4 strategy from the *Key Stage 3 National Strategy: Design and Technology* (DfES, 2004), fruit smoothies, fruit crumble, 2D sketches for a stir fry, top and side views of a cheesecake. Pupils also looked at packaging, focusing on packaging design and food labelling. Two schools did this in Year 7, one school in Year 8 and one school in Year 9.

There was evidence of lots of practical work taking place, to develop pupils' making skills as well as their familiarity with tools and equipment, knowledge of safety and hygiene and safe working practices. In Year 7 and Year 8, dishes made were simple, including soup, pizza, crumble, muffins, scones, flapjack, fruit salad, fruit smoothie. In one school pupils made burgers and in another noodle stir fry in Year 7, and in Year 8 pupils in different schools made spaghetti Bolognese and other pasta plus sauce dishes, but in general the level of skills required was low and focused on rubbing-in, creaming and mixing. This could be due to pupils' own low level of skills or to the time constraint limiting what is possible. In Year 9, practical work became a little more skilled with the introduction of roux sauces (one school), whisking and choux pastry (one school). A wider range of dishes was made in Year 9, including quiche, cheesecake, paella and pavlova. In one school, where pupils were studying 'Catering', they had several opportunities to choose dishes they were going to make.

Underpinned by an understanding of the science of food, cooking and nutrition;

All the schools taught pupils about nutritional guidelines and healthy eating, sometimes focusing on the 'Eat Well' plate and sometimes on the '5-a-day' campaign. This knowledge was then applied to the development of recipes to make dishes 'more healthy'. Two of the schools in which year 9 pupils were following examination specifications also taught about planning meals to meet the needs of different groups. One school taught about food from different cultures in year 8 and one covered this in year 9.

In terms of the science of food, cooking and nutrition, in year 7 and year 8 this focused on the physical aspect and taste of foods with only three schools looking at the function of ingredients (yeast as a raising agent in bread products). In year 9, two schools looked at the physical properties of foods. In year 8, three schools looked at the function of ingredients in relation to bread-making and in year 9 different schools looked at the function of eggs in food, gelatinisation in a roux sauce and coagulation of meat protein. Some attention was paid to different methods of cooking, to a small extent in years 7 and 8 with more emphasis in year 9, but it was difficult to tell the level at which this was covered, pupils certainly learnt how to use different cooking methods but there is little evidence that they were taught to understand the scientific differences between these methods. The teaching of nutrition was limited in Year 7 and Year 8, focusing on a limited range of nutrients and basic food commodities. In Year 9 schools covered the macro and micro nutrients and one school taught about Dietary Reference values (DRVs) or current dietary goals.

Incorporating an exploration of both existing and new and emerging food technologies;
There was no evidence of pupils in Year 7 being taught about existing or new food technologies or any aspects of food manufacturing. In year 8, one school taught pupils about mass and batch production, one taught food marketing and two schools taught about Hazard Analysis Critical Points (HACCP). In Year 9, two schools taught about food preservation and one school about manufacturing processes, although only in relation to one-off, batch and mass production methods. One school taught HACCP in Year 9, and another taught about 'quality control'.

The context of sustainable development of food supplies locally, nationally and globally;
Again, in Year 7 there was no evidence for the teaching of sustainable development issues around food. In Year 8, one school taught the issues of food imports, the issues of eating meat and fish, sustainable fish stocks and meat alternatives and another school taught a project on 'ethical food' which covered fair trade, ethical business and the issues of local produce and food miles. In Year 9 one school taught a project based on 'local produce' which looked at food sources and food miles.

An appreciation of the roles of the consumer, the food industry and government agencies in influencing, monitoring, regulating and developing the foods we eat.
In relation to issues of the roles of the consumer, food agencies and the government the focus was on promoting the government healthy eating and 5-a-day campaigns, making informed decisions as consumers. Two schools, one explicitly following the 'Licence to Cook Scheme'[1] , taught pupils in Year 8 about 'wise shopping' but it is not known what this covered or to what level. In relation to food safety and health issues, only one school referred to this through salmonella and eggs. There was no teaching about the role of the food industry or government agencies.

Discussion

From this analysis it would appear that there is much more scope in schools to improve pupils' ability to develop food products through using a wider range of design strategies. Teachers were introduced to these through the *Key Stage 3 National Strategy: Design and Technology* (DfES, 2004) so it is disappointing to see that they are not widely used. In addition, it seems that little attention is being given to developing food products using food industry methods, such as target markets, specifications, product development and product testing. Design decisions are focused on aesthetics without consideration of other elements, such as conceptual development, technical or constructional elements. It is also disappointing to see that some schools are still requiring pupils to draw design ideas for food, this is likely to be as a result of external examination specification requirements but it is difficult to see the learning value of such an exercise.

It is good to see that pupils are being taught about healthy eating guidelines, although this is not supported by a detailed teaching of nutrition in Key Stage 3. The science of food, cooking and nutrition is very limited in most schools, and this could be developed much more. Perhaps pupils' interest in food science, or their ability in relation to it, is under-estimated but the healthy eating guidelines and understanding of food could be greatly enhanced by developing this aspect of teaching further.

Similarly, there is evidence that pupils are taught little about food technologies, the environmental issues around food or the role of government and food agencies in food matters. These are topics which are likely to be of interest to young people and teachers should be prepared to teach some of these more difficult issues.

There is evidence that pupils are engaging in practical work and developing a range of skills. Though the type of products pupils make in Key Stage 3 are, in some cases, ones that are made in Year 2 and 3 of primary schools, for example fruit salad and fruit smoothie. These skills are limited

1. Licence to cook was a programme to support secondary school pupils in learning how to cook and understand the principles of diet, health and safety and wise shopping.

and this may be the result of constraints of teaching time available, economic constraints as most pupils are required to provide their own ingredients and social constraints as there remains an expectation that pupils will make food products that can be taken home and eaten. Practical work should be developed so that it can support pupils' learning not only of practical skills but also of food science and nutrition, food sustainability issues and food product development. This would be beneficial for pupils' future career prospects and for their future lives as healthy and informed citizens.

Recommendations

- Pupils should be taught to use a wider range of designing skills in food technology to enhance the design decisions they make. It has been common for external examination boards to require pupils to 'sketch' rather than use a range of design strategies to explore the behaviour of food to achieve the required aesthetic, technical and constructional characteristics of a product (Rutland et al, 2005). Food teachers should evaluate the value of such a strategy.

- Thought should be given to the range of food products pupils made in Key Stage 3. Ofsted (2011, p4) noted that pupils' work in D&T was rarely built upon by secondary schools, yet continuity and progression in food technology is essential when building pupils' learning across the key stages. Ofsted (2011) commented that lack of continuity led to weak curriculum planning at Key Stage 3 and projects where the work was too easy and pitched at too low level or duplicated earlier learning. A Key Stage 3 curriculum built on sound primary practice would lead to a demanding, interesting GCSE Food technology courses and rigorous A Level food technology courses.

- Lack of progression is an important issue when considering the teaching of food technology linked with scientific knowledge and understanding. Food technology in the primary curriculum shows evidence of successful and effective practice where children explore the properties of ingredients, where they come from, how and why they can be used and changed in the context of a practical designing and making activity with food in D&T (Rutland & Miles-Pearson, 2009). This should be extended and built on at Key Stage 3 so that pupils can develop new ideas rather than just modify existing recipes and also understand the concepts underpinning different methods of cooking.

- The recent national emphasis in England on cooking and healthy eating through the 'Licence to Cook' initiative has led to more opportunities for practical work with food and meal preparation, though opportunities to teach practical nutrition as an integral part of learning have been missed in some lessons (DfE, 2011). Pupils should be taught more in-depth nutritional knowledge progressively throughout Key Stage 3 (DfE, 2011, p38) so that they can make sound design decisions related to a range of people's dietary needs.

- The lack of evidence in this research to the teaching of existing and new food technologies, the environmental issues around food or the role of government and food agencies in food matters is disappointing and needs to be addressed. The Key Stage 3 food technology curriculum should be balanced to include the technologically challenging and more modern parts of the subject so that pupils can apply their scientific understanding and develop greater technical rigour in designing and making (DfE, 2011).

The evidence in this study, though of a limited nature, indicates that there is a need for teachers of Key Stage 3 food technology to re-evaluate and modernise their curriculum. This presents a challenge for teachers and a need to keep pace with technological developments to ensure that their curriculum is 'fit for purpose' in the 21st Century.

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Twenty-first century learning in the senior secondary school: a New Zealand teacher's innovation

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Introduction

The twenty-first century Knowledge Age is seen as a tipping point (Gladwell, 2000), equivalent in effect to the Age of Discovery, The Renaissance, the Industrial Revolution and the internal combustion engine. Educational goals for this century are identified more as the development of learning dispositions (Claxton, 2007), competencies and life-long learning than the enduring content-driven and assessment-based approach of an Industrial Age paradigm. Bolstad and Gilbert (2008) state continuation of this age-old strategy will not best serve or prepare students for living in the twenty-first century. In particular they see senior secondary school education as geared too much toward screening, sorting and disciplining students for university study.

The situation in the senior secondary school has changed significantly in the last few decades from its traditional position where specialist teachers adopt a content-centred approach in order to develop mini mes that continue their legacies. What are these changes? Bolstad and Gilbert (2008) identify a number of factors including: increased retention rates, expansion of the tertiary sector, changes to qualifications and assessment systems, emphasis on student 'pathways' and transitions from school, and the Knowledge Society and twenty-first century learning.

Passionate and professionally aware educators have begun to acknowledge the changes required and are investigating creative solutions to ensure their students are well-grounded in relevant and meaningful learning pursuits. I have identified a local teacher (John) who has this year gained school administration approval to promote an innovative course for senior students in the field of Technology. I have chosen this innovation as the theme for my doctoral study and introduce the initiative and my approach in this paper.

John's programme

Recently in New Zealand the Ministry of Education made a decision to more appropriately align the regime of achievement and unit standards for assessment of Year 11–13 students in the National Certificate of Educational Achievement (NCEA). At the same time they saw an opportunity to develop teaching and learning guides as a resource in the senior school specialist subjects. These guides identify the learning required for students at Levels 6-8 of the New Zealand Curriculum (2007) (NZC) in each of the eight learning areas. Each specialist subject was required to link itself to one of these learning areas. This has caused issues with some subject associations who do not necessarily see themselves as coming under the auspices of a mandated curriculum learning area. This is particularly the case with some subjects on the technology fringe. For students in these subjects, Technology has been seen as 'embedded' within the teaching programmes but often not explicit enough for them to gain an understanding of the nature or practice of sound technological literacy.

John has established a programme for a class of Year 11-13 students mostly from a computer science or digital technologies background. Through an inquiry or project-based approach they will develop an understanding of the technology achievement objectives at Levels 6-8 and complete generic technology achievement standards for NCEA assessment. An emphasis within the programme will be the integration of key competencies and values from the 'front end' of the NZC and explicit teaching of the learning dispositions for twenty-first century living. They will be given opportunities to experience collaborative technological practice that will provide a range of skills and understandings to transfer to their individual projects. The significance of this initiative is threefold. Firstly, the grouping of Year 11-13 students in the same class will likely create some interesting and potentially positive dynamics. Secondly, greater understanding of the technological process and pedagogical content knowledge will likely enhance the quality of their technological practice and outcomes. Finally the integration of key competencies and values in their learning to promote positive learning dispositions will promote twenty-first century learning. These aspects will form the basis of my research which will be completed in a number of stages, developing a longitudinal type study.

The key question for this research project will be. What is the nature of teaching and learning in Technology Education using twenty-first century approaches in a multi-level classroom and how will this promote a deeper understanding?

Data gathering in the first year will be based on the students' and teacher's experiences, thoughts, and evaluations. This will provide a baseline for a two-pronged approach in the second year as students extend their first year learning and John provides interventions that will lead to the development of a longer term sustainable design. The effect of these interventions will be further studied in the third year when it is hoped that some students will progress to scholarship level in Technology having experienced three years of specialist teaching and learning programmes in this class.

Baseline data will be gathered using questionnaire and interview to ascertain technological literacy knowledge, understandings of learning dispositions, key competencies, values and motivational factors of a range of students from each year level. Interview transcripts will then be developed and questionnaire information collated. Analysis will identify commonalities and differences in student understanding and background knowledge of the above descriptors. Analysis of this information will identify goals for subsequent teaching of the twenty-first century themes and student technological project planning. Each student will maintain their own learning journal to regularly record reflections and summaries. They will also maintain individual portfolios recording their technological process and practice. Both of these will be analysed to identify connections to the key research questions.

Research Design

Neuman (1994) defines three main theoretical groupings that will influence research design: positivist, interpretivist, or critical approaches. It is the interpretivist group of theories which best suits the investigation of the initiative in this study. Neuman describes this approach as: "the systematic analysis of socially meaningful action through the direct detailed observation of people in natural settings in order to arrive at understandings and interpretations of how people create and maintain their social worlds." (p. 68)

The emphasis on learning skills and dispositions for the twenty-first century and their inclusion in John's programme mean an interpretivist approach is the best one to take. Such an approach is more accepting of the free will of participants and data gathering will need to analyse the different meaning and understanding that these participants make of the situation they share. It involves getting inside the world of those experiencing it (Orlikowski & Baroudi, 1991). Students will take differing views and ideas of the twenty-first century skills introduced and data gathering will need to seek out the meanings they take. Their work with technology mentors and experts will also be varied and the interpretivist data gathering approaches will address the shared meaning and understandings featured.

The study will be a qualitative design, using phenomenological inquiry (Best & Kahn, 2006), constructivist, and symbolic interactionism theoretical perspectives (Cohen, Manion & Morrison, 2000). This approach, utilising a range of data sources, will also allow a degree of flexibility should new design decisions need to be reconsidered (Maxwell, 1998) as a result of findings. In referring to qualitative research Baxter and Jack (2008) state: "This ensures that the issue is not explored through one lens, but rather a variety of lenses which allow multiple facets of the phenomenon to be revealed or understood." (p. 544)

Analysis of students' learning and technological practice is well suited to the use of these designs. Observations of interactions with design process, technological experts and portfolio development, will be augmented with interviews and surveys. Data gathering will focus on the ways students use their understanding, skills and knowledge to make and justify decisions in the process and production of their technological outcomes. The study offers opportunities to inquire into the benefit of a sound technological literacy and twenty-first century learning for students developing outcomes in computer science and digital technologies. Examples of these outcomes might come from the fields of software design, gaming, and animation and film especially. Investigation into the nature and benefits of key competency and values learning for these learners is also a worthwhile contribution to the study (Bolstad & Gilbert, 2008).

Cresswell (1994) identifies qualitative studies as being useful as they tend to deeply explore topics and develop theories to explain participant behaviour. He also indicates that a qualitative study has the advantage of gathering materials of participants in their natural context and setting, helping to eliminate contrived findings. Cohen et al., (2000) review a range of researchers' opinions on naturalistic research to summarise:

- Inquiry is influenced by the values that inhere in the context
- the attribution of meaning is continuous and evolving over time
- researchers generate rather than test hypotheses
- theory generation is derivative – grounded (Glaser & Strauss, 1967)
- studies must be set in their natural settings as context is heavily implicated in meanings
- the research is holistic, that is, it seeks a description and interpretation of 'total phenomena'
- there is a move from description and data to inference, explanation, suggestion of causation, and theory generation
- hypotheses emerge *in situ* as the study develops in the observed setting.

Cohen et al., (2000) however, also identify some problems that may affect the reliability and validity of the research and will need to be considered with this approach to research.

- Participants may be unaware of the 'real' situation, distorting information or being highly selective
- Participants may wish to avoid, impress, direct, deny, or influence the researcher as his presence alters the situation
- The researcher may bring about a particular reading of a situation
- Research accepts the perspectives of the participants and corroborates the status quo, being focussed on the present and past rather than the future
- Wider social contexts and constraints may be neglected

It will be important in this study to be aware of these issues and seek some form of theoretical and methodological triangulation. Multiple data sources will be significant here.

Research Methodology

Two methodologies will be used in the study. In the early stages it will be more prudent to use a case study approach to identify the critical natures of the classroom environment, the teacher/student interactions, and the chosen contexts of the students. In the later stages as interventions are developed and trialled in order to determine a more sustainable model, a newer design-based implementation research model (Penuel, Fishman, Cheng & Sabelli, 2011) will be used.

A case study is an "empirical enquiry that investigates a contemporary phenomenon within its real-life context……. and relies on multiple sources of evidence" (Yin, 1994. P. 13). Orlikowski & Baroudi (1991) link case study to interpretivist researching noting that it attempts to: "understand phenomena through accessing the meanings that participants assign to them" (p. 5) but noting that researchers must acknowledge their own subjectivity in the process. In the case of this study the researcher needs to acknowledge he is implicated in the research by being involved in the class as a teacher of technology and advisor in their technological process. Multiple sources of evidence will again be important in the triangulation process. "Successful completion of case study research requires enthusiasm and intense curiosity about the phenomenon being investigated" Darke, Shanks & Broadbent (1998).

Stake (1995) and Yin (2003) base their approach to case study on a constructivist paradigm. It, "recognises the importance of the subjective human creation of meaning" (Baxter & Jack 2008). There is a close collaboration between the researcher and the participants in the study (Miller & Crabtree, 1999).

Yin (2003) identifies a variety of types of case study. The case study in this research will be a 'descriptive' type. These are used to describe an intervention or phenomenon and the real-life context in which it occurred (Yin). The study will be a multiple-case study because of its longitudinal nature. While there will be similarities in the classes over the years of the study each will contain its own individual nature and dynamics. As the study progresses findings will be related to previous years to note similarities, differences and developments. On-going students will most likely show benefits from their previous experience in this class.

Educational researchers agree that educational research is often divorced from the problems and issues of everyday practice which requires new research approaches centred on improving classroom practice (National Research Council, 2002: cited in Anonymous, 2003). Once interventions in the research study are instigated from Year Two, the programme will significantly be researched using a design-based implementation research methodology (Anonymous, 2003). This will provide for clearer evaluation of the programme's design and result in a suitable paradigm for sharing with the Technology community. Penuel et al., (2011) define this approach as including, "development and testing of innovations that foster alignment and coordination of supports for improving teaching and learning.

Penuel et al., (2011) state the approach is distinguished by four key elements:

A focus on persistent problems of practice from multiple stakeholders perspectives

A commitment to iterative, collaborative design

A concern with developing theory related to both classroom learning and implementation through systematic inquiry

A concern with developing capacity for sustaining change in systems.

Future success in improving Technology teaching and learning in the senior secondary school system will rely on people, teams, and programmes being aligned appropriately (Rowan, 2002). This will be a complex task as each institution varies in the way it is founded, the way it is resourced and how it operates. Design research involves iterative approaches to developing innovations. "Its focus on developing practical theory and tools that can be used to support local innovation and to solve problems (Reinking & Bradley, 2008), demonstrates its true potential.

In considering this model it is important to remember that the students in the study have come from a background in technology-related fields but have not been explicitly informed of the technological pedagogical content knowledge. Neither have they been given the understanding of the influences or impacts on their technological practice and outcome development. These aspects, noted in Table 1, will become important features of the study.

Table 1: The significance of Penuel et al., (2011) to the study of the initiative

Key Element	Important factors from design-based literature	Research significance
1. Problems of practice	Develop a shared understanding of the situation and nature of this research.	Build rapport with students and teacher. Interview and survey student beliefs and attitudes. Students raise issues and concerns
2. Collaborative design	Develop and test usable tools for improving teaching and learning.	Teacher and researcher work together to develop understanding. Develop student knowledge of technological practice. Explore the use of key competencies, values (NZC) Establish a guided inquiry learning model (Kuhlthau, Maniotes & Caspari, 2007). Year 11-13 students working together with experts in their field.

3. Developing theory	"In design research, it is through the analysis of what happens when researchers engage in design and help support implementation that theory develops," (Edelson, 2002)	Identify new theories for teaching and learning through systematic inquiry. Theories developed must be suitable for the school's culture, resources and policies (Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000).
4. Developing sustainable change	Intentional efforts will be made to develop processes to broadcast the innovation. Design efforts should improve social capital that individuals can access to accomplish purposive action. Design-based implementation research can foster cohesion among networks of subject associations.	Theories developed will be dispersed to teachers of subjects within the senior secondary technology learning area. Continuing students will bring prior experiences and will be powerful mentors for new students. Encouraging discourse among members. Later stages of the project will focus on writing articles on the project and professional development opportunities for teachers.

A range of data gathering techniques from Mills' (2000) "Three Es" groupings (experiencing, enquiring and examining) will be utilised including observations, students' learning stories, open-ended interviews, questionnaires, journals, portfolios and technological outcome development. These methods lend themselves well to the research question and will identify the strengths of this programme to raise technological literacy and twenty-first century learning.

Twenty-first century learning and Technology Education

Transformation of the emphasis of twenty-first century learning in Technology does need a great shift from what is currently featuring (Bolstad & Gilbert, 2008). It is more about complementing the discipline knowledge with an explicit approach to developing the habits of mind and learning dispositions (Claxton, 2007) that will create the intellectual skills to enable them to, "…think analytically, to synthesise, to think creatively and practically, and apply this thinking in a range of new and different situations" (Bolstad & Gilbert, p. 99). It is skills supporting innovation, creativity, critical thinking, and problem solving that are needed to fulfil the expectations of the new economy (Bellanca & Brandt, 2010).

Current content and assessment-driven approaches are frequently lacking in interest and motivation for students to truly engage and develop deeper and 'big picture' learning. This requires the explicit teaching of life-long, learning dispositions and higher order thinking skills. Rather than using an apprenticeship model of knowledge building, having students use knowledge to generate new knowledge will prepare them better. They are more likely to be the resilient and all-round learners capable to living well in the twenty-first century.

Wagner (2008), in The Global Achievement Gap, has advocated seven survival skills for the 21st century. These will become key features of John's programme. They include:

- Critical thinking and problem solving
- Collaboration across networks and learning by influence
- Agility and adaptability

- Initiative and entrepreneurialism
- Effective oral and written communication
- Accessing and analysing information
- Curiosity and imagination

The New Zealand Curriculum (2007) was developed to set a clear direction for teaching and learning in the new millennium. Its focus on principles, values and key competencies is an acknowledgement that discipline content alone will not produce the resilience necessary. Much broader 'big understandings' and 'throughlines' (Blythe, 1998) need to over-arch discipline learning to create the connection to the more significant themes prevalent in this current era. The curriculum also identifies a range of effective pedagogies that connect with meaningful education in this new millennium and provide teachers with a better understanding of what will best promote twenty-first century learning.

Curriculum 'front end' learning in New Zealand includes the:

- Vision – young people who are: confident, connected, and actively involved, life-long learners
- Principles – high expectations, cultural diversity, inclusion, learning to learn, community engagement, coherence, future focus and Treaty of Waitangi awareness
- Values – excellence; innovation, inquiry and curiosity; diversity; equity; community and participation; ecological sustainability; and integrity
- Key Competencies – thinking; using language, symbols and texts; managing self; relating to others; and participating and contributing.

In the United States over the last decade the Partnership for 21st Century Skills organisation has developed the Framework for 21st Century Learning (Partnership for 21st Century Skills, 2009) to meet the educational needs and support systems required to radically refocus the education system. This framework identifies the wide range of considerations necessary to meet the new demands. This framework includes:

- Core subjects
- 21st century themes – global awareness; financial, economic, business, and entrepreneurial literacy; civic literacy; health literacy and environmental literacy
- Learning and innovation skills – creativity and innovation, critical thinking and problem-solving, communication and collaboration
- Information and communication, media and technology literacy
- Life and career skills – flexibility, adaptability, initiative, self-direction, social and cross-cultural skills, productivity, accountability, leadership, and responsibility
- 21st century education support systems – assessment, instruction, professional development, and learning environments.

Findings of this research will most likely confirm the need to explicitly teach twenty-first century skills and dispositions and identify the impact that these have on students' motivation and engagement in Technology Education and other learning areas also. Increased engagement through better motivation and collaborative practice with peers and older students is also expected. Positive findings in the way multi-level classes might promote better learning and collaborative practice in schools may lead to some reconsideration of the way classes are organised in the senior secondary school, not only in Technology but in other learning areas too. This research may potentially identify the benefits of teaching higher curriculum levels, learning dispositions and higher-order thinking skills in the senior secondary school and help change the current emphasis on content-driven programmes.

Conclusion

The rate of change in the twenty-first century is exponential. Keeping up is a challenging process and possessing a range of skills and dispositions that will assist life-long learning to cope with this change will become an important goal in education. Technology Education provides an excellent vehicle to facilitate and promote these twenty-first century learning needs. This study will investigate the nature of inquiry in the technological design process and identify the higher-order thinking skills, and collaborative approaches to work, to enable students to, "come at life venturesome, imaginative and questioning" (Claxton, 2007).

Bolstad & Gilbert (2008) use a biological metaphor to describe the changes needed in twenty-first century curriculum. The traditional programmes in use produce conformist, and evolutionary dead end clones. What is needed are 'clades'. These are unspecialised organisms that will colonise new environments of learning. They are diverse, dynamic, innovative, and ever-evolving. Technology encourages students to see this shift from just 'knowing stuff' to 'doing stuff'. John's programme and my study will bring to light the nature of teaching and learning in Technology Education using twenty-first century approaches in a multi-level classroom and how will this promote a deeper understanding?

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Designerly well-being: Can mainstream schooling offer a curriculum that provides a foundation for developing the lifelong design and technological capability of individuals and societies?

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Abstract
This paper is presented as a position paper that introduces the idea of designerly well-being as the underpinning concept for the development of the Design and Technology (D&T) and Technology Education curricula to be more fit for purpose in the 21st Century. It starts by unpacking the concept of design capability and designerly well-being and then reviews the current turmoil around the D&T curriculum in England as a way of exploring the potential of the subject, reasons why it is seen to have 'underachieved' and ways in which the curriculum could be re-thought. Examples of initiatives outside of the formal curriculum are provided to illustrate the value of educational activity that isn't driven by a formal, prescribed curriculum and a case is made for a radical change to the curriculum that re-prioritises the curriculum away from prescribed knowledge and skill and towards developing attributes of designerly well-being such as passion, curiosity, enthusiasm, risk taking, competence and confidence – all developed through the activity of designing and making.

Introduction
In England, recent months have seen turmoil for D&T as we await the out-turn of the latest Government review of the National Curriculum. Over the last 25 years, curriculum review has presented eras of instability in the curriculum, but the current concerns, panic, discussions, meetings and general professional soul searching has been equaled only by the introduction of the original National Curriculum in 1990. This current situation may be mainly of local interest, but there is evidence, not least through papers presented over the years at PATT conferences (de Vries, & Mottier, 2006; de Vries, 2011) that curricula world-wide are subject to equivalent threats, upheavals and reviews. The outcome of such reviews and the resulting revisions are rarely based on full consensus, even within the profession. This raises questions about the level of satisfaction anyone in the international Technology Education community has with their prescribed curricula. Is the reality that, globally, we are all working in a context of compromise?

The current English situation is causing the profession to ask fundamental questions. Is it better to be within the National Curriculum or to be left out, leaving decisions about what is taught, and to whom it is taught, to individual schools and teachers? Should D&T be in the curriculum of all learners? Should D&T specify distinct areas such as electronics and control, resistant materials, textiles, food or graphics, or take a more interdisciplinary approach? Does sub-division provide breadth or create unhelpful and unrealistic boundaries? Should the subject align itself more with STEM or take on the nomenclature of engineering? Is the subject over-specified, over-laden with content? Is the product-focused basis of the subject as currently taught 'fit for purpose' in a world challenged by historic dangers of the designerly thinking (Baynes, 2009) and the chronic consumerism and 'affluenza' (James, 2007) that has taken a stranglehold on societies across the globe?

Behind all of these questions and the professional views expressed in response, lies an implicit belief that society is a better place when young people have experienced design and technological learning - that the *designerly well-being* of the individual makes for the designerly well-being of society. In this paper I explore the concept of designerly well-being (of the satisfaction, pride, confidence and competence of being able to engage designerly thinking and action with criticality and capability) and the potential of utilising this concept as the radical foundation for future curricula in D&T, or Technology, Education.

What is designerly well-being – or what might it be?

In a joint presentation to the Technological Learning and Thinking conference in Vancouver in June 2010 I introduced the concept of 'designerly well-being' in a discussion on the importance of nurturing designerly thinking through education. This nascent concept is the starting point for this paper and so deserves a little unpacking to provide some clarity about how I conceive this concept and why I consider it to be of importance at a time when there appears to be a level of disquiet with the curriculum in England (and possibly elsewhere in the world) in general and most specifically in D&T.

Behind this concept is a strongly held view that all humans have the potential to be designers – not just professional designers who make their living by designing, but to bring designerly thinking and action to the way that all humans operate on a daily basis. This is a view of design capability a key element of human capability – one of the defining characteristics of being human. This idea is not one of my own making, but is one that implicitly underpins the original (and continuing) vision for Design and Technology as a curriculum subject in England (DES/WO. 1988; DCSF/QCA, 2007; Design Commission, 2011). Embedded in the idea of design capability is the way humans are innovative by envisioning new and (hopefully) better ways of creating the 'made' world of the future through the development of products, systems, environments and services. An important word here is 'capability'. Together with Richard Kimbell I have put down elsewhere why a capability view of Design and Technology is critical (Kimbell & Stables, 2007). But in a nutshell the word captures the *motivation* and *ability* to bring future possibilities into reality through an *intentional* iterative process of *thought and action*; designing and making.

In our previous writing about capability, a broader view was highlighted and a link made with the Capabilities Approach that signifies the work of the Nobel prize-winning economist Amartya Sen and his seemingly simple definition of capability as being what a person can be, and what they can do (Sen, 1992). In the context of designerly well-being, reference to Sen's Capabilities Approach has even greater resonance. Indeed his whole thesis and its further development with Martha Nussbaum (2000) has a direct link to the concept of well-being – not just physical well-being, but also emotional, social and psychological well-being that comes from taking active decisions about living life with dignity, within a set of personal values and in a manner that brings both freedom and agency. While neither Sen or Nussbaum explicitly refer to design capability (although in Nussbaum's expansion into a categorisation of types of capability she does include "Being able to use the senses, to imagine, think and reason" and "Being able to form a conception of the good and to engage in critical reflection about the planning of one's life", Nussbaum, 2000, pp78-9), the sense of individual well-being engendered by being an active participant in creating future ideas and actively and responsibly bringing them into reality, captures some of the essence of what I am calling designerly well-being and in my view sits well with the broader view the Capabilities Approach promotes.

But there is a danger in the above, in that what I am presenting is a romantic view of human satisfaction engendered by engaging in designing and making activities, as if by definition such activities are wholesome, rewarding and 'do-able' by all. A key point here is that design capability is about potential – it needs to be nurtured and developed. And so a key ingredient is education.

There is also a sense in the above that all design is for the good and yet we know that this is not true – in anything newly designed there are likely to be winners and losers – as the extreme example of designing a machine gun starkly illustrates. Ken Baynes goes further than this and describes designerly thinking as "one of the most dangerous of all human characteristics" (Baynes, 2009, p.5). Reflecting on the extreme consumer culture of recent years, the role of designers in fuelling the fire of this culture and the disastrous impact of the creation of consumer products on the environment shows only too clearly how true his statement is. So, designerly well-being of individuals needs to have a cumulative effect of designerly well-being of communities and society, highlighting the importance of design capability having a thoughtful, critical edge that provides opportunity for responsible designing.

Is designerly well-being a vague, romantic notion? Or can it be articulated as a valuable and sustainable concept and can it be nurtured by developing design capability potential in us all through effective design education?

Dissatisfaction with current curriculum

What is apparent is that there is some dissatisfaction with the current state of play of English design education, including the D&T school curriculum. There is also a suspicion that England may not be alone in this. Papers at previous PATT conferences indicate a more viral dissatisfaction with Technology Education in a range of national and provincial settings (de Vries, & Mottier, 2006; de Vries, 2011). The reasons for the dissatisfaction vary – lack of resources, mismatch between policy and practice, conflicting views about priorities, negative impacts of audit and assessment practices, but the over-riding sense is that there is very little evidence globally of a utopian Design, D&T or Technology Education curriculum in mainstream schooling.

In England we are now at a watershed – there has not been so much and such varied interest and anguish about the D&T curriculum than since the preparation to introduce a National Curriculum nearly 25 years ago – a curriculum that not only changed radically how schooling operated in England, but that also had significant impact on the development of Technology Education in many other parts of the world. The question now is should D&T continue to be included in the National Curriculum. And how might this inform, and be informed by, the concept of designerly well-being.

The terrain is thick with critiques, opinions and reviews that provide a series of lenses to explore the current context. A major contribution is being made by the D&T Association through extensive lobbying, advocacy and promotional work, including the production of a manifesto supported by an impressive array of the great and the good from the world of the UK Design industry and a 'Believe in D&T' campaign (http://www.believeindandt.org.uk/). There has also been considerable informal discussions via blogs, working groups and organised seminars and in addition we have had a series of reports to inform on the topic, including

- *Meeting Technological Challenges? Design and technology in schools 2007-10* – a report from Ofsted (the national education inspection service) on the D&T curriculum (Ofsted 2011)

- *Making a mark: art, craft and design education 2008-2011* – a report from Ofsted on Art and Design curriculum (Ofsted 2012)

- *The Framework for the National Curriculum. A report by the Expert Panel for the National Curriculum review.* – An independent report for the Department for Education, (DfE, 2011).

- *RSA Design & Society. What's Wrong with DT?* (Miller, 2011)

- *Cultural Education in England*: An independent review by Darren Henley for the Department for Culture, Media and Sport and the Department for Education (Henley, 2012)

- Restarting Britain: Design education and Growth – a report by the Design Commission (A group established by the Associate Parliamentary Design and Innovation Group (Design Commission, 2011).

While the scope and nature of these reports all differ, by-and-large all offer support for the value and contribution of D&T. It is acknowledged that learners of all ages enjoy the subject - it continues to maintain a high level of popularity as a 16+ (GCSE) examination subject. Where it is seen to be in good shape, teachers have high expectations of learners, there is 'palpable excitement' in engaging with work, projects are ambitious, take on Big Design challenges (a current phrase capturing Design's increasing engagement with major human issues, such as dignity in healthcare, entitlement to clean water and so on), involve group work, are set in relevant contexts, fascinate and intrigue learners,

But since its introduction as a National Curriculum subject in 1990, it is seen to have 'underachieved' (Miller, 2011, p. 3).

> "the original ambition of Design & Technology – to be a subject that breaks down boundaries between disciplines, synthesises and builds on learning in other areas, turns out individuals who are three-dimensionally capable and critical appreciators of the 'made world' – has not yet been fully achieved. This is in part due to the milieu in which it has been tasked to operate" (Design Commission, 2011, p. 12)

Across the reports there is criticism that where D&T isn't good it lacks challenge, is narrowly focused, too formulaic and spends considerable time on "worthless tasks" producing "undemanding and unfinished work" , (Miller, 2011, p.7) There is also a suggestion that, particularly towards the later years of schooling, there is too much focus on inappropriate assessment – the sort that leads to 'teaching to the test'.

Opinion is generally clear that D&T needs to be maintained within the curriculum in some form, but that it needs re-thinking, re-habilitating. Suggestions include closer links with art and/or with STEM possibly allowing it to be a genuine bridge between art and science. There is a strong message about a greater focus on design – and by this meaning the broader view of design that has developed in recent years that is interdisciplinary and addresses big human and societal issues. There is also clear support for what are seen as 'enrichment' activities – working with professionals, working in outside school settings, after school clubs and other extra-curricular initiatives.

Across the reports there is a strong message of support for what design (and D&T) does for young people's lives - their individual designerly well-being – when it is taught in an enlightening, inspiring, challenging, innovative way that sparks enthusiasm, passion, competence, confidence and pride – shaping the future as well as meeting current needs. Also there is a tendency towards highlighting an instrumental view – design is good for society, the economy etc – and this indicates its role in the well-being of the nation albeit largely from an economics standpoint. But this is territory for a further paper.

With all this (albeit constructively critical) support, the question still remains – should D&T maintain its position as a 'foundation' subject in the National Curriculum, should it be moved to the 'basic curriculum' – where the subject will be compulsory but the content will not be legislated, or should it be removed from the curriculum altogether? On this the jury is still out.

A cluttered curriculum?

A further view that emerges from current debate is that the D&T curriculum is overloaded. Despite the fact that since the introduction of the original National Curriculum in 1990 each revision has aimed at reducing the specified content – to the point that the current curriculum for 11-14 year olds is structured around a set of key concepts (Design and making; Cultural understanding; Creativity; and Critical Awareness), schools are still largely organizing the curriculum around the different specified material areas and teaching these as if they were subjects in their own right – each bringing a long list of content that seems to be considered necessary and often taught on a 'carousel' that brings with it a 'silo' mentality. This is particularly so in secondary schools where there is such a strong emphasis on the impact of GCSE (16+) assessment on league tables – and a 'teaching to the test' mentality leads to well-intentioned focus on knowledge and technical skills. The issue of assessment and the impact this has had on the curriculum has been raised across the various reports listed above – and an overarching impact is summed up neatly by David Miller through his comment "There seems to be too much in the DT curriculum to have time to reflect on the broader picture of Big Design." (Miller, 2011, p.9)

The prioritising of knowledge and technical skills has become so ingrained in the culture of D&T (again, especially at secondary level) that it may seem heresy to challenge it, but the question needs to be asked – are we prioritising the right things? In the context of my concept of designerly well-being I would say that we aren't – and some clues about an alternative lie in the list of attributes that emerge from the current debate – the ability of D&T to *spark enthusiasm, passion, competence, confidence and pride – shaping the future as well as meeting current needs.* As far back as the publication of the framework we used for the APU D&T project (Kelly et al., 1987; Kimbell et al., 1991) we promoted the importance of 'need to know' as the driver for acquiring knowledge and skill. Even further back, in an essay originally written in 1916, A. N. Whitehead was declaring (in his characteristic straightforward manner) that in education we should teach a small number of important things, and teach them 'properly' by which he means in a way that the learner can "make them his own, and should understand their application here and now in the circumstances of his actual life" (Whitehead, 1929, p.14). His view is that by teaching what he calls inert ideas – "ideas that are merely received into the mind without being utilized, or tested, or thrown into fresh combinations" (p.13) we create an education "radically infected" with mental dry rot. He describes inert ideas as both useless and harmful. To bring home his point (and in reading this it is important to remember the context of 1916) he declares that

> "uneducated clever women, who have seen much of the world, are in middle life so much the most cultured part of the community. They have been saved from this horrible burden of inert ideas" (p.13)

The ability to operate effectively on the basis of a less cluttered curriculum is dependent on learning on a 'need to know' basis, which, in turn, is dependent on the learner's ability to find out – both through careful scaffolding by a teacher and independently. The latter course of action requires a certain level of competence but an even higher level of both confidence and risk taking – all of which I would include as attributes of designerly well-being. Further than this, I believe we need a curriculum that truly focuses on 'heads, hands and hearts' – intellectually challenging, focused on the first hand experience of the creative act of designing and making and motivating in every respect, a curriculum that, again drawing from Whitehead's view of 'technical' education promotes

> *creative experience while you think, experience which realises your thought, experience which teaches you to coordinate act and thought, experience leading you to associate thought with foresight and foresight with achievement. (*Whitehead, 1929, p. 64)

Turning the curriculum outside in

From evidence in the series of reports considered here and from other sources such as previous Ofsted reports, it is clear that the very best examples of teaching in D&T can engender such attributes. There are also examples of other curricula that provide important models – and key amongst these would be the historic Sloyd curriculum, even more so with the recent emphasis on design and 'holistic craft' in Sloyd (Pöllänen, 2009; Sjöberg, 2009). Interestingly, in raising the issue of the misunderstanding of design within the general population in the UK, the Design Commission report (2011) highlights the example of Finland as having a good understanding of design, drawing a causal link to Finland's long history of craft education.

But if we look more widely for evidence of initiatives that develop design and technological capability, and alongside this the attributes of curiosity, pride, an "ethic of excellence" (Berger, 2003), ambition, risk taking, passion, competence and confidence, they are more typically found beyond the curriculum. Examples of this are becoming somewhat ubiquitous, but some that have achieved high exposure (not least through TED talks) and that illustrate my point would include

- The Sorrell Foundation National Art&Design Saturday Club – where 14-16 year olds have the unique opportunity of attending their local art and design college on a Saturday, experiencing 'master classes' with highly acclaimed professional artists and designers, and create their own summer exhibition in central London. (http://thesorrellfoundation.com/saturday-club.php)

- Gever Tully's "Tinkering School" that started as a series of summer programmes for children in which they learned to do 'dangerous' things that sparked curiosity and imagination and has now developed to 'Brightworks' – a small number of independent K-12 schools that take the Tinkering School philosophy and apply it to the whole curriculum. (http://gevertulley.com/)

- MIT 'Fablabs' "digital fabrication labs that allow you to make (almost) anything" (http://fab.cba.mit.edu/) that have been taken all over the world to allow children and adults to create inspirational 'made' projects in informal education settings and have led to school-focused projects such as the Fab@schools project – taking fablabs into elementary schools as part of STEM education, or Sparklab, a Kickstarter project by Stanford D School students who are passionate about making, education and technology who have created a portable workshop to take to schools to fill the gap that lack of funding has created in preventing resource provision for hands-on making and learning. (http://www.kickstarter.com/projects/107975578/sparklab-an-educational-build-mobile)

- Emily Pilliton's Project H that brings volunteer designers together to work with disadvantaged communities on design projects. (http://www.projecthdesign.org/)

All of these projects run on passion and enthusiasm for design and technology. All have track records in motivating and inspiring young people to achieve more than they ever thought they could. All operate without the stucture of a prescribed curriculum, but by ideas driven by curiosity and innovation and resourced by a 'need to know' mentality.

So, here is the paradox. In school we get to do the worthy but often un-inspirational stuff – that meets the needs of a curriculum full of content and monitored by an assessment regime that is stifling it. Out of school we get to do the inspirational, exciting, challenging stuff that (in my view) nurtures designerly well-being. Now this is a massive overstatement, but it is one that begs the question, what if we turned the curriculum outside in? What if we took the outside the curriculum initiatives and brought them inside the curriculum? What if we focused on projects that addressed Big Design questions, that utlised teamwork, critical thinking, that inspired curiosity, promoted creativity, innovation, autonomy, but that didn't obsess about the content that had been covered. And if we don't take this risk, what might happen? Will the school subject become obsolete as young people overtake what is offered in school, happily taking on their own challenges outside of school, resourced by Internet sites such as hackerspace and opendesign?

It could be argued that this route would lead to more democratic designing, but what of democratic design education? In my experience, both as a teacher and as a teacher educator, people become D&T teachers because they are passionate about designing and making and the qualitative effect it has had on them as people – the sense of designerly well-being they feel. And they are equally passionate about supporting and developing young people to develop their own capability – along with the pride, competence and confidence this brings. So is it such a fanciful idea to suggest that we prioritise the very things that brought us to the subject in the first place?

As I stated at the outset, this is a position paper, exploring a concept rather than looking at a well-researched and optimized solution. The proposal has flaws, but as a starting point it seems better than where we are at the moment.

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Engineering by Design™: Preparing Students For the 21st Century

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Abstract

For students to become globally competitive and productive in the 21st century, they need to be taught how to solve problems they will encounter. Designing a curriculum that integrates science, technology, engineering, and mathematics (STEM) principles while utilizing the engineering design process is critical (Business-Higher Education, 2011). The Engineering byDesign™ (EbD™) curriculum has been designed to attain this goal using methods that can be beneficial for all teachers to understand and use to develop student skills. The implementation and evaluation of this curriculum has provided assessment data that is valuable for increasing student success in technology and engineering education.

Introduction

This paper describes the Engineering byDesign™ technology and engineering program developed by the International Technology and Engineering Educators Association (ITEEA). This Program integrates key science, technology, engineering, and mathematic (STEM) concepts into their structure for preparing students to meet the needs of the 21st century. The EbD™ standards-based program is a K-12 solution for schools in the United States and possibly worldwide, as an approach for achieving engineering and technological literacy. This approach can lead to educational performances necessary for the success of students on a global level. The rationale for the need of this type of program will be discussed, as well as, the foundations of the EbD™ program. This paper will also describe the methods of evaluating the program through the current EbD™ assessment process. Preliminary data has been gathered to determine the success of the use of this technology and engineering program in U.S. schools.

Rationale STEM Education

In an effort to prepare today's children for tomorrow's world educators must provide learners with the knowledge and skills needed for problem-solving and creation of innovation. According to the Partnership for 21st Century Skills, life-long learning and innovation abilities are being recognized as the skills that will separate students who are equipped for the increasingly complex life and workforce of the future and those who are not. The partnership also states that a focus on creativity, critical thinking, collaboration, and communication will be necessary in preparing students for the future. These are all skills that a planned technology and engineering program which integrates STEM concepts should include to encourage and nurture a student's and a nation's success.

A country's achievement in the 21st century will depend on the ideas, knowledge, and abilities of its population. These are the assets that can characterize a nation as powerful. As the 21st century workforce shapes into one that is increasingly technological, the value of these assets will be determined by the effectiveness of its STEM education programs (Report to the President, 2010). Programs, such as, EbD™ may help generate the scientists, technologists, engineers, and mathematicians, who will invent and innovate new ideas, products, processes, and industries for the future (Prepare & Inspire, 2010).

Engineering byDesign™

EbD™ curriculum was designed based on the need for a U.S. STEM educational model. Figure 1 shows the EbD™ course scope and sequence developed by the International Technology and Engineering Educators Association. The vision of EbD™ is to provide a K-12 technology and engineering program that facilitates a creative study of STEM while generating the consistency needed in meeting the national standards for technological literacy. Students can be provided with the essential knowledge, skills, and attitudes in science, technology, engineering, and mathematics which could aid in creating an informed global citizen and workforce (Business-Higher Education, 2011). This is a focus that can lead to the program's goal of restoring America's status as the leader in innovation by creating the next generation of technologists, innovators, inventors, and engineers (ITEEA, 2011).

CORE PROGRAM	K-2	**EbD™ TEEMS Technology Starters/KITS** N
	3-5	**EbD™ TEEMS I3 KITS**
	6	**Exploring Technology**
	7	**Invention and Innovation**
	8	**Technological Systems**
	9	**Foundations of Technology**
	10-12	**Technology and Society**
	10-12	**Technological Design**
	11-12	**Advanced Design Applications**
	11-12	**Advanced Technical Applications**
	11-12	**Engineering Design (Capstone Course)**

Figure 1. The Eb™ course scope & sequence (ITEEA, 2012).

Engineering byDesign™ Network

EbD™ has established a unique approach to creating a program that is dynamic for continual development towards a successful national standards-based STEM model for grades K-12. The EbD™ model has created a consortium of U.S. states to serve as leaders in collaborating for higher quality education. The leaders in these states communicate to ITEEA and other members thus creating a consistency in the advancement of STEM education that has been lacking according to President Barack Obama's STEM Council (Report to the President, 2010). The state leaders implement the EbD™ curriculum in their school systems and together evaluate student achievement to make informed decisions in enhancing technological literacy for all through science, technology, engineering, and mathematics integrative study. With the increase of state participation (see Figure 2) their decisions can become a powerful tool in shaping the future of education.

The EbD™ network provides an evaluation of the program through an analysis of data that is collected through a course assessment process. The assessment system has been developed to measure the levels at which students meet the desired standards and objectives for technological literacy as taught through EbD™ curriculum. To become a network school an agreement must be signed stating that the school will utilize the standards-based curriculum, the curriculums' suggested instructional practices, and its assessment system. In doing this, national data can be evaluated to develop changes needed in the program to lead to improved student success. The schools in the network will have access to the dynamic online curricula, professional development opportunities, and online collaboration tools for communicating with other network teachers. Schools will also receive their own assessment data in order to make informed decisions about their instruction (Burke, 2012). Data are stratified according to individual units of students, as well as, by each desired standards and objectives. By using assessment data, schools may be better prepared to establish successful results.

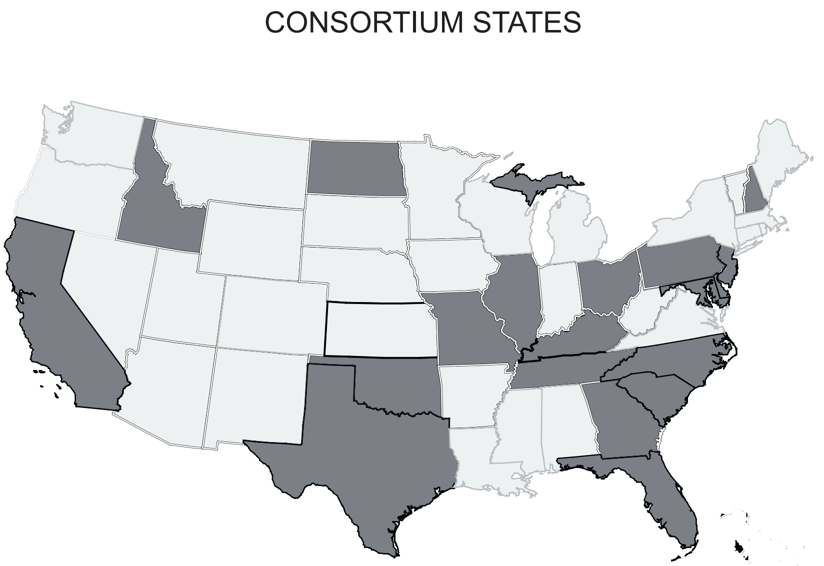

Figure 2. The EbD™ consortium states are shaded (ITEEA, 2012).

Engineering byDesign™ Course Foundations

EbD™ has developed and implemented many methods and strategies to establish a foundation to achieve its desired vision of preparing students for the future. In an economy and time so focused on innovation, it is important that students are exposed to the skills necessary to make a global contribution. To be innovative, one must be a critical thinker, a creative problem solver, and an effective collaborator, all of which are focal points of Engineering byDesign™ curriculum. The curriculum is designed in a way that allows students to creatively solve problems in the context of real life situations.

This problem-based learning approach is founded in the Standards for Technological Literacy (ITEEA, 2001), the Principles and Standards for School Mathematics (NCTM), and Project 2061, Benchmarks for Science Literacy (AAAS) (see Figure 3 for the model of curriculum development). In summary, Engineering byDesign™ is a model STEM program that uses the Standards for Technological Literacy as the primary organizer, while assessing its effectiveness through summative online assessments.

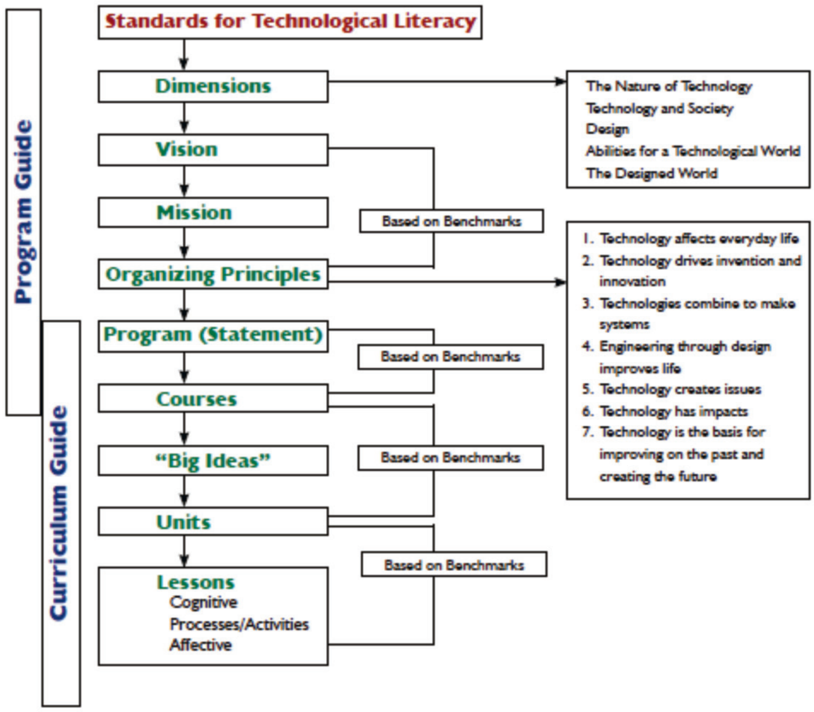

Figure 3. The EbD™ curriculum development model (ITEEA, 2012).

Engineering byDesign™ Curriculum

What makes the EbD™ model program desirable is its dynamic curriculum design. The curriculum is no longer a solitary collection of resources that generally become obsolete within a short amount of time. Instead the curriculum is a living, breathing collection of online assets to education. This means that it is easily modified and changed based on the feedback of network members and the needs of schooling and society. This can be extremely effective since the United States often lacks clear, shared standards for STEM education that would help all contributors in the education system set and achieve desired goals (Report to the President, 2010). EbD™ is also built upon the constructivist learning theory. This entire constructivist process is set in an authentic problem-based learning context (ITEEA, 2011). An example taken from the 9th grade EbD™ course, titled Foundations of Technology (FOT), can be seen in Table 1.

Table 1. Foundations of Technology Sample Lesson Snapshot

<table>
<tr><th colspan="2">SAMPLE LESSON SNAPSHOT (Unit 4 Lesson 2)</th></tr>
<tr><td colspan="1">Big Idea:
The Engineering Design process is a systematic, iterative problem solving method, which produces solutions to meet human, wants and desires.

Student Performance
Students will:
1. Apply the steps of the design process including defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing, and communicating results.8H
2. Contribute to a group endeavor by offering useful ideas, supporting the efforts of others, and focusing on the task.
3. Work safely and accurately with a variety of tools, machines, and materials.
4. Actively participate in group discussions, ideation exercises, and debates.</td>
<td>Standards& Objectives
<u>Technology: Standards for Technological Literacy (STL)</u>
1. Understanding the attributes of design (STL-8)
2. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results. (STL-8H)
<u>Mathematics: Principles and Standards for School Mathematics (NCTM, 2000)</u>
1. Represent and analyze mathematical situations and structures using algebraic symbols (NCTM-5)
2. Use symbolic algebra to represent and explain mathematical relationships; (NCTM-5L)
3. Use visualization, spatial reasoning, and geometric modeling to solve problems (NCTM-11)
4. Visualize three-dimensional objects and spaces from different perspectives and analyze their cross sections; (NCTM-11X)</td></tr>
<tr><th colspan="2">LESSON ACTIVITY HIGHLIGHTS</th></tr>
<tr><td>Engagement</td><td>The teacher will show students the Design Squad Nation paper tower video and ask the students to define the steps the design squad nation used to solve the problem</td></tr>
<tr><td>Exploration</td><td>The student researches the Engineering Design Process and places the steps in the proper order</td></tr>
<tr><td>Explanation</td><td>The teacher explains what is meant by the terms Science, Engineering Design, the Engineering Design Process and the steps in the process.</td></tr>
<tr><td>Extension</td><td>The student completes the Crane Strain Problem Brief to design and build a crane that supports the greatest weight. The teacher will also include the “Crain Strain Math Focus,” activity and the “Crain Efficiency” activity.</td></tr>
<tr><td>Evaluation</td><td>The student’s knowledge, skills and attitudes are assessed using brief constructed response items, and performance rubrics for class participation, discussion and design briefs.</td></tr>
<tr><td>Enrichment</td><td>The students will complete advanced truss math calculations to determine the weak points in their crane designs, which will inform their redesigns.</td></tr>
</table>

Program Assessment

One factor that could aid in the success of a national integrated STEM program is the evaluation of its design and implementation through assessment. Evaluation is necessary since it is the process of collecting evidence on learning, understanding, and abilities through assessment to inform instruction and provide feedback to the learner, thereby enhancing a student’s success (O’Farrell, 2001). The results from the EbD™ assessment data can be used to increase the effectiveness at which positive and valid outcomes for students are reached (National Research Council, 2004). The evaluation can be used to identify current strong points and shortcomings in the curricula. While EbD™ is still in its infancy, evaluations of the assessment results are indicating areas of success and areas that require improvements. The program is assessed in three major components to evaluate its performance: curriculum evaluation, professional development evaluation, and student STEM perceptions.

Curriculum Evaluation

The EbD™ online curriculum assessment went live in May of 2007. Currently over 40,000 students, in more than 350 schools, are participating in the pre- and post-test course assessments for high schools and middle schools (see Figure 5). The number of participants in the assessments can now provide enough data to make positive changes in STEM education (Burke, 2006). These assessments measure the technological literacy of students as it relates to each EbD™ course, as well as student perceptions of science, technology, engineering, and mathematics (Burke, 2012). The assessment piece can be extremely beneficial to education since school systems generally lack tools for assessing progress and rewarding success in integrated STEM classrooms (Report to the President, 2010).

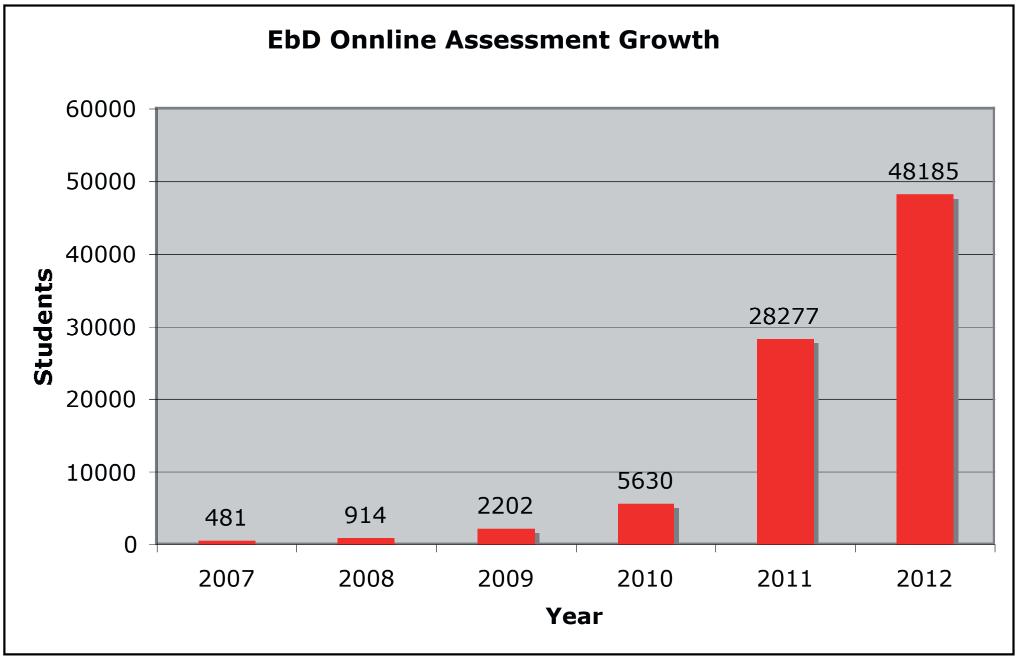

Figure 5. The Engineering byDesign™ online assessment growth (ITEEA, 2012).

Teachers in the EbD™ network of schools deliver the assessments in four phases. The first phase is an online standard pre-assessment that is administered at the beginning of each course. The second phase is a hands-on design challenge where students work in teams to solve a given problem using the engineering design process. The teachers assess this portion through a developed rubric that focuses on the intended problem-solving, creativity, critical thinking, and collaboration outcomes that are promoted throughout each course. The third phase is an online follow-up to the design challenge that asks questions related to the processes students used. Lastly, there is an online post-assessment of the entire course. The results are then returned to the schools for internal use in determining how to improve instruction and student achievement. The teachers of these courses are trained on how to interpret the data through EbD™ professional development trainings (Engineering by design standards-based, 2012).

The EbD™ assessment data gathered from 2009 through 2012 has been analyzed to help evaluate the progress of the EbD™ curriculum. The following items are the preliminary findings through 2012:

1. Current data has shown that the EbD™ main high school course, Foundations of Technology (FOT), is affecting a more diverse population of students. In the 2011- 2012 school year there is approximately an even split between males and females (52.6% male, 46.9% female, .5% No Response) enrolled in the course. Also, the percentage of Caucasian/White students has dropped from 79% in 2009 to 64% in 2011. The second

highest ethnicity of students taking this course is African American followed by two or more races. This is also true when looking at EbD™ middle school courses where approximately 55% of students were not Caucasian. The diversity in these courses is heading in the right direction, since there has historically been a large interest and achievement gap among underrepresented groups in STEM. African American, Hispanics, and women are seriously underrepresented in many STEM fields. These groups are then limited in the participation of many well-paid and high growth professions. This also deprives a nation from the potential talents of these individuals (Business-Higher Education, 2011). Data show the interest in STEM is increasing among school systems throughout the United States.

2. The amount of student participants in the EbD™ assessment has continued to grow through each school year. In FOT alone there has been an increase of 14,107 student participants from 2009 to 2011, increasing the reliability and validity of the data. Furthermore, the amount of middle schools taking the EbD™ assessments has seen a 30% growth from 2009 to 2011. This is evidence that school systems are beginning to recognize the problems with student performance in STEM subjects and taking steps to solve them.

3. At of the end of the 2010-2011 school year, data have shown there has been an increase of student achievement in every unit of study in each of the EbD™ course since it began. The FOT high school course has seen a mean of 8.30% overall increase each year in student achievement between pre-test and post-test. The Exploring Technology middle school course has seen an overall student mean achievement increased each year by 7.27% from pre-test to post-test. This information can be used to show students are more technologically literate after taking the EbD™ courses since each assessment item is based upon the standards for technological literacy.

4. Data show the highest student achievement within FOT is the study of technological systems, energy & power technologies, and engineering design. The lowest student achievement was in construction technologies and technological relationships. These data have informed the current rewrite of the third edition of FOT course (Engineering byDesign eAssessment High School Preliminary Data Findings, 2012; Engineering byDesign eAssessment Middle School Preliminary Data Findings, 2012)

Professional Development Evaluation

EbD™ is a total approach to education that aims to meet the needs of teachers, students, and administrators. Schools often lack educators who know how to teach integrated subjects of science, technology, engineering, and mathematics effectively. The amountof teachers who know and love their subject well enough to inspire their students is even fewer. This issue is common due to the lack of adequate support, including appropriate professional development as well as interesting and intriguing curricula, the teachers receive. As a result, too many students conclude early in their education that STEM subjects are boring, too difficult, or unwelcoming, leaving them ill-prepared to meet the challenges they will face throughout the 21st century (Report to the President, 2010). EbD™ provides a community for continuing professional development to help increase the effectiveness of its curriculum on student achievement. An online segment of EbD™ provides for constant, ongoing professional development.

The site-based professional development offered through this curriculum program has been studied and improved over its lifespan. A set of surveys was administered to all participants in the EbD™ professional development workshops. Based on the results of these evaluations, it was concluded that the professional development sessions did help prepare teachers to teach the integrated

STEM curriculum. The strengths from the participants' perspectives included that it provided a clear overview of the curriculum, presented student work examples, and introduced new goals of the program. However, the study indicated several ways to improve professional development. The results showed three major themes to meet the needs of educators teaching STEM. The first theme identified was how to plan for teaching an integrated STEM curriculum. Teachers wanted to know how much time to spend on lessons, what materials and equipment are needed, and how to manage the budget for the courses. Secondly, the participants wanted more information on implementing the curriculum with successful strategies. Lastly, the participants wanted more time to spend on the content of the courses (Daugherty, 2007).

Findings have led to improvements in the way EbD™ conducts their professional development. The results caused the researchers to fall upon principles of effective technology education preparation that have been created by Bybee and Loucks-Horsely (2000). Five design principles for effective professional development of technology education teachers emerged through a consensus of literature. These principles include: 1) Student learning should always be at the core, 2) Technology education pedagogical content should be developed, 3) Student learning principles should guide teacher learning, 4) Learners' current understandings should be acknowledged, and 5) Professional development must align with current support systems.

When aligning principles with the evaluation of professional development, one can find the strategies to take that will improve curricular effectiveness. The study of EbD™ led to several recommendations that have been implemented in enhancing its content, process, strategies, and context. The following is a list of recommendations that EbD™ has adopted in its professional development model:

1. Allow participants to work through an entire student lesson or activity.
2. Share with the participants the perspective of both the student and teacher when demonstrating a lesson
3. Provide opportunities for creating exemplars to take back to the classroom
4. Provide week-long professional development opportunities
5. Draw on the experience of teachers nation-wide
6. Provide online tools for communication with curriculum developers and specialists
7. Provide strong content on the math and science concepts (Daugherty, 2007)

Student STEM Perception Evaluation

Currently, the present status of the United States, where this curriculum has been developed, has fallen behind other nations in STEM education and career development. According to the National Assessment of Educational Progress, there are less than one-third of eighth graders in the United States that score at a proficient level in Math and Science (Report to the President, 2010). Mediocre test scores are a result of a lack of student interest in STEM subjects. These views will lead the subsequent generations of this nation to be unprepared in meeting the challenges that the future will bring. This is a problem that EbD™ has set out to resolve. To evaluate the effectiveness of EbD™ on these issues, three questions have been studied throughout the course assessments to determine student perceptions of engineering, science, and mathematics.

The first question that is asked to the students on the pre-test and post-test is "How likely are you to pursue a career in engineering?" This question is particularly important with the FOT course, because by 9th grade many students begin to consider what they would like to do for a career. Since engineering is a critically needed career in the United Stated, this program hopes to find ways to increase student interest in this field. In the middle school courses, 10% of students would consider a career in engineering while in the FOT high school course it drops to 8%. At this time there is no reliable data showing why this drop is caused by EbD™ courses, but it is certainly an area that can be studied for improvement. Furthermore, when these data are compared by gender, it reveals that about three times as many males consider a career in engineering when compared to their female classmates. Both issues of the lack of interests in STEM careers and under representation of females have been the ever-pressing concern in the United States (Report to the President, 2010). Since these data are collected from all over the U.S., informed decisions can be made to combat the problems in the lack of STEM interest, especially in females.

The second question deals with student perceptions of mathematics asking them, "How relevant are mathematical concepts to the course?" Between the pre-test and post-test of the FOT course, there is a consistency with the relevance of mathematics. Eighty-seven % of students rated the relevance of mathematics as "Important" to "Very Important" on the pre-test, while 75% of students gave the same rating at the conclusion of the course. This depicts that 3 out of every 4 students recognize the importance of mathematics when learning the objectives from the standards for technological literacy. However, there are some instances where data show a drop in students' belief in the relevance of mathematics in technology and engineering. Due to this data, EbD™ has currently aligned its curricula with the new common core standards for mathematics while creating a more mathematics concentrated teacher professional development model.

The third question asks students, "How relevant are science concepts to this course?" Seventy % of students saw science concepts as "important" to "very important". While these data are promising, they still show areas for improvement when re-designing the curricula (Engineering byDesign eAssessment High School Preliminary Data Findings, 2012). The student perception data are extremely beneficial to collect during the assessment process, but the last component missing for a full evaluation of the program is teacher perceptions.

Teacher Perceptions

A teacher survey was administered to sixteen Maryland high schools that were offering the FOT course. The results of this survey showed that teachers did like teaching the course materials and agreed with the concepts. Teachers also shared that their students liked taking the course and they agreed that it was organized properly and easy to implement. It was also stated through the study that teachers believed this course was a step in the right direction to help implement STEM initiatives nationwide. While the majority of the teachers had positive feelings about the FOT course, some indicated that it is a good foundation that needs to be continually enhanced to reach a higher level of education for high school (Moye, 2009).

Conclusion

EbD™ has been created to continually develop the way students acquire the knowledge and abilities necessary for the changes in the 21st century. Through the processes that EbD™ has developed, students may eventually have a better chance to make a significant impact on the future. Although preliminary findings show a movement in the positive direction for student success in STEM, there are fundamentals that require attention for a high level of achievement. With more refinements, this will lead to a future of inventors, innovators, problem solvers, and college/career-ready individuals that will work collaboratively in a global environment to make our world a better place.

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Learning to teach the design in technology education

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Keywords: Design, technology, activity, situation, teacher training

Abstract

In France, the last five years have been marked by the reforms of the lessons of the college and high school. It is in this context that the design has made its entry in the teaching of technology at the college and in the series STI2D (Science and technology of the industry and sustainable development).

In parallel with this entry of the design in technology education, the series STD2A (Science and Technology of Design and Applied Arts) strengthens the place of lessons technological and scientific in the learning. This evolution of knowledge taught, by the link between design and technology, naturally connected in the industrial professional field, but treaty separately to the school, accentuated the fact to rethink teacher training.

This paper aims to address the issue of the interactions between design and technology in education in college and in high school, and to think about teacher training. The analysis presented here is based on observations made within the curricula of applied arts and technology in France as well as within the activities of teaching and learning of students, for students and teachers.

How to teach Design and Technology to teachers who will be responsible to account for the relationship of these two professional fields to students in college and high school?

In what the concepts of vocational teaching and activity of design can help to understand the process that led, today, to teach the knowledge on the design to teachers whose profiles are also different? To answer these questions, we focus on the study of the establishment of a Master Craft of the teaching of the training and education option "Technology & Engineering of industrial design" in France.

It will be as well to think about the objectives associated with the training of teachers for college and vocational "lycée" and their ability to articulate technological education and teaching of design thus aiming to circumscribe the effectiveness of their practices.

From a theoretical point of view, the analysis of the joints task-activity and situations of teaching and learning, within the framework of the teachings of technology and design, is proving to be a theoretical framework particularly suited to try to understand the specificities and common points.

Introduction

In a context of French educational reforms, the teachings of Design and Technology have moved significantly in recent years. While they were separated before, these curricula were crossed by comparing the knowledge belonging to each area. The Design invited itself in the teaching of technology in middle and high schools. And Technology is written legibly in the new curriculum Design. Note that the curriculum can have at least two directions (Marsh, 2004): On one hand, "this is all planned learnings for which the school is responsible"; on the other, the curriculum is "the totality of learning experiences provided to students so that they can attain general skills and knowledge, at a variety of learning sites" (p. 5).

Meanwhile, teacher training have undergone many changes in France since the Jospin Law (1989) and the creation of university institutes of education (in French: IUFM). Today, we can speak of a teacher vocational training university. Between 2006 and 2008, in law enforcement of guidance and program for the future of the school (or Fillon Law in 2005), IUFMs are integrated into their regional university. At the same time the construction of an offer of training made for the future teachers, requires to create Master's degrees.

Thus, IUFM do not prepare anymore only in education competitive examination but also prepare for a diploma of Master's degree (the BAC+5 level, in France). In some ways, the mastering of teacher training combines professionalization and "academicalization". The academic contribution to teacher training has been articulated with the previously curriculum in IUFM. Changes have been made both at the organizational level and at the level of training content. This is the way that teacher training has been backed by educational research. Indeed, the introduction of the LMD at European level has been followed up by the official claim of a formal link between research and professional training. It is in this context that the IUFM of the Aix-Marseille University, offers a Master of Instruction Profession, Education and Training (in French: MEEF). This master is cut into six specialties that contain multiple ways.

At first, we offer a brief curricular situation of the Technology and Design teachings. Then, secondly, we present some elements of our research on Design and Technology teaching activity, particularly through the way teachers take over the curriculum and through the way students act in this context. Finally, by taking into account the formulated reports, we focus on teacher training in vocational industrial and technological courses. So we try to connect multiple levels of thought: the organizational conditions for learning, the actual interactions and the epistemological and curricular teaching stakes.

The Place Of DESIGN TEACHING IN THE MIDDLE AND HIGH SCHOOLS

Over the years, design education in France has entered both in the academic field, in the art schools, in the middle and high schools (Tortochot & Lebahar, 2008a and b). At the beginning of the 80s, design education is offered in high school from the first year. The vocational high school diploma field still exists after undergoing two reforms. It is now a Science and Technology Design and Applied Arts high school diploma (STD2A, in French, too).

For the higher education, design education has now found its place in the engineering schools. We may recall in this respect the innovative experience of the Compiègne technological University in the 80s, the first French university to open a major degree in industrial design and the first to train engineers-designers. This new model of university based on project-based teaching allows the actions of multiple educational fields in its different departments: mechanical engineering, chemical engineering, biological engineering, applied mathematics and computer science, electronics. These exchanges are at teaching, at research or at project level.

More recently, in secondary education, the design has also made its entry into the teachings of

Technology and Arts inside the middle school and in the Science and Technology Industry and Sustainable Development high school diploma (STI2D, in French, too). At the same time, the STD2A high school diploma strengthens the place of technical and scientific education in apprenticeship.

This evolution of the knowledge taught, by the attempt to approach of design and technology in curriculum (they bring closer naturally in the industrial field and in university today), does not seem to have ended in the middle or high schools. Indeed, we have seen the lack of appropriateness between the curriculum which is mixing design and technology and the teachers practical experiences. Yet the increasing complexity of technology, the obvious connections of industrial design and technological data but also artistic, are now demanding favorable options to think about more interdisciplinary technological education.

It is in this context that, as recalled Lebahar (2008), design education is a major technological and cultural stake. Today, old but recurrent questions still have no answers: “how to teach the design?”; “what respective educational parts to give to the technology and design?” The one is often privileged for the benefit of the other one (Tortochot, 2011, 2012). There is a conflict between the art and technology, between the need for subjective expression and the calculated harshness of the industrial feasibility (Rutland, 2009). We can imagine the usefulness of teaching design because of this notion of interdisciplinarity. We must go beyond the controversy of design education in the technology sector or of design education in artistic field. We must also consider the training of teachers in charge of these teachings.

Design Teachers And Curriculum Recommendation

A survey based on an activity analysis was conducted with nine teachers. They work in a team of trained vocational training certificate taken after the age of 18 (BTS, in French) in Design products. The aim of this survey is to better understand how the recommendation, written by Applied Arts Education, is understood by teachers (Tortochot, 2007). Since this is a design learning activity that includes a multidisciplinary approach, the principle of the survey was also to understand how teachers who are not specialists in the field include the specifics of the preparation for the diploma. For this reason, among the nine teachers interviewed, five belong to the general subjects (French, Foreign language, Philosophy, Mathematics, Physical Sciences) and one is an economic-management teacher. The last three teach Applied Arts. One of them is a professional designer who is regularly involved in training for several years.

The first three findings are crucial to better understand the reality of teaching industrial design: firstly, there is no agreement among teachers on a definition of design; secondly, the requirement is not known or very badly; and finally some design practical references are known by few professors teaching through knowledge that students may have and not through their own personal experience.

The reactions of the teachers confronted with the reference table as element of a recommended curriculum (Perrenoud, 2002), are hardly surprising. Almost all the teachers considered to respect it by assigning virtues of clarity compared to the old curriculum. But all admit to take liberties. Some recognize not to have read it, or late (teachers of French and Philosophy, for example), or reject it at once (one of the Applied Arts teachers). Others do not hesitate to say that they confer it a real importance in their educational choices, while being “obliged” to falsify it to make easier their work with the students. But all seem to have read the part that concerns them and under no circumstances throughout the text recommended in an attempt to share all the objectives. There is no more actual curriculum, but a hidden curriculum (Perrenoud, 2002), which is not revealed, and yet, is implemented in the classroom.

Design Students And Recommendation

The suspicion of the recommendation is shared by all operators as soon as the guide is essential to their activity and as they cannot maintain their necessary autonomy in the overall representation of the situation (Leplat , 2004). Between recommended text as a guide for action, and recommendation of the design activity, there are distinctions that should be updated to try to see more closely what is unique about the student activity.

For example, Moineau (2011) observed students in two separate curricula: a design BTS and a bachelor of Applied Arts in France. The first students are faced with an exercise developed by a professor, and, for the latter, an actual order of a manufacturer. Moineau finds a confusion expressed by students in both curricula. This confusion indicates that the produced assumption of artifact model has a different status in the two situations. In the case of the teaching situation, the assumption of artifact is gone with a goal which is the development of a skill. In the case of the situation of operational design, industrialization is the purpose of a product or, more generally, the making of the artifact from the final state of the model designed by the designer. We find this dichotomy in Dutson et al. (1997) in the course description called "capstone" for technological design in U.S. industrial engineering: those who rely on "simulations" in "laboratories" and those based on a "authentic involvement" in a real situation with real "clients" (p. 18).

The falsification of the task ("subjective assimilation by erasing or modification of certain essential requirements", Lebahar, 2007, p. 255) is inherent in the situation of artificial design: general strategies and coping strategies are then used by students. The necessary balance between the two factors of this dialectic assimilation/accommodation (Piaget, 1974) supposes:

- Design activity may be slowed down by the subjective assimilation, or feed on it (novelty seeking or awareness of the reality principle).
- This awareness is sought by some teachers who base their teaching on a knowledge of the student activity.

With such a consciousness of itself and its activity, the student subjectively assimilates some specification imposed by dialogue with others. This form of falsification, requirements modification, widespread among students, is similar to the evolutionary solutions given by the designer to the different problems (multiple, ill-defined, incompletely defined, etc.).

Students learn to read specifications, to answer to the more or less complete problems, to plan tasks, from an initial state to a final state representations, leading them to an artifact model. It is through the tasks set by teachers that students get acquainted with such processes specific to the design activity. It is with teachers action guides that students learn to fight at first. At least that is what shows the state of research in this field (Lebahar, 2007; Tortochot, 2012). This struggle of the "fancy" against the specifications inherited the profession questions inevitably about the possible or about the impossible transmission of the professional methodologies to exercise designer's activity.

We note particularly the relationship that students develop with the recommendation through teachers (Koehler & Mishra, 2005; Tortochot, 2012). The analysis of the discourses on design activity supervised by teachers brings a lot of information.

For example, in another more recently research, we learn what teachers expect such relationship, as dialogue, and how students perceive this relationship (Tortochot, 2012). If this aspect of teacher-student dialogue is not unique to design education, it indicates the implications of a single word, of one meeting, of one comment on planning design tasks by students. The emotional and affective interactions aspect is also revealed by this analysis. Between recommended and actually performed, between intention and actually implemented, we see that people do not realize the same thing. When teachers say they do not want to impose methods, in fact, they do not impose, but also intervene decisively, sometimes. And these interventions, or statements about any aspect of the student design activity is like a hidden method, a value system that interferes in the relationship between teacher and student.

We also learn that the approach to technology design is considered by Masters students as a challenge, a fun (Koehler & Mishra, 2005). By the technological pedagogical content knowledge (TPCK), the authors show that the students assembled a team of designers with teachers, get involved in “the development of deeper understandings of the complex web of relationships between content, pedagogy and technology and the contexts within which they function” (p. 149).

Training Teachers In The Design Teaching

Research on teaching and teachers, on students and their relationship with teachers, and with design and technology teaching, provide us information about a situation that can be considered satisfactory or not.

After asking the question “can you teach industrial design and how?”, another is imperative: “can we train future teachers to teach design and how?”. Because we have recognized subject content in the technology teaching, we have focused our main effort on the acquisition of new objectives: to develop in our future Technology teachers a professional interdisciplinary practice quality to teach design.

Like Reeves et al (2005) say, teaching by an approach based on the design in the field of computer engineering, leads to highlight six major features (pp. 109-110):

- “Explore significant educational problems, rather than conduct research for its own sake.
- Define a pedagogical outcome and create learning environments that address it.
- Emphasize content and pedagogy rather than technology.
- Give special attention to supporting human interactions and nurturing learning communities.
- Modify the learning environments until the pedagogical outcome is reached..
- Reflect on the process to reveal design principles that can inform other instructors and researchers, and future development projects.”

This observation, combined with research that has been conducted on the forms of design teaching in applied arts or in technology, brings us to radically change our educational approach to teacher training by placing the student teacher at the center of his learning and by creating conditions for continuous stimulation taking to sustained motivation (Dewey, 1915; Piaget, 1979; Vygotsky, 1997).

The idea of active learning by the project is to place students in situations of “learning need” by offering challenges (problems, projects, assignments) and using the group as motor learning (Brassac & Gregori, 2003; Safin, Leclercq & Decortis, 2007; Ostergaard & Summers, 2009; Zager, 2002). Besides the interest of such an organization recognized by many universities, we want to analyze the advantages and disadvantages of such a mode of teacher training and its direct influence on actual practices from the field of education.

We decided to organize teacher training in professional and industry using an approach based on project-based learning (PBL) (Dym, et al., 2005; Poell, Yorks & Marsick, 2009; Raucent, 2004; Savery & Duffy, 1996, Swan, Scar-brough, & Newell, 2010; Wrigley, 1998). The project-based learning allows students to train for interdisciplinarity, design principles and management activities of long duration (2 semesters). This organization has been established in many universities (national upper school of industrial design [ENSCI], Paris; University of Technology of Compiègne [UTC]; Lima, Ohio; Buck Institute for Education [IBE], USA; etc.). Courses such as “capstone” project-oriented in the USA (Project-Oriented Capstone-Course) are built on this principle. This structure is innovative in the field of teacher training.

The Based-Project Learning For The “Meef” Master

The students will face industrial design projects opening on the development of learning materials and / or didactic engineering. No teaching has been given them beforehand. Students will define and accurately analyze each problem. They will formulate draft solution based on prior knowledge of the group. Each student will identify its own targets in terms of new learning to perform. It is assumed that they will construct their own knowledge and take it over, without restricting to receive passively knowledge transmitted by a teacher. The role of the teacher, who becomes a tutor, will guide students in their learning.

As part of our training for future teachers with the project-based learning, students will face a real scenario, involving a real problem of instructional design (due to time, limited resource, group work, making the final result, etc.), which also involves learning a specific working methodology. The final prototype is no longer a "result" but the concept validation and the confirming that the group has achieved the objectives.

The goal of project-based learning is threefold:

- Develop skills related subjects (knowledge and skills);
- Expand the educational skills related to the subjects;
- Make acquire working methods (clarification, research solutions, study solutions, modeling, simulation, testing, implementation, documentation, management of group work, reflection on the work).

Our work will be based on an activity analysis by the analysis from the points of view (Wolf, Burkhardt & de la Garza, 2005). Within this framework we will use in a joint way a discursive analysis and a data geometrical analysis (principal components analysis) in reference to work of Burkhardt concerning the analysis of the points of view of designers in production system.

Thus, our methodological approach will contribute to explore the points of view of the actors of the formation. We will use talks and verbalization analyses through specific methods allowing the reproducibility and the comparison of various corpora.

This approach will enable us to analyze the speakers speech finely and to give consequently useable results by the means of semi-directed talks. For all these studies, the speeches of the teachers and students will be re-transcribed in verbatim. In addition, the software Tropes, founded on work relating to the propositional model of Kintsch and Van Dijk (1978), Van Dijk and Kintsch (1983), Kintsch (1988), will make it possible to validate a good amount of content analysis, starting from propositional analysis of the speech.

In the long run, it will be a question of continuing our study through an analysis of the teaching practices developed in establishment by the students. A prospect for use of the Transana software to analyze video data or digital audios will be considered.

Conclusion

The future teachers design training, in France, has a concrete purpose: it meets the needs that the field programs generate while leading to a reflection on the multi-field exchanges and collaborates. Nevertheless, it is often in an empirical way that the teachers built gradually a practice based on the interdisciplinary approach. It is the goal of this research: observing the young teachers in training and to offer them to build a project-based learning project. This training should make it possible to the teachers to apprehend their teaching while being based on exchanges with other subjects and while working in a collaborative way within more or less important pedagogical teams. The result will be the object of a psycho-semiotic analysis deepened by a propositional analyses of the speech and a principal components analysis. The analyses of the trainers speeches and the future teachers should enable us to release the large features of this method of teaching, the objective of which, determinedly, is to renew the relations bound to the situations of teaching-trainings.

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Exploring the language of technology with student-teachers through genre pedagogy

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Keywords: technology education; genre pedagogy; technology and society; teacher education

Abstract
Teachers can open up the world of technology through language, but they are often unaware of the specific features of the language of science and technology. Genre pedagogy is an approach whereby students learn to understand domain specific text characteristics in order to produce such texts. In this paper an explorative study is presented in which students at a teacher education institution were trained to produce oral and written language that is an inherent part of the domain of technology and society.

Introduction

Language proficiency and learning are strongly related in all subject areas. The explicit integration of language development in content teaching can improve learning results. This also holds for science and technology (Hajer en Geerdink 2010; Lee & Buxton 2010). In The Netherlands – as in many countries - schools opt for language across the curriculum policies, but the chosen pedagogical approaches are general in nature and lack a subject specific component (Hajer & Meestringa, 2009). In Australia and Sweden an interesting pedagogy, based on analyses of subject specific text types, has given way for a practice that explicitly addresses subject specific language.

For teachers of technology it is important to understand the language of their subject, if they are to introduce their students in the domain of technology and its language. It is doubtful to what extend teachers are aware of these linguistic features. In teacher training we observed a lacking proficiency in e.g. writing tasks. Therefore we decided to start the development of a two step approach: designing tasks that would raise teachers awareness and proficiency, and then designing training modules that would enable teachers to raise their students awareness and proficiency in the language of technology. This paper reports on the exploratory first phase of the research.

We will first characterize the genre approach and pedagogy and then describe how we applied these ideas in the course for technology teachers.

A genre approach to subject specific language

In genre pedagogy, a subject teacher is assumed to take part in, or at least have access to, a domain bound community of practice that uses language in specific ways (Martin, 2009). A technology teacher may not be a professional engineer, designer or philosopher of technology, but he is certainly expected to know how professionals in these fields use language to do their work and to communicate about it.

> *"Genre refers to abstract, socially recognized ways of using language. It is based on the idea that members of a community usually have little difficulty in recognizing similarities in the texts they use frequently and are able to draw on their repeated experiences with such texts to read, understand, and perhaps write them relatively easily."* (Hyland, 2007).

This specific notion of text genres is rooted in the so called *systemic functional linguistics* (SFL) that was elaborated by Michael Halliday. The Sydney School elaborated a taxonomy of texts, categorized to its function as for instance narrative, report, recount, procedure, explanation or discussion, each with its own preferred structure (Derewianka, 1990). A threefold conception of meaning is employed when texts are further analyzed in terms of A) ideational linguistic resources that are an inherent part of the content, B) interpersonal resources for negotiating social relations, and C) textual resources for managing information flow (Martin, 2009). Once teachers have a better understanding of texts, in terms of these three categories of analysis, they can explicate relevant characteristics to their students. This enables students to understand these texts and produce similar texts at their own level.

In the Australian practice, a teaching-learning cycle has been developed, called genre pedagogy that is to a large degree based on modeling strategies. It often employs a four stage teaching-learning cycle, whereby cycle one (building the field) is continued throughout.

1. Building the field: development of concepts
2. Deconstruction: pinpointing field, tenor, mode
3. Joint construction: Writing with students
4. Independent writing

(Gibbons, 2002)

Genre pedagogy has become a standard in teaching in Australia. When studying and discussing its potential, we were doubtful, however, whether the complex analytical approach would be considered useful for teachers without specific linguistic schooling.

Method

In order to understand the benefits of genre pedagogy, we chose to outline a educational design experiment (Van den Akker, Gravemeijer, McKenney & Nieveen 2006). In educational design studies a learning environment for researchers is created in order to build a theory about learning processes. Hypothetical learning trajectories are formulated and tested through case studies in a cyclic iterative process.

The main research question was: *Can genre pedagogy be realized within our context and does it contribute to the awareness and proficiency in writing a specific genre in technology education, e.g. the essay in philosophy of technology.*

In order to design such a trajectory in technology teaching we studied available literature on the language of technology and science. Subsequently we designed a first cycle of the design research project in which genre pedagogy was applied in teacher education, in a course about technology and society.

The course was delivered through eight sessions, of three hours each, by one of the authors of this paper. The group of students consisted of 17 students, all with a job in secondary or tertiary education, ranging in age from 23 to 55. As a final product for the course, they were requested to write an article for a technology teacher's journal on a topic within the domain of technology and society. We will refer to this macro genre as 'essay in philosophy of technology'. Throughout the course, lessons were videotaped, student material was gathered and analysed and students were interviewed.

Characteristics of genres in technology and science

If we want to identify science and technology texts in terms of genres, we will have to collect and analyze samples. This choice and selection, however, is not neutral. Especially in technology education, which is a contested field, the outcome of an analysis highly depends on our conception of our very school subject (Dakers, 2006; Vries de, 2005). If we would conceive technology mainly as a collection of artefacts, we would perhaps analyse a manual of some apparatus, whereas a conception of 'technology as volition' could yield an analysis of a newspaper article that addresses the dangers of nano-technology to society. In short: If genre pedagogy aims to provide students with the means to become participants in the world of technology, the question arises which texts represent this world best. It is our position that 'thinking about technology' is an inherent part of the subject, at least in education, and therefor we set out to analyse argumentative texts by authors who do so for a living and who communicate their ideas to a wider audience through newspaper articles and popular philosophy journals.

Much has been written about one important feature of the field of genres in science and technology, e.g. the frequent use of nominalizations: A process or a series of processes is packed into a single noun or small group of words.

A fragment of a lesson about simple machines illustrates this principle (Christie, 1998).

> *[Teacher:] And each machine is used to give you a mechanical advantage*
> *(writes 'work—mechanical advantage' on the board).*

According to Christie:

> *A more congruent way to make the point might have been to say: "machines work for you".*
> *In both cases, the piece of experiential information is constructed in a transitivity process, in which the process itself is material while 'machines' operates in the participant role of actor. The same point is made, but metaphorically, when the activity is turned into a thing, through the resource of a nominal group: 'mechanical advantage'. With the entry to some awareness of the latter, the students have reached a new, more abstract stage of understanding* (Christie, 1998).

In this way the grammar of scientific and technological English becomes increasingly abstract and harder to learn (Rose, 1997). Halliday shows that such nominalizations have become commonplace since the early days of the natural sciences. Halliday (1998) demonstrates this by means of a sentence from Newton's optica, in which three instances of nominalizations can be recognized.

> *Now those colours argue a diverging and separation of the heterogeneous rays from one another by means of their unequal refractions, as in what follows will more fully appear.*

SFL uses the term 'tenor' to describe the way the relation between the writer and the reader becomes manifest in texts. Science and technology texts do not usually focus on the writer or reader directly. Nature, in its broad sense, is described as an entity that is positioned separate from humans. This becomes manifest in language, for instance in Newton's writing above, where agents are things and nominalized processes rather than humans. An exception in science texts can be found in texts about the environment and in texts about technology and society (Veel, 1998). In such texts the writer will often try to convince the reader of his opinion, for instance in a discussion. Not only will the writer use words such as 'I' or 'we', but he will also likely pinpoint at groups of people who gain or lose by the introduction of certain technological innovations.

In terms of 'mode', or 'how' meaning is being exchanged, a large proportion of the language that students encounter, be it at secondary school or at university, can be called pedagogic discourse. Texts, spoken or written, are directed at students in order to make them understand or do something. Technology students may for instance encounter many texts of the type: "A program of requirements is ..." or "Write a program of requirements for your 'silent music room'. The field of such texts may be similar to texts such as: "Walls that separate rooms will have a minimal Sound Reduction Index of 50 dB". The tenor and the mode, however, are radically different.

In our literature study, few analyses were found specifically for design and technology, but if we borrow from the sciences, the following text structures stand out (Derewianka, 1990) (Love, Baker, & Quinn, 2005) (Gibbons, 2002).

Genre	**structure**
Procedure	Aim, materials, steps, suggestions
Report	Introduction and classification, characteristics aspect A, characteristics aspect B etc.
Explanation	Identification of phenomenon, sequential explanation
Discussion	Introduction, arguments pro and contra, conclusion

Combinations of genres are called macro genres. A science report could for instance comprise of a procedure, a recount and an explanation (Love, Baker, & Quinn, 2005).

As a next step, after this study of how science and technology texts differ from other texts on three dimensions and the identification of different genres in science and technology , we outlined how these genres might be taught.

We haven't found any systemic functional linguistic analyses of the genre that was at the core of the technology course, the essay in philosophy of technology'. In order to identify genre characteristics ourselves, we analyzed a few students' papers of previous years. We then found that those articles were a rather unclear amalgam of genres, lacking in structure and coherence. This finding was consistent wit the feedback of the editor of the journal a year before. Consequently a newspaper article of a philosopher of technology was analyzed in terms of genre (Zuijderland, 2009). It appeared to be suitable as an example and its analysis showed characteristics of a historical essay and a discussion. Other newspaper articles as well as two articles in a journal for popular philosophy confirmed these findings. Moreover, we deemed these findings consistent with our understanding of the field of philosophy of technology and society, which, among other things, is concerned with a historical perspective on technological innovation as well as with technology as being a 'value laden' domain.

When we had established the vital characteristics of the macro genre, we could design course materials. In our design we consistently tried to make the training in language production functional in the light of developing knowledge in the domain of philosophy of technology.

Findings during a first proof of the learning trajectory

Phase 1: Building the field

During the first three sessions we worked primarily on the development of subject concepts, such as 'the socio-technological system', 'disciplinary agency of artefacts' and 'the moralizing of apparatus'. In an exercise that was particularly valued by students, they had to identify core themes of the course in an exemplary article.

> *John: Since I had never read a text this way, it was very useful, because I also started this kind of focused reading for subsequent texts.*

In the students' work we saw that they all managed to link relevant overarching concepts and themes, which weren't always explicitly used in the article, to specific text fragments. After a remark by the lecturer about the usefulness of the new concepts, one of the students however commented that it all sounded very good, and that he would use these sophisticated words because it was expected of him, but that he wasn't convinced of the relevancy of all this attention to formal language. Reading of the book (Achterhuis, 2001) was experienced as difficult by many of the students, despite two preparatory lectures and various attempts at microscaffolding (Martin & Rose 2007).

In order to learn to express themselves in matters of technology and society in the same manner as philosophers would, students were requested to prepare and execute a structured debate. The idea was that students would use the knowledge they had acquired during the first lectures and their homework to debate more convincingly. A debate was chosen, because in genre pedagogy students are scaffolded to develop skills on a spectrum from informal spoken language to formal written language. A structured debate facilitates the exchange of language somewhere halfway in this spectrum.

Students were pleased with the learning gains of the debate, particularly with regard to the preparatory task whereby they had to write a position paper pro and contra a proposition.

> *Hans: By thinking in advance about the possible arguments of the other party, you become a better debater.*

Only a few students were able to really make use of genre characteristics that had been covered in phase 2. One student started a sentence with the expression "research has shown that", which is a way of using the authority of institutions for one's own goals (tenor). Use of philosophical concepts was scarce, even though the lecturer had encouraged students to do so.

> *Jane: When writing, one can take all the time necessary to think. In a debate one can be well prepared, but one has to say the right things at the right moment. Preparation was necessary though, to be able to debate well.*

What was perceived as relatively easy by the lecturer, was to discuss the differences between oral and written language with students. In the videos we see a number of instances where similarities and differences in mode and tenor between the debate and the journal article were discussed. A comparison was made, for instance, between the resources used to express opinions baldly or with moderation. Also the students identified effective ways to compete in a debate by means of exaggeration and humor.

Phase 2 'Deconstruction': Attention to structure of entire text, level of sentences and words.

> *From the syllabus for students:*
> In the analysis of the exemplary article, we have seen that in a philosophical essay certain words are used to pinpoint time and that changes in society are described. Causes and effects of these changes are often linked to technological innovation. Words to describe such relations are 'because of', 'hence', 'thus', 'as a result' etc. The article also emphasizes the notion of certain human behavior that is encouraged by technology. In philosophical literature the concept of 'disciplinary agency of artifacts' refers to this idea.
>
> Identify similar textual characteristics in the next article.

Other exercises were meant to practice describing technological innovation in a historical perspective (field), to identify the reader and his motivation to read the target journal (tenor) and to structure a text around arguments and counter arguments (mode).

Phase 3 Joint Construction
This phase, in which the lecturer modeled and wrote a fragment of text in cooperation with the students on the whiteboard, was perceived as relatively difficult. The videos also showed that the approach as described in literature wasn't entirely successful in this case. Collaborative construction of sentences was slow and tedious. The lecturer did not feel that he was able to 'think out loud' while writing in order to model writing strategies. The students, however, remained task oriented throughout, and their evaluation of this phase certainly wasn't predominantly negative.

Phase 4 Independent writing
Students wrote their final text independently with one round of peer feedback, organized during a lecture. Two students remarked that they'd rather co-written the article with another student. All papers were rated by the lecturer and a random sample of three student products was graded also by a colleague who knew the course well. Her grades were approximately the same as the lecturer's. Three students failed to attain the expected standards, whereby one student failed because of severe plagiarism. The best three articles were qualified as being up to the standards of the target journal.

> *Fragment of a product*
> *The development of the internet has been strongly beneficial to narrowcasting. No longer did marketeers have to visit every shop in order to supply them with adverts on video tape. Instead they could now send tailor made videos to retailers via the internet.*

Conclusions
Deconstructing exemplary articles was perceived as effective by both the students and the lecturer. An interesting finding was that it proved to be possible to avoid the complexity of Systemic Functional text analyses and its new terminology which could have discouraged technology students (Rose, 2008). It seems reasonable to assess that the exercises were generally perceived as effective by the students as a result of the fundamentals of SFL that had dictated the underlying linguistic analysis. In genre pedagogy, functionality, or 'what is accomplished by means of text', dictates every step along the way from analysis of exemplary texts to delivery of the curriculum.

Students did not only find the course effective because they found that they had gained more insight in philosophy of technology, but also because they thought it had been valuable to learn to write down their ideas in a clear way. The lecturer had repeatedly emphasized the importance of clear speaking and writing for teachers. Possibly this made the students think that the emphasis on language in the course was legitimate, rather than for reasons of content development. In other words: Perhaps the students deemed it necessary to become better at explaining, which made them think that genre pedagogy had been useful. The assumption had been, however, that genre pedagogy would provide an effective intervention with the aim to develop content, e.g. understanding of the function of technology in society and critical reflection on it. The data of this study only provide weak evidence to back up this assumption. In a next round of this ongoing study, we will ask students to make this distinction in their assessment of the effectiveness of the course.

We also asked students whether they would incorporate elements of genre pedagogy in their own teaching. The majority of the students replied that they would from now on incorporate technology and society in their own teaching and that they would do so by means of oral discussions with students. Writing is a rare activity in their lessons, most students said. There is no evidence that our course will change that.

Our literature study in combination with the empirical study indicates that genre pedagogy can provide valuable tools to deliver curriculum in teacher education. The next step will be to proof a new version of the course and to connect it to the teachers' practice with their students in secondary schools. We will also extend the teaching learning cycle to improve students' writing of science practical reports and other genres. We also hope to extend our work to find out what competencies our students need to use genre pedagogy in their own teaching and how we can help them to acquire such competencies.

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Design and assessment in technology education – case: the "Birdhouse Band" project

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Abstract

According to the Finnish National Framework Curriculum one of the objectives in technology education (craft, technical work) is to develop pupils' designing skills. However there are no detailed criteria how to assess these important skills and therefore teachers have to determine those by themselves. Assessment without clear criteria tends to drive teaching towards promoting "guaranteed" and "safe" solutions that stifle pupils' creativity and independent thinking skills. One of the objectives in technology education is that pupils should learn technological problem solving skills. This objective requires teachers to engage pupils in technological problem solving activities. The design process is regarded as a learning strategy and through this pupils obtain systematic, sustained and independent working skills.

Instruction in technology education is implemented through projects corresponding to the pupil's stage of development. Methods of experimentation, investigation, and invention should be practiced actively. Starting points for projects can be found from everyday life problems, artefacts and materials. The technological problem solving process encompasses phases of setting out the problem/task, exploring possibilities, brainstorming, from a chosen idea to planning an accurate solution, realizing the project and testing and evaluation.

In order to improve assessment of designing in technology education, a model was developed that works as a pedagogical step-by-step tool to enhance the design process. This tool serves two purposes: first, for the pupils to develop their metacognitive skills about the design process and their ability to self-assess, and also for the teacher to be able to assess the process. The model is demonstrated by one case: the "Birdhouse Band" project, as an example of applying the technological problem solving process.

Introduction

It is essential to teach pupils to solve problems and encourage them to think independently, because it can be seen already that creativity, innovativity, critical thinking, responsibility and self-directness are qualities that are needed now and definitely in the future in modern society. (Oivallus, 2011; Parikka & Rasinen, 1997.) Self-directed and process-oriented citizens are more likely able to cope with the rapidly changing and situated knowledge in the societies, and, thus, the school should teach the skills needed in the world of today and in the future (Huhta & Tarnanen, 2009). In short, learning to solve problems in everyday-life or a pedagogical method namely "starting point approach", could be used to support pupil's development in various skills listed above. Technical craft (technology education) could provide possibilities for pupils to concretely learn these important skills. However, one key problem is the assessment practice in craft education. It seems that too often the teacher assesses only pupil's product at the end of the process though assessment should support pupil's self-directed and process-oriented learning throughout the whole learning process.

In Finland there is no subject called technology or design and technology. Since National Core Curriculum for Basic Education 2004 (NCC), there has been a cross-curriculum theme called "Human being and technology". It is one of the seven themes that should be considered in all subject areas. Craft is an individual subject area in the comprehensive school (compulsory at grades 1–7 and optional at grades 8 and 9) and it comprises contents of textile craft and technical craft. Many objectives and contents of the cross-curriculum theme "Human being and technology" and technical craft are overlapping. Based on our experience and analysis of NCC technology is mainly taught during technical craft lessons (Rasinen, Ikonen & Rissanen, 2008). Therefore, in this paper we refer mainly to technical craft in context of technology education.

Assessment can be seen as a road sign for learner that guides their learning process. Traditionally, such guidance is provided mainly by teacher, accordingly teacher's assessment practices at the classroom. Teacher-led agenda that does not allow the learner to have an active role in working can lead to missed learning opportunities, and to a failure to develop learner autonomy and the skills needed in the modern world. Despite the development of new socio-constructivist theory of learning that has become the predominant view that underlies instruction in many countries, assessment practices often lag behind and continue to be based on old models of learning and curriculum design. (Huhta & Tarnanen, 2009.) Based on our experience this is still the reality in too many schools. In technology education pupils are making products by copying the product that teacher has designed and created.

Assessment in the Finnish context

During the time of comprehensive school system (same education to all from grade one to grade nine), since 1970 there has been no national testing of pupils. Some national tests for instance in mathematics and languages are available, but it is up to the teacher or school to decide if she or he wants to use them (Salmio, 2004). The emphasis in assessment has been to give guidance to the pupils rather than authorizing marks at the end of the term or academic year. Instead of marks (from 4 to 10) pedagogical discussions take place. Also parents are invited to schools to attend these sessions. Pupils are given written assessments instead of marks only, particularly, in lower grades. At the end of grade nine all pupils are given marks from 4 (fail) to 10 (outstanding). For this there are statements about good performance in the NCC 2004. Previous NCC 1994 did not give any instructions on assessing, but the National Board of Education published separate guidelines on pupils' assessment. In craft education teachers have been encouraged to evaluate the whole learning process from planning to the final artefact since 1970, but it seems that still today only the final product is assessed by many teachers.

According to the NCC 2004 instruction in craft (technical craft/technology education) should be implemented through projects corresponding to the pupil's stage of development. Methods of experimentation, investigation, and invention should be practiced actively. One of the objectives in technology education is that pupils should learn technological problem solving skills and this requires teachers to engage pupils in such type of activities. Starting points for projects can be found from everyday life problems, artefacts and materials. The technological problem solving process encompasses (should encompass) phases of setting out the problem/task, exploring possibilities, brainstorming, from a chosen idea to planning an accurate solution, realizing the project and testing and evaluation.

One of the objectives in craft is to develop pupils' designing skills. However, NCC document doesn't advocate any detailed criteria how to assess these important skills and therefore teachers have to determine those by themselves. Assessment without clear criteria tends to drive teaching towards promoting "guaranteed" and "safe" solutions that stifle pupils' creativity and independent thinking skills. If designing is not regarded as a part of a learning strategy, pupils will not go through the whole process and therefore they will not obtain systematic, sustained and independent working skills. When speaking about design or designing in this paper an emphasis is on the process.

A model of designing in technology education

Technology means activities, but what kind of activities and processes do we find in technology? And what kind of methodological approaches should be used to teach these processes for children in a comprehensive school? In general technological processes can be design processes, making processes and processes in the phase of using and assessing technology. (de Vries, 2005, 49.) Because of the history of craft education in Finnish primary and secondary schools, pupils are still too often making products by copying the product that teacher has designed and created. Education like this, gives no place for pupil's designing skills or how to develop them.

In reflecting on design process, design methodologists more and more became aware of the complexity of design problems because of the many influencing factors. Adjusted to primary level, following four types of factors (de Vries, 2005, 54) may be taken into account when planning the design task in school:

- Scientific factors: the natural phenomena on which the functioning of the product is based
- Technological factors: the materials and processes that are available
- Market factors: the ideas that the customer/user have about the product (in schools normally the user is the student him/her self)
- Ethical and environmental factors: materials used when making the artefact

In order to improve assessment of designing in technology education, we as primary school teacher educators wanted to develop a pedagogical model to introduce and test it with our technology education (teacher education) students. The model (Figure 1) was developed based on two various models which describe the stages in the design process (Garratt,1996, 6–11; Layton, 1993, 45–48). We modified Garratt's and Layton's models to better suit in Finnish technology education. We also added criteria for each stage that describe students' activity in a design process. The model works as a pedagogical step-by-step tool to enhance the design process in technology education. It both guides the students to develop their metacognitive skills about the design process and their ability to self-assess, and gives the possibility for the teacher to be able to assess the process. The idea is that the teacher must adjust how to use this model to match the grade level at school. For example at grades 1–4 the steps 2, 3 and 5 could be combined or skipped according to the task. The model describes accurately "steps", which pupils and the teacher can follow. By going onwards through the steps pupils can follow their working and reflect what is already done. For the teacher it is possible to assess at the same time both the whole process and various "steps". Every step has its own criteria for assessing and therefore the final grading consists of several markings.

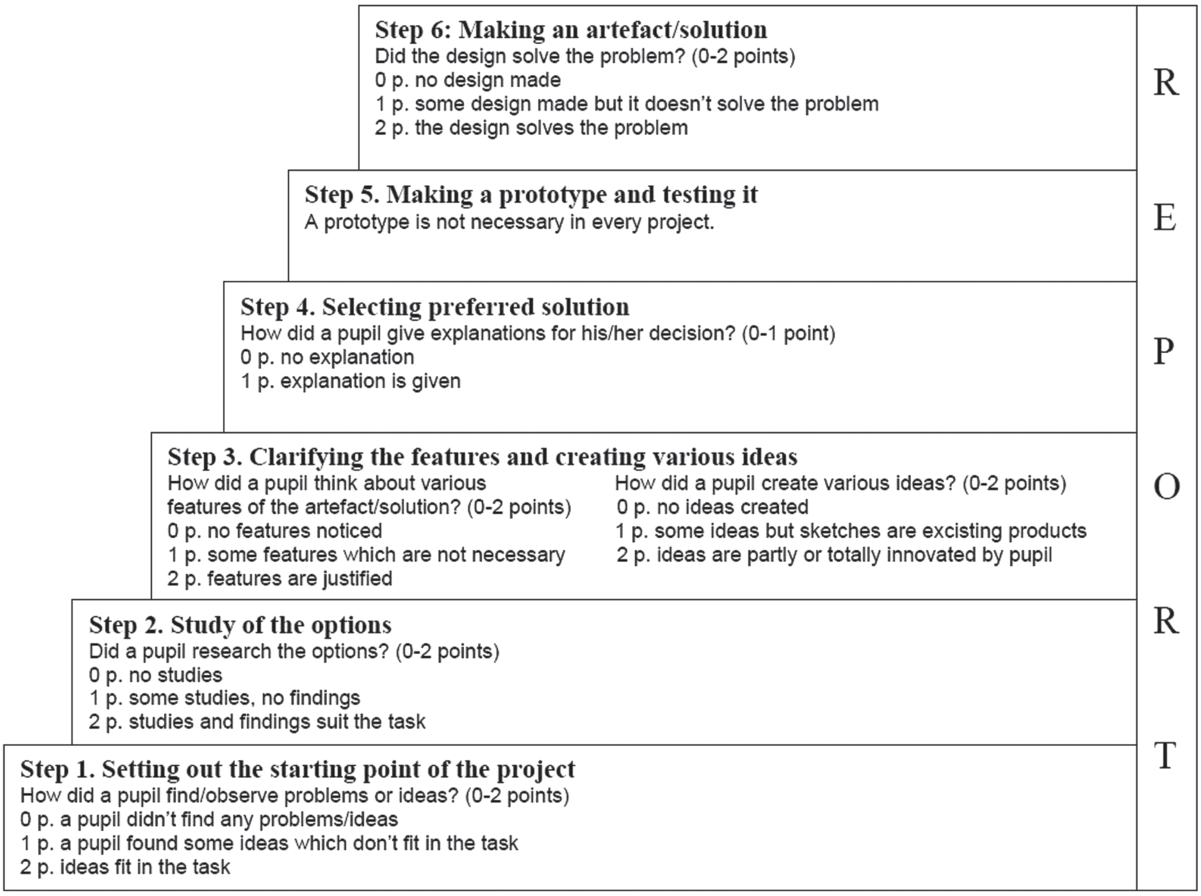

Figure 1. Development of pupil's designing skills

Developing pupils' designing skills is one of the objectives in technology education. There are no detailed criteria how to assess these important skills so teachers have to determine those by themselves. This model is suggestion for teachers how to assess pupils' development of designing skills. The model illustrates the design process step by step with detailed criteria and points in scale 0–2 in each step (altogether maximum 11). On the other hand the model enables pupils' self-evaluation during design process. In the following we will describe each step with assessment criteria.

Step 1. Setting out the starting point of the project. The first step of the model demonstrates how pupils are guided to observe and find the starting point for the project. We have categorised the starting points for three different approaches: projects that 1. solve "everyday life"/abstract problems, 2. are some kind of artefacts and 3. are created of certain material/s (wood, metal, textile etc).

- Assessment criteria of designing: How did pupil find/observe problems or ideas (0–2 points)? The level of how open ended the problem or task is, must be adjusted according to pupil's age.

Step 2. Study of the options. The second step demonstrates how pupils make a little study about the options for different kinds of solution and what has already been made for same kind of purpose as the starting point of the project indicates. Pupils are encouraged to find many solutions, which are somehow connected to starting point. The purpose is that pupils come up with some ideas probably from existing products, but they should develop the idea further. When observing the options pupils could take photos or/and sketch.

- Assessment criteria of designing: How did pupil study the options (0–2 points)?

Step 3. Clarifying the features and creating various ideas. At this phase pupils are guided to think about the artefact they want to create and the features that they need to take into account when designing it. They are guided to draw 2 or 3 sketches of the artefact/solution they would like to create. It is important to encourage pupils to sketch freely and guide them to think about the design to the direction of what kind of artefact/solution would solve the problem.

- Assessment criteria of designing: How did pupils come up with various features of the artefact/solution (0–2 points)?
- Assessment criteria of designing: How did pupils create various ideas (0–2 points)?

Step 4. Selecting preferred solution. At this phase of the process pupil will choose one of the sketches and make a (technical) drawing of it. He /she has to explain why that sketch is chosen. By arguing, pupil has to think about the whole process, what has been done and what should be done next.

- Assessment criteria of designing: How did pupil give explanations for his/her decision (0–2 points)?

Step 5. Making a prototype and testing it. When the (technical) drawing is ready, pupil will make a prototype, if needed. When testing the prototype pupils are guided to find both strengths and weaknesses of the product she/he has designed. There are no assessment criteria at this phase, because making a prototype is not necessary in every project.

Step 6: Making an artefact/solution.
The final product will be made following to possible prototype. Pupil will assess whether the product corresponds to an original task.

- Assessment criteria of designing: Does the design suit the task? (0–2 points).

In the end, pupils will write a short report with reflections of the whole process from the beginning to the end. The written notes of each step work as a learning diary and they form a basis for the final report. By writing a brief report pupils will reflect the decisions they have made and describe their working. When pupils think about the process step by step they are able to understand the meaning of all the steps (particularly designing) which lead to the final outcome.

The tool serves two purposes: first, for the pupils to develop their metacognitive skills about the design process and their ability to self-assess, and also for the teacher to be able to assess the process. In the following section the use of the model is demonstrated through a pilot study, case the "Birdhouse Band" project realised by teacher education students. The main idea was that the students were guided to practise metacognitive skills and the process was not assessed this time. The "Birdhouse Band" project works as an example of the above described strategy of designing in technology education.

Case: the "Birdhouse Band" project

We chose to introduce the model first for the group of students that studied to be class teachers (at grades 1–6) and also specialized to technology education. The model was introduced for the students at spring semester 2010 when they started to plan their group-projects of integrating technology with the perspective the group chose themselves. At this stage the model was used only for students' self evaluation of the process, but it was not used for grading the students' work, only to enhance designing and metacognitive skills.

Starting point for the project was set out as a question like "In what are we good at?" and "How would we like to develop technology education in school?" These students had chosen to specialize in technology education and this type of a project was a part of their studies. Duration of the project was approximately 30h. In the following one of the projects, the "Birdhouse Band", is presented.

Step 1. What is the problem we need to solve? The first step in the problem-based project was to set out or find the "problem or task". Students in the technology education course were guided to choose their problem freely and the task was set out to be very open ended. Students were encouraged to put their knowledge of materials and tools into practice, and to find their "problem" or idea in a group by themselves. The "Birdhouse band" group, three male students started with an idea of creating something that has generally been done in schools, a birdhouse, in a new way. So the problem became to be to change the tradition.

Step 2. How can we solve the problem? At the second step students were guided to make a small study about the options for different kind of solution. All three of the students in the "Birdhouse band" group liked music, to play guitar, bass or drums, so they got the idea of making instruments to look like a birdhouse. They started to design their instruments on the basis that the instrument looked like a birdhouse box and decided who would like to create and play it. Each member of the group started to design the instrument he would like to create. The main idea was, that the group worked together and helped each other, but at the same time was responsible for making one's own instrument.

Step 3. What kind of features needs to be taken into account when designing the artefact/solution? At this phase students were guided to study about the artefact they wanted to create. One way to do it was to make a list of features that they need to take into account. The "Birdhouse band" group studied different kind of guitars and drums on the Internet and picked up important features, which were necessary for playing them. For building a drum there was a ready-made model of *cajon,* which inspired the drummer to mix the cajon's shape and a birdhouse. The criterion for this instrument was that it should be acoustic. The guitar player noticed that it was possible to make a lap steel to look like a birdhouse. Bass guitar player noticed that the bass needed to be something else, than just a box, because the sound had to be lower than guitar sound has. So it became clear that bass had to have a neck. Both "lap steel birdhouse" and "bass birdhouse" needed to have instrumental microphones.

Step 4. Choosing one of the sketches and drawing a detailed technical drawing of it. The Birdhouse group had studied their instruments and noticed the features so that in technical drawings the lap steel was designed to take the pulling of the strings and there was the place for the microphone. The bass needed the neck because of the low sound and there was the place for a microphone, too. In the bass one wire was enough because of the thickness of it. The drum had to have two kinds of sound, higher and lower, so in technical drawings the frame was designed in the way that two kinds of sounds were possible to play.

Step 5. Making a prototype and testing it. Building instruments demanded the group to test different kind of solutions during the process. According to the defined features and drawings, students built their instruments without prototypes because the instruments themselves were like prototypes and solutions needed modifications and planning all the time. One example of testing was that the group found instruction to build an instrumental microphone and they built the prototype, which was actually the part of the final artefact.
Step 6: Making the artefact/solution. Does the design solve the problem? The group tried to get a solution that suit the problem "How to create something that has generally been done in

schools, a birdhouse, in a new way" and they achieved their aim. The students built three "birdhouse box instruments" and they performed as a band playing a classic rock song "Smoke On The Water". Watch the Birdhouse Band playing: http://www.youtube.com/watch?v=AoGRARlKNog (or write Lintupönttöbändi in youtube).

Discussion

It can be seen already that creativity, innovativity, critical thinking, responsibility and self-directness are qualities that are needed now and definitely in the future. (Oivallus, 2011; Parikka & Rasinen, 1997.) Technology education could provide possibilities for pupils to learn these important skills by working concretely with various tasks. One key problem is that the assessment practices in Finnish craft (technology) education tend to drive teaching towards promoting "guaranteed" and "safe" solutions that stifle pupils' creativity and independent thinking skills. In order to improve assessment in technology education, we developed a pedagogical model namely "Development of pupil's designing skills" and demonstrated it by one case created by teacher education students: the "Birdhouse Band" project.

Finnish NCC 2004 states that instruction in technology education should be implemented through projects and methods of experimentation, investigation, and invention should be practiced actively. The model introduced in this article may encourage teachers to instruct pupils' working with open ended projects so that pupils can work creatively and innovatively. By observing different kind of solutions according to the task and planning their own project, pupils are guided to make decisions and give arguments. This also serves the purpose of developing pupils' critical thinking, when pupils have to consider the design they want to create according to materials and techniques they can use. The design process is divided into smaller steps that may help pupils to work self-directly. Therefore it can be assumed that it also raises pupil's responsibility of her/his work. For the teacher this model serves as a tool to assess pupils' working with detailed criteria.

Even though this model is only a suggestion for teacher educators and teachers to enhance designing in technology education this could form a useful starting point for further research of pupils' development in designing or assessment of a design process. The next step for us as teacher educators would be taking up the gauntlet of studying students' development of designing skills.

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An Analysis of PCK to elaborate the difference between Scientific and Technological Knowledge

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Abstract

This research addressed the key area of early career teacher education and aimed to explore the use of a 'Content Representation' (CoRe) as a planning tool to develop early career secondary teacher Pedagogical Content Knowledge (PCK). This study was situated in the subject areas of science and technology, in which sound teacher knowledge is important to student engagement. The study was designed to examine whether such a tool (CoRe), co-designed by an early career teacher with expert content and pedagogy specialists, can enhance the PCK of early career science and technology secondary teachers. The research design incorporated a unique partnership between expert classroom teachers, content experts, early career teachers, and researchers experienced in science and technology education.

This paper will present an analysis of CoRe development and the effect that had on the early career teacher's PCK. In addition, as the same tools and methodology were applied to both a science and a technology teaching context, differences between the two areas became clear. This paper will elaborate and discuss the differences which arose as a result of the development of the CoRe's and an analysis of PCK differences in science and technology.

Introduction

Research has shown that one of the factors that enables effective teachers is their rich pedagogical content knowledge (PCK), a special blend of content knowledge and pedagogical knowledge that is built up over time and experience. This form of professional knowledge, first theorized by Shulman (1987), is topic-specific, unique to each teacher, and can only be gained through teaching practice. The academic construct of PCK is recognition that teaching is not simply the transmission of concepts and skills from teacher to students but rather a complex and problematic activity that requires many and varied "on the spot" decisions and responses to students' ongoing learning needs. While much has been written about the nature of PCK since Shulman first introduced the concept in 1987, and its elusive characteristics have led to much debate, there are still gaps in our knowledge about teacher development of PCK. However, the work of Magnusson, Krajcik and Borko (1999) is helpful in clarifying this special form of a teacher's professional knowledge by proposing that PCK is made up of five components. In their view, an experienced teacher's PCK encompasses his/her:

- orientations towards teaching (knowledge of and about their subject and beliefs about it, and how to teach it);
- knowledge of curriculum (what and when to teach);
- knowledge of assessment (why, what and how to assess);
- knowledge of students' understanding of the subject; and
- knowledge of instructional strategies.

Research in technology education reveals a less well-developed understanding of the role of PCK than exists in science, though an international discourse does exist with studies being reported in both general design and technology education (De Miranda, 2008; Jones & Moreland, 2004; Rohaan et al., 2010; Rohaan, Taconis, & Jochems, 2009; Rollnick & Mavhunga, 2012), as well as in different areas of technology such as Information and Communication Technology (Koehler & Mishra, 2005). While researchers like McCormack (1997, 2004) and Banks (2009) have discussed the nature of knowledge in technology education, international diversity remains a characteristic of the discourse in technology, which is an impediment to the development of PCK in the area of technology education. Consequently, one purpose of this paper is to extend this understanding through the lens of PCK.

To address the paucity of PCK exemplars in science teaching, Loughran et al. (2006) explored the PCK of highly regarded science teachers for particular topics in junior secondary science, to see if they could tease out some common threads in their pedagogy that could be considered as comprising the knowledge base of science teachers, that might be helpful to share within the profession. Loughran et al. developed a set of conceptual tools known as Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) that make explicit the different dimensions of, and links between, knowledge of content, teaching and learning about a particular topic. The CoRes, represented in table form (see Table 1), attempt to portray holistic overviews of expert teachers' PCK related to the teaching of a particular topic. They contain a set of enduring ideas about a particular topic at the head of the columns, and a set of pedagogical questions for each row.

Table 1. Sample CoRe matrix

TOPIC	Enduring idea 1	Enduring idea 2	Enduring idea 3	Enduring idea 4
Why is it important for the students to know this?				
Difficulties connected with teaching this idea				
Knowledge about student thinking which influences teaching about this idea				
Teaching procedures				
Ways of ascertaining student understanding or confusion about the idea				

CoRes have been used successfully in pre-service science teacher education to help novice teachers understand what PCK might involve and to develop their own representations of teaching in particular topic areas. In the study by Loughran et al. (2008), a pre-service educator invited student teachers to construct their own examples of CoRes after they had examined and reflected on those created by expert teachers. The findings from Loughran et al.'s (2008) study strongly suggest that the focus on PCK using CoRes to frame their thinking about the links between science content and pedagogy did help the student teachers to gain a more sophisticated view about learning to teach science and how to teach for understanding. Another study along similar lines also sought to promote science student teachers' PCK through CoRe design (Hume & Berry, 2010). The student teachers found the task challenging and their lack of classroom experience and experimentation proved to be a limiting factor in being able to develop CoRes successfully. However, the contribution such a task could make to their future PCK development remained a distinct possibility.

This developing body of literature related to teacher PCK suggests that research into the use of expert-informed CoRes in the untested arena of PCK development by early career secondary teachers is important. Further, neither the role of experts of content in the formulation of CoRes, nor the analysis of resulting student outcomes when early career teachers use CoRes in their classrooms, have been extensively examined. This innovative research consolidates and builds knowledge about the use of CoRes to help address the gaps described above. Addressing these gaps in the research could help contribute to effective development of PCK for secondary teachers of science and technology, which will support success for all types of learners.

Research design and methodology

This research addressed the key area of early career teacher education and aimed to research the use of a CoRe as a planning tool to develop early career secondary teacher PCK. The study was designed to examine whether such a tool, co-designed by an early career teacher with expert content and pedagogy specialists, can enhance the PCK of early career science and technology secondary teachers. A research design was developed that incorporated a unique partnership between expert classroom teachers, an expert scientist and an expert technologist, early career teachers of science and technology, and researchers experienced in science and technology education.

This study built on nascent work by Hume and Berry (2010) into the use of CoRes in secondary teacher education. It combines the previously-mentioned frameworks of Shulman (1987) and Magnusson et al. (1999) on PCK with the work of Loughran *et al.* (2006) on CoRes to address the development of secondary teachers of science and technology. Teachers typically enter secondary teaching in New Zealand with a degree in a specialist subject area plus one year of teacher education. These teachers then have specific content knowledge upon entering secondary teaching, such as biology, chemistry or physics in science, and may come with a much broader range of backgrounds in technology, such as electronics or engineering. Evidence suggests that, even with this degree background, these early career teachers find it difficult to conceptualise the key concepts behind science and technology (Gess-Newsome, 1999; Loughran et al., 2008). Whilst their one year of teacher education provides some support for development of general pedagogy, development of PCK in their specialist subject areas is limited in the timeframe available. This issue becomes more acute for early career teachers who find themselves addressing science or technology topics in their classrooms that they may not have covered well in their undergraduate degrees.

This study aimed to address this problem by researching how the development of PCK in early career secondary teachers is influenced through construction and trial of the use of CoRes in specific topics as planning tools for teaching science and technology.

Research questions

The following research questions were addressed:

- How can experts in content and pedagogy work together with early career teachers to develop one science topic CoRe and one technology topic CoRe to support the development of PCK for early career secondary teachers?
- What differences are revealed between science and technology through the development of the CoRe?
- How has engagement in the development and use of an expert-informed CoRe developed an early career teacher's PCK?

Data collection

This study employed an interpretive methodology using an action research approach (Creswell, 2005) involving a cohort of 2 early career secondary teachers of science and 2 of technology, as practitioner-researchers as they undertake their second or third year of teaching. The study was organized in three phases.

Phase 1 of the study was the design of one CoRe in a science topic and one CoRe in a technology topic. Each CoRe was designed with the help of an expert scientist or an expert technologist who provided advice on the key ideas of the content knowledge for the topic of the CoRes, and an expert teacher of science and another of technology at secondary level who provided advice on the pedagogical questions appropriate to address those key ideas. The experts and the early career teachers co-constructed the CoRe(s) in a workshop situation facilitated by two of the researchers who are experienced in working with teachers, and who are familiar with research-informed challenges in teaching and learning in science and technology. Two different researchers observed and made field notes of the process of construction of the CoRe to determine the nature of the contributions made by the expert scientist/technologist, expert teachers, and the early career teachers. This was followed by focus group interviews.

Phase 2 began an action research process for the teacher in partnership with a researcher. Each early career teacher who was engaged in developing the CoRe then undertook a period of planning for delivery of a scheduled unit using the CoRe as a planning tool. In this process the researcher's role was asking why and how questions of the early career teacher as they planned their unit with or without taking account of the CoRe. The early career teachers were asked to keep a reflective journal that records their thoughts about the CoRe collaborative design development process and how they used the CoRe in planning.

In **Phase 3** of the study each early career teacher delivered a science or technology unit using the CoRe as a guide and they co-researched, with a researcher partner, the outcomes of its use with one class of students. This involved observation of classroom activity by the researcher while the teacher was delivering the unit, to promote reflective conversations in an action research process between the teacher and researcher around the teacher's delivery of appropriate and relevant content, and its appropriate pedagogy, as specified in the CoRe. Three class periods during which one or more of the enduring ideas from the CoRe is a focus for teaching and learning was observed. Data as field notes from the three classroom observations focussed on how the teacher works with their students and how the students respond. Reflective conversations were held between the researcher and the early career teacher at the conclusion of each of these observations and any changes the teacher planned to make in future lessons in response to their experiences in the unit was noted. A focus group interview of students was conducted by the researcher at the end of the unit to examine how the students' learning experiences may have been influenced by the pedagogical structure in the CoRe. The focus group encouraged the teenage students to share their views and experiences in a supportive manner.

Data analysis was structured around the three research questions as shown in Table 2 below using an Activity Theory framework. This framework was further informed by communities of practice and PCK frameworks and the CoRe itself as appropriate in each phase.

Table 2. Research Summary

Research Question	Data source	Data analysis
How can experts in content and pedagogy work together with early career teachers to develop one science topic CoRe and one technology topic CoRe to support the development of PCK for early career secondary teachers?	Field notes from observation of the contributions and interactions within the workshop groups, and interviews at the end of the Phase 1 workshop.	Data content analysed against a community of practice framework of contributions and interactions regarding content and pedagogy for the topic.
What differences are revealed between science and technology through the development of the CoRe?	Teachers' reflective journals, classroom observations, teacher's reflective conversations,	Observations and focus group interview content analysed against a framework of content knowledge and pedagogy and each CoRe compared.
How has engagement in the development and use of an expert-informed CoRe developed an early career teacher's PCK?	Teachers' reflective journals and interview with the teacher.	Data content analysed against the five components of PCK in relation to the CoRe.

Findings

The content and pedagogy experts generally worked constructively with the early career teachers (ECTs) in designing their CoRes. The ECTs noted that they highly valued the input of the experts and felt that the design process had enabled them to identify and access the knowledge about the key concepts of the topic, as well as learn new pedagogical techniques for delivering particular content material. All the ECTs reported that they felt that being involved in discussions with the experts in the construction of the CoRe helped them to understand the big picture of the topic. Although the teachers kept in mind the needs of the curriculum and assessment through these discussions, they felt that the CoRe discussions were somewhat liberating in allowing exploration of what the topic itself was all about. Figure 1 illustrates how the research team saw the connections between the CoRe and other influences on teaching and learning at secondary school level.

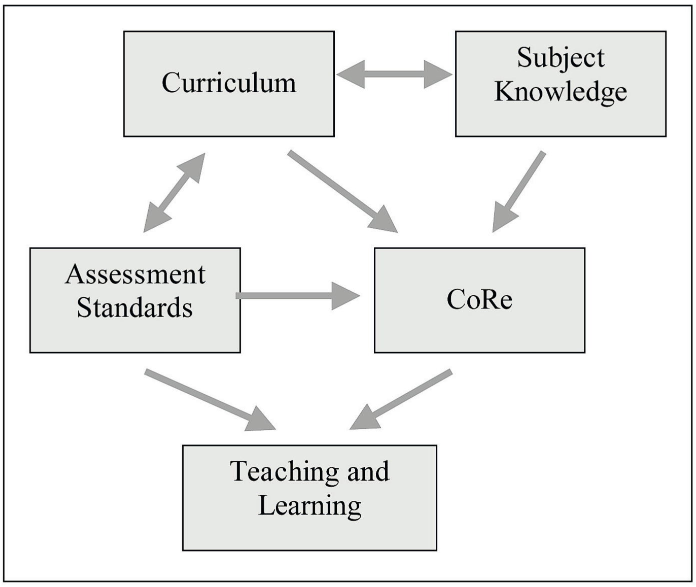

Figure 1 Model of how a CoRe might fit in senior secondary schooling

There was a variety of teacher response to using the CoRe in their planning. For the technology teachers, the CoRe encouraged them to weave more conceptual thinking into their lessons, something which the students found a little difficult, as they were more used to focussing on practical skill development. However, the teachers felt that the additional conceptual thinking would help the students understand more of the fundamental ideas behind materials technology, which they would be able to transfer to future projects.

There was a marked difference between the way the Science ECTs and the Technology ECTs approached the task of developing the conceptual "Enduring Ideas" for the CoRe topics of Organic Chemistry and Materials Technology respectively. The science teachers much more quickly developed a consensus about the Enduring Ideas, because they already had in mind a common idea of what was important for this topic, developed from text book and curriculum agreement, and so the discussion involved simply deducing from this agreed list which ones they wanted to include in the CoRe. In the technology group, there was a sense of developing the list of potential enduring ideas from first principals, consequently there was far more negotiation and justification in the workshop leading to the development of agreed enduring ideas. There was no schema that was familiar to all the workshop participants which could provide a common starting point. Consequently a lot more of the workshop time was spent by the technology group coming to agreement on the enduring ideas.

In the case of Science, the process of choosing the topic was relatively unproblematic. An initial choice was made to move from Science to the subset of Chemistry, and then within that, the area of Organic Chemistry was selected as the topic for the CoRe. In the less structured epistemology of Technology, Materials Technology was selected as the topic, a second tier level of knowledge organization. It may be the case, that had a third tier area been selected as the topic (for example Composite Materials), as was done in Science, the more narrow subset may have resulted in less discussion and debate and a faster resolution in agreeing to the 'enduring ideas' of, say, Composite Materials Technology.

The immediate usefulness of the CoRe seemed to lie in different areas for Technology and Science. The science ECTs seemed to get the most benefit from seeing the need for and developing with confidence, examples of organic chemistry in authentic contexts to support the theoretical understandings they were focussing on developing with their students. In Technology the ECTs saw the immediate benefit in quite the opposite way. For them the opportunity to see the big picture of Materials Technology, to articulate its theoretical underpinnings and consequently development of a philosophy that was conducive to a rational epistemology was perceived to be the main benefit. What followed from this was a more thoughtful approach to developing lesson content by the ECT's as evidenced by the introduction of a range of different pedagogies and teaching resources. Whereas in the absence of the CoRe, the technology teachers would just teach those aspects of materials technology that the students needed to complete their current project.

The application of the CoRe to a teaching unit was different in Science and Technology. In Science, the chemistry CoRe was truly a content representation, dealing with a discrete and contained unit of work which was treated as such by textbooks and was aligned with the curriculum for this year level. In Technology, the Materials CoRe had to be contextualized within a project which permitted the application of the content. So it was not a self contained content representation, but rather a topic that could be applied within a project context.

The practical/theoretical dichotomy was an aspect of both the science and technology teacher's implementation of the CoRe, but in opposing ways. The science teachers noted that after an examination of, and through discussion of, in particular, the pedagogical questions related to the content ideas, they had a deeper understanding of the importance of engaging in practical activities in order to assist students understanding of the relevance of the topic. The reverse outcome was the case for the technology teachers. After the realization of the need for a conceptual framework prior to determining the enduring ideas for the topic during the first workshop, the teachers felt that students also needed a broader framework of understanding than their immediate and felt needs related to the completion of their current project. Consequently, during the implementation of the CoRe, the teachers planned for more classroom activity than they normally would in order to provide this framework for the students, and to spend time generalizing from the specifics of their current project to broader principles that could be applied elsewhere. A number of students indicated that they did not appreciate this provision, reflecting their belief that the main reason for their being in class was to get on with building something.

In the context of a CoRe, the differences between that nature of technological and scientific knowledge have not been considered by research. Relevant technological knowledge is defined by its usefulness to the task at hand. If it does not help to achieve a specific goal then it is neither useful nor relevant and so can be discarded. Consequently it is difficult to predetermine what technological knowledge is relevant because problems that may arise in the pursuit of a technological goal cannot be anticipated. So the notion of designing a CoRe in the current format and using that as the basis for the design and implementation of a unit of work in technology is fraught.

An additional and related issue in the implementation of a CoRe in technology education as a means of enhancing a teacher's PCK is the importance of both conceptual and procedural knowledge. Vincenti (1984) describes conceptual knowledge as explicit, the theory of technology. Procedural knowledge is the often tacit driver of decision making and relates to appropriate decisions made through designing, problem solving, modelling, testing and planning. Parayil (1991) interestingly characterizes this tacit knowledge as papyrophobic in nature, admittedly less so as time goes on, but maybe still recognizable in many technology classrooms. The early career technology teachers in this research highly valued procedural knowledge, but this was not really elaborated in the CoRe, which is why they felt they had to re-contextualize what had been developed in the first workshop.

The assumption has been, in the application of CoRes to the area of Science, that the 'enduring ideas' relate mainly to conceptual knowledge. In an application to Technology, the ideas need to be reflective of both procedural and conceptual knowledge. The integration of this knowledge in a Technology CoRe could also assist in overcoming the common dichotomy between theory and practice in Technology, by having questions which consider both in an integrated way.

Implications of this study

Teacher professional development and learning. This study has indicated that CoRes developed in this way have potential for helping ECTs access content experts' and expert teachers' knowledge and experience. Our findings revealed a willingness for the experts to be involved in the CoRe process, and that they felt that they gained a better understanding of the challenges that beginning teachers face in teaching their subject. Both the experts and the ECTs enjoyed the opportunity to discuss the key concepts and the ways to teach them. There was evidence that the mutually-informing outcomes of these discussions represented a worthwhile investment of time for all parties concerned. However, it was also clear that to create space for such a design process outside of a funded research project, would require time commitment and innovative ways to collaborate between ECTs and experts.

This leads to consideration of how all ECTs can benefit from being involved in CoRe design with experts across a variety of learning areas and topics. Whilst participants in this project clearly appreciated the opportunity to work face to face with experts, it would seem unlikely that this opportunity could be provided for all ECTs in all learning areas. A potential solution to this dilemma may be the use of electronic media. Applications such as Wikis or e-portfolios via computer are already being used as collaborative work spaces in many areas of education. Bringing together a group of ECT's and some experts in a virtual space may allow for collaborative but asynchronous (and therefore time-flexible) development of CoRes. This has potential for involvement of greater numbers of ECTs in a cluster, and also facilitates consideration of the ongoing evolution of a CoRe as ECT PCK develops. This latter idea is important, as development of PCK should not be seen as reaching an endpoint. Indeed, in this study, it would be of interest to return to our ECTs in years to come to examine how their PCK had further developed, and what a revised CoRe of the same concept might then look like.

The nature of CoRe design and PCK in different learning areas. A further implication of this study arose from the unsurprising finding that the nature of each learning areas is different, for example, in this study between science and technology. These differences were manifest in the historical conceptual thinking underlying the learning area, the way that the subject is taught, and the traditional backgrounds of the teachers in those subjects. These differences raise implications for the design of CoRes in different learning areas. The original CoRe structure was designed in science, and whilst the technology teachers were able to work with the CoRe structure, there was some debate at the end of the project as to whether the set of eight pedagogical questions might be the most appropriate ones for all learning areas. Further research into the use of CoRes in other learning areas would help to respond to this question.

The concept of the content area or topic that a CoRe refers to is relatively unproblematic in Science. Science has a well-established epistemology leading to an established organisation of knowledge into accepted topics of inquiry. Technology on the other hand has a shorter history of study as a philosophical enterprise and no commonly agreed upon epistemology. Robust debate still exists about the nature of knowledge in technology and the way knowledge empowers technological practice. The results of this research indicate that as the concept of CoRe design is widened to incorporate teaching and learning in areas other than Science, what is considered to be a “content area” or topic within that learnig area may need to be considered carefully.

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Discovering Technology teachers' pedagogical content knowledge: A comparative study between South Africa and New Zealand

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Abstract

An important and under-researched area of Technology Education is teachers' pedagogical content knowledge (PCK). This concept reflects the notion that expert teachers' knowledge is a unique integration of their pedagogical technique and their understanding of Technology content as applied in a particular instance.

This research enquires into Technology teachers' PCK in New Zealand and South Africa, using a comparative perspective and a methodology derived from the philosophy of PCK. The rationale for the selection of these two countries is the similar timeframe of implementations and review of Technology Education curriculum which has occurred in each country.

This presentation will compare the PCK of New Zealand Technology teachers and the PCK of South African Technology teachers through a case study approach. The findings in this paper are reported from the interviews, classroom observations, and document reviews of teachers in each country.

Introduction

An expert teacher is a master of the content knowledge about the subject being taught, and uses effective ways of imparting such content knowledge to learners (Ben-Peretz, 2010). This notion is commonly referred to as PCK (Ben-Peretz, 2010), the body of the teacher's professional knowledge that encapsulates knowledge of the subject taught and general pedagogical principles and skills that guide a learner to develop personal meaningful understanding. The origins of PCK date back to 1986 when Shulman (1986a) introduced the concept, referring to it as a 'missing paradigm', a description that remains applicable to Technology Education.

This study aims to inquire into the PCK of secondary school Technology teachers. The study is a collaborative and comparative project between South Africa and New Zealand. Both South Africa and New Zealand have recently experienced curriculum transformation and change, which motivated the authors to use a comparative study to investigate technology teachers' PCK. Technology Education is a relatively new subject in both of these contexts, and research into this area has the capacity to enhance understanding of what constitutes an expert teacher.

Thus, the research question arises: What is secondary school technology teachers' PCK? This research question can be elaborated through the following sub-questions that have been derived from the literature:

- What do Technology teachers understand as the nature and purpose of Technology Education?
- What constitutes Technology teachers' knowledge of the Technology Education curriculum?
- What are the pedagogies that Technology teachers believe are suitable to teaching Technology?
- What types of assessment activities do Technology teachers utilize and how are these related to the content?
- What technological teaching and learning resources do Technology teachers use?
- How do Technology teachers integrate Indigenous Technology in their teaching?

Theoretical Framework

Traditionally, teachers' content knowledge (CK) and pedagogical knowledge (PK) was conceptualized in a dichotomized way (Ball & McDiarmid, 1990; Shulman, 1986a; Veal & MaKinster, 1999). In technology, the parallel dichotomy is often characterized as between theory and practice (Williams, 2002) where the pressures of timetables, classrooms, and examinations encourage teachers to separate theory and practice, each accompanied by a suite of different conventions related to pedagogy and content.

Lee Shulman is credited with coining the concept of PCK (De Miranda, 2008) when he gave his presidential address to the American Educational Research Association (Van Driel, Veal, & Janssen, 2001). Shulman (1986a) developed a framework for teacher education by introducing the concept of PCK, such that teacher training programmes should combine CK and PK to effectively prepare teachers.

According to Shulman (1987), PCK includes special attributes that a teacher possesses, which help him/her to guide a student to understand content in a manner that is personally meaningful – including knowledge of subject matter; pedagogical content knowledge; general pedagogical knowledge; knowledge of curriculum; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational aims, purposes, and values. Other alternative conceptualizations of PCK have been developed consisting of four (Cochran, King, and deRuiter, 1991) or five elements (Magnusson, Krajcik, and Borko, 1999).

PCK implicates both Western and indigenous forms of technological knowledge. Hence, teachers also need to integrate indigenous Technologies, understand their nature, and work to address the technological bias toward them (Gumbo, 2000; Maluleka, Wilkinson, & Gumbo, 2006).

Research Design

The research design followed a case study approach to explore secondary school Technology teachers' PCK (Boyce & Neale, 2006) to address the research problem: What is secondary school Technology teachers' PCK? A convenience sample of eight schools was selected to become case studies, four in cities, two in small towns, and two in the countryside. All the schools were mixed gender, they varied in size from 600 to 1800 students, and all the classes observed were at the lower secondary level.

A convenient time was negotiated with each teacher; during which they would be teaching lessons that could be observed. An observation schedule based on the elements of PCK derived from the literature was used. Observation is deemed important to counter possibilities of bias that could emerge during interviews (Kelly, 2006). Generally the observation was followed by an interview. Documents and resources used by the teachers were analyzed.

In order to validate the data, all classes were observed by both researchers and the interviewees were asked to confirm what they had said once the data had been transcribed. The findings from the interviews, observations and document analysis were triangulated.

The interview data was coded first, adopting a variation of the coding strategy used by Marshall and Rossman (1999). This involved a stepped process moving from a general approach to develop themes and codes and then detailing the themes. The variation on this coding strategy was the use of analyst-constructed typologies, which were based on the principles of PCK developed from the literature. The analyst-constructed themes were: subject matter, curriculum, assessment, learners, pedagogy, educational context, educational aims, purposes and values, and indigenous dimensions. The interview questions were based on these themes as well the reporting of the findings.

Once the interview data was analyzed, it was integrated with the teaching observation notes, the document analyses and incidental personal memos that the researchers had been keeping (Marshall & Rossman, 1999). The outcome was eight integrated narratives about each of the cases.

Findings

In this section, the findings from the consolidated case studies are presented under the following themes:

Nature and purpose of Technology Education

Teachers in both countries related one of the purposes of Technology Education to their national context. In South Africa, the need to minimize foreign dependency in areas such as architecture and engineering is often espoused by the government, and the teachers saw Technology playing a role in skill development in these areas:

> It will help learners learn about technology so that they can add to the skills development in the country. We depend on people from other countries rather than those from our country. Technology Education will help minimise this (SA:J).

For SA teachers, to reduce foreign dependency starts with exposing learners to technology so they can become technologically literate:

> Technology is fine because it teaches learners about things that they were ignorant about before. Like now we have been doing a structures project, suspension bridge and learners do not know structures. They also need to be encouraged about how important technology is because we apply it every day in our homes (SA:L).

In NZ the rationale was that it is a small country that does not have a broad manufacturing base, so there is a need to be cutting-edge in creativity and inventiveness, and design and technology can contribute to this end.

So the relationship of Technology Education to national needs was perceived as a significant alignment in terms of skill development, but these skills were seen as more practical in SA and cognitive in NZ. In SA, practical technological skills were highlighted. As aspects of both personal and vocational development, NZ teachers believed that student conceptual development through the medium of Design and Technology would help develop research and thinking skills which are useful regardless of the vocation students eventually pursue:

> Technology is a subject that teaches our students to think through the medium of design, construction and making things. Whether students go into a trade or carry on studying at university, it still gives them a process of problem solving and thinking about things, coming up with answers and being able to discuss ideas with other people (NZ:J).

The rationale for the nature of technological knowledge seemed to vary between countries. In NZ, three of the teachers explicitly mentioned the importance of linking theory to current practice. They only taught new knowledge (conceptual and procedural) when the students had a practical application for the knowledge, so they needed to know it and consequently saw it as relevant.

> You feed the students slowly – when they need to know it, when the time is right, when it becomes appropriate for them and is relevant, and that makes it less burdensome. You can deliver it comfortably to the students without putting them under stress, but also stretching them enough to make them think about what they're doing (NZ:J).
>
> When students come into technology in Year 9, they just want to do the practical, but they have to have the understanding from early on that there is theory to be done, they have to start thinking and recording their ideas. The student's are told all the time that you can't actually make something without thinking about it. Without good research, without good analysing, without good decisions, the project will be crap (NZ:M).

In SA, the rationale was based more on the curriculum and textbook sequencing of topics, which seemed quite acceptable to students. This was in a context in most classrooms in which practical tasks were not the main organizer of technology education.

> We follow the curriculum. Today we did Learning Outcome 1 and Learning Outcome 2 (SA:L).

Knowledge of the Technology Education curriculum

All teachers were aware of the curriculum, but to varying degrees. One teacher in NZ had been involved in the development of the latest curriculum revision, and so had an intimate knowledge of all aspects of the curriculum which was evident in his assessment structures. Other teachers in both countries did not have a clear understanding of either the structure or the demands of the curriculum. These teachers consequently utilized other organizers for their planning. In NZ it was the vocationally aligned and skills oriented unit standards, and in SA the teachers were following the textbook. Exercises in the SA context were heavily reliant on a textbook to a point one teacher even produces hand-outs for learners who do not have it.

> Many of the exercises, for example the hand-outs that I used today, come from the textbook that I had. Not all learners have textbooks, that is why I produce these hand-outs (SA:J).

While both of these alternatives reflect the curriculum, they do not replace it as a full understanding of learning area requirements.

One difference between the countries derives from the nature of the curriculum. In NZ Technology extends through to the end of secondary schooling as an option for students who can use their Technology studies toward their terminal National Certificate of Educational Achievement (NCEA). In SA, continuation of Technology through to the end of secondary schooling is very limited because of the nature of the subjects and the accompanying facilities and equipment limitations, which exist in very few schools.

The teachers in NZ, therefore, tended to plan progression for their students in light of the pathways that were available to them as they progressed through schooling, developing a foundation of skills, knowledge and understanding that would support their achievement in senior years Technology.

> In Year 13 students have a client with a genuine issue that has to be solved. We don't usually let any kids into Year 13 that haven't done the preparatory work in Years 11 and 12. My role is to make sure it's not too expensive and get out of control, and that the stakeholders are available to talk to the students and it's also going to have the depth that we need (NZ:J).

> Progress in technology is reflected in the students conceptual idea development. In Year 9 students different concepts are really just the one idea modified, so progress is getting them to diversify their thinking. It really is important when they get up to the senior level that they show a good diverse range of thinking (NZ:C).

In SA the teachers were, at the most, concerned with progression over the 2 years that they knew their students would be studying Technology, and their concern was more with covering the required topics rather than developing progression.

> Technology has 3 learning outcomes. The learners must know how to use the design process to solve problems. They must also have the knowledge of technology to solve problems. We also look at how technology affects the environment and affect the people and how it has been developing over the years (SA:M).

Pedagogies suitable for teaching Technology

Though some teachers found it difficult to explain their pedagogies, through discussion and observation it became clear that these varied. One teacher had a limited repertoire of strategies to use with students; mainly consisting of demonstrating skills followed by responding to individual needs. On the other hand, another teacher indicated a range of pedagogical strategies, which varied by year of the students, the goal of the activity, and the nature of the project.

Teachers in both countries made reference to a practical – theory dichotomy in Technology. Although it was more difficult for SA teachers to have their students engage in practical work because of equipment and facilities limitations, they recognized that practical engagement was important, and felt that students learnt and retained more after doing practical activities.

> When you do practicals, they remember. Theory they easily forget (SA:M).

NZ teachers seemed to recognize to a greater degree the expectation from students to do practical work, but emphasized the need for complementary theory. So because of expectations and facilities, NZ teachers seemed to find the implementation of practical activities easy and had to work harder to integrate written work and theory, while in SA it seemed easier to focus on theory and more effort was required to incorporate practical activities.

> As students go through each year and the different programmes, we indicate progress by the projects getting a little bit more complicated each year, and there's more paperwork associated with the projects. We try to get the students to think through some of the issues themselves – not necessarily handing it to them on a plate but guiding them through the steps. I think they get better at technology by their thought processes, if they can pretty much think for themselves (NZ:C).

Physical facilities were felt to be both an impediment and a tool for certain pedagogies. One teacher used the physical arrangement of the facilities to complement his pedagogies by utilizing a long bench in the workshop to seat students for impromptu teaching incidents. While teachers in both countries used small groups extensively, the more restrictive facilities in SA schools made this more difficult. In none of the SA schools was there a suite of Technology facilities, and in just one school was there a dedicated Technology room, though it was a classroom and not a workshop.

Assessment

The teachers reflected a broad range of assessment strategies based on projects, weekly tests, end-of-year examinations, portfolios, case studies and homework. Types of assessment included teacher assessment, self assessment, peer assessment and group assessment. Assessment criteria were derived from the teachers' own ideas, assessment matrices, and curricular levels of attainment. The combination of all these elements painted a complex and inconsistent picture of assessment. In neither country was there a consistency of assessment practice, each teacher seemed to have a preferred method of assessment.

The teachers in SA tended to refer to their use of tests and examinations more frequently than the NZ teachers, whose assessments tended to be of products (projects or portfolios). One SA teacher stated:

> Tuesdays and Thursdays we have 30 minutes test. Learners are expected to diarise them (SA:J).

Teachers in both countries discussed group assessment, one using the members of each group for peer assessment within the group as a way to moderate the teacher's assessment of the group. A SA teacher used group portfolios, some sections of which contributed to a group mark, and other sections which related to individuals marks.

> They also have to produce a project that I must assess. I assess them on the design process and technological processes. The design project portfolio contains individual activities and group activities and they are assessed as such. Individual activities go up to the design stage where each group member must design at least three possible solutions, evaluate them on the basis of advantages and disadvantages of each, and choose the optimum solution. Then the members must negotiate the optimum solution from each member's best one, to adopt as a group design. Group members assign each other time frames when to complete the project within the main assigned time frame (SA: L).

And in NZ:

> We have design groups right through to Year 11 and they get looser as they progress. It gives students confidence within the group. I keep my design groups to no more than three and I try and pick the groups to mix the ability. The groups evaluate their peers' innovation and engineering. We do it at the conceptual stage, we do it at final design stage, we do it when construction has started and they've started to build their projects, and then also at the end we do them again. And students evaluate their own as well (NZ:M).

Resources

There was a significant difference between the two countries related to resources. In NZ the teachers tended not to use books as a resource, while in SA the teachers commonly used textbooks extensively. Teacher M from NZ stated that:

> As resources, I use fellow teachers as much as I can, visiting schools and catching up every time we do professional development. So I'll bounce anything off anyone that I have got some respect for. I go on the net and I spend a lot of time in toyshops looking like a paedophile. I go into home appliance and hardware shops and browse looking for project ideas and resources (NZ:M).

A possible reason for this difference lies in the fact that the majority of the teachers teaching Technology in SA were not trained in technology, but either began teaching Technology because of a personal interest in the area or underwent a short retraining course. Consequently they may be less secure in their understanding of the Technology content, and follow a textbook as a way of sequencing their teaching. NZ teachers often had some books in their office which were used as reference books, but there were no class sets of work or text books.

The existence of active regional professional associations in NZ means that teachers can meet with their colleagues frequently and so can use each other as a resource, whereas in SA such opportunities are less readily available.

There was greater consistency of resources in NZ schools than in the SA schools. All the NZ schools had a Technology department with a number of materials oriented workshops, a machine room, a computer lab and an adjacent class or design room. One SA school had a dedicated technology room, the others used classrooms and none had a workshop. When engaged in an activity, students had to bring materials from home. These teachers consequently felt that Technology was not taken seriously by the school or the Department of Education, and this severely limited the scope of activities they could organize with their students.

> No resources. I have provided the school with the list of items that we need for technology teaching. I have not received anything yet. There is a lot that we need to be able to teach a topic, like structures. We have to find a workshop for food technology, systems and control, and the like; we do not have any (SA:M).

Indigenous Technology

Despite expectations, there was very little more incorporation of Indigenous Technology by the SA teachers compared with the NZ teachers. This expectation was derived from the fact that Indigenous Technology is one of the curriculum content areas in the SA Technology curriculum.

Some SA teachers were guided to some extent by chapters in textbooks which dealt with indigenous technological issues and perspectives. Others had not considered the area of indigenous technology at all, and in this sense were more like the NZ teachers. There is no curricular imperative in NZ to address Indigenous Technology, apart from a general inclusiveness of Maori culture, and consequently the incorporation of Indigenous Technology was quite superficial, relating to decorations on products, the use of symbolic colored beads or wall posters. The most significant instance of Indigenous Technology incorporation was an SA teacher who, in the context of a unit on packaging, described his approach:

> We plan to include it in the packaging project. For example, we will talk about packaging by the Bushmen who used to carry water in egg shells. It will also be catered for when we do the development of packaging (SA:M).

In a number of instances, the background of the students in Technology classes was cited as an impediment. In a SA school there were students from coloured, European, Zulu and Xhosa backgrounds, and with this range of indigenous orientations the teacher felt it would be difficult to include indigenous issues in the Technology classes. Two of the teachers in NZ felt that indigenous issues were not important because of low numbers of Maori students in their classes.

One of the problems that we have is that we don't have a lot of Maori students come through, there might be two Maori students in our Technology program, so why should I be trying to convert the ones that I don't need to? But in saying that, there are great opportunities for indigenous influences, and when it's done properly it can benefit many people (NZ:J).

Conclusions

Teachers' PCK varied significantly in these case studies, which confirms the research that PCK is individual, unique, varies from class to class, and changes over time. As a framework for developing an understanding of teachers' PCK, the methodology used in this project seems to be appropriate. The observation of the teachers' context and of their teaching, the interviews, and to a lesser extent the document analysis provided for the collection of a rich data source for each teacher, and generally triangulated to provide valid results (Cohen, Manion & Morrison, 2007). Where triangulation did not validate data, for example, where the teachers' interviews did not match the observations of their class, the dual sources of data are particularly important.

While quite diverse PCK was revealed amongst the teachers across all the components of PCK (content, curriculum, assessment, conceptions of the learner, philosophy and indigenous considerations), there were few areas in which greater diversity was revealed between countries.

There were clear differences in the resources that were used by the teachers with NZ teachers tending to use the internet and their environment, and SA teachers tending to use textbooks. This is explicable given the absence of any comprehensive textbooks in NZ, and also the less readily available access to the internet in SA.

While the facilities in each country were clearly different, with Technology Education in SA less well established, this did not seem to have a major impact on the teachers' PCK. For example, teachers in both countries utilized a variety of assessment and pedagogical strategies, and modified these to suit the physical environment in which they taught.

In a number of instances, it seems that teachers' PCK is moderated by the context in which they teach. For example, in the facilities-poor but textbook-rich environment of SA, the sequencing of relevant conceptual knowledge is determined by the textbook and the curriculum, whereas in NZ, it is related to the needs of the practical projects in which the students are engaged.

The philosophical rationale for Technology Education, from which many elements of PCK derive, was quite clearly focused on general Technology Education for the SA teachers. For them, Technology Education was a component of general education and developed skills and knowledge which are important for all students. In NZ, there is a clear dichotomy amongst teachers' rationales for Technology Education, with many having a vocational approach to develop set competencies in select groups of students.

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CAD and Creativity – A New Pedagogy

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Abstract

In 2007, the Design and Technology (D&T) national curriculum for England suggested: 'In design and technology pupils combine practical and technological skills with creative thinking to design and make products and systems that meet human needs. They learn to use current technologies and consider the impact of future technological developments'. Consequently in England, the use of Computer Aided Design (CAD) packages has become a significant part of the teaching of D&T to students from the ages of 11 to 16 years but often using a teaching strategy that concentrates on the functionality of the CAD package.

In contrast, this paper presents findings from a three-year intervention study. The programme investigated how 11-14 year old students can develop their creativity at the same time as learning complex 3D solid modelling computer aided design programmes through an improved pedagogy.

The study was broadly an 'action research' programme in five phases in which the researcher was also the teacher in the secondary school in which four of the five phases were conducted. This paper provides details of the construction of a new approach to the teaching of CAD, and evidence that the novel teaching methods have improved the students' and teachers' confidence to take risks when using the CAD software, therefore leading to more creative and complex outcomes.

Introduction

In school in general, and in Technology lessons in particular, teachers need to prepare students for a working life in environments which will often have evolved by the time they reach the work place. Fisch and Mcleod (2007) stated this quite succinctly when they wrote that as teachers 'we are preparing students for jobs that don't exist yet, using technologies that haven't been invented yet, in order to solve problems we don't even know are problems yet'.

Teaching students to be creative is seen as an essential foundation in preparing them for this future (Robinson, 2001: Cox, 2005). We need to encourage them to seek novel solutions to problems, to take risks and make links they may not have previously thought of (Cropley 2001, Best and Thomas 2007, Rutland and Barlex 2008). Isaksen *et al*. (2001) recognises a nine dimension model for establishing a working environment to encourage creativity. 1) Challenge and involvement, 2) freedom, 3) trust and openness, 4) idea time, 5) playfulness and humour, 6) conflict, 7) idea support, 8) debate and 9) risk-taking.

These facets are particularly concerning when teaching Computer Aided Design (CAD) within Design and Technology lessons. The programs used to teach CAD, particularly 3D solid modelling CAD, not only evolve rapidly but are also complex and difficult to learn and therefore allowing younger students the freedom to also be creative can be seen as virtually impossible. This concern is further compounded by the lack of confidence shown by many teachers when teaching CAD. Teaching CAD is only one small part of the range of lessons needing to be taught, and teachers often do not have the time to become experts in using the program especially, as previously stated, the software used changes rapidly.

Current methods of teaching CAD in classrooms tend to centre on the teaching of "command knowledge". This provides students with the knowledge of sequences of commands to create a feature on the screen but often do not teach "strategic knowledge", which is knowing the best features and the best order for the features to create the desired model (Lang et al 1991, Chester 2006). Bhavani et al (1993) write that 'students are so busy learning the commands that little time is available for acquiring other kinds of information such as procedural (strategic) knowledge'.

Adopting the traditional step-by-step method of teaching CAD commands to students does not allow them to take ownership of their work or develop it in their own way, which is essential to encourage the student to become creative when using the more complex CAD programs.

Below I describe classroom studies conducted in five phases that examine what students actually need to know and understand when learning a program that evolves as frequently as CAD software, and furthermore suggest a suitable pedagogy that would support teachers and learners to achieve successful and, most importantly, creative outcomes.

Potential issues when learning to be creative when using CAD

The literature reveals a range of possible factors that may affect students' progress when learning CAD software and in their ability to be creative when using it. In summary:

- Students' attitude to learning when using computers varies considerably, with particular concerns being raised over differences between the attitude and approach presented by males and females. (AAUW, 2000. Siann, 1997. Clegg and Trayhurn, 1999)
- Using CAD involves mentally rotating and manipulating images. Varying levels of *types* of intelligence may result in difficulties being able to create new models with CAD software. (Gaughran, 1996)
- Creativity has been reported to be an essential part of education on a personal and professional level and several initiatives have been instigated by the UK Government. These may have resulted in improved creative ability in students however the impact of this on learning CAD programs has been unclear. (DfE, 2003)
- Different approaches by males and females to using technology may require different methods of teaching CAD to each gender.

Phase One

To provide a clear understanding of which of the issues highlighted above most significantly influenced the students' ability to learn and use CAD creatively, a pilot study was undertaken involving 254 students of 10 years of age (124 girls and 130 boys). Over a two day period groups of 25 students experienced a 40 minute activity intended to introduce them to both 2D and 3D CAD programs. The activity was part of a programme of events provided for primary (elementary) school students who would be starting at the secondary (high) school the following year. As such the school, teachers and equipment were new to the students.

The activity started with a demonstration of a 2D, then a 3D CAD programme. This was taught by the same teacher, in the same room throughout the two day period to maintain consistency. The students then completed a short questionnaire. Most of the questions in this involved the use of a Likert scale. This was considered to be the most appropriate method due to the large number of students and time constraints, in addition as the Likert scale was used most of the data was quantitative and could be compared to results gained in later studies. The students also completed a short spatial awareness test consisting of range of problems which asked the students to mentally rotate shapes. Finally, prior to the event the students had submitted a design for a key fob, which was assessed for its creativity by a panel of experienced teachers. These designs were transferred to a 2D CAD programme and the students were able to watch these being made and could take their product home with them thereby completing the students understanding of the design and make process.

The study revealed that 93% of the student participants have access to a computer at home with 60% of these students who do have access to a computer at home using it between 1 and 5 hours a week. The remaining 40% use the computer between 6 and 16 plus hours a week. In contrast to earlier studies, gender appeared to make little difference to the amount of time spent on the computer although the study did not investigate what activities the computers were used for. It may be that males and females participate in different activities, which may change the way they approach designing with a computer. 83% of students expected the 3D solid modelling software to be more *difficult* to use than the 2D program. 68% of students expected to *enjoy* using the more complicated software compared to the 77% who expected to enjoy the 2D CAD programme. Both of these findings are reasonably high suggesting that students were looking forward to both types of CAD even if it presented a challenge. Spatial ability appeared to make little difference to the students' expected enjoyment or difficulty or either programme or to their ability to be creative. The spatial ability test was short, however, and was not completed under strict test conditions. Overall the designs produced were considered to be not very creative, with only two of the students producing work that was placed in the top level when judged against the usual D&T criteria.

Phase Two

Once the students aged 10-11 had enrolled at the High school, the students took part in three Design and Technology lessons lasting 50 minutes per week as part of their normal lessons. The students rotated around different aspects of D&T every six weeks on a 'carousel' of various activities including a CAD unit following the traditional command-led teaching method. This consisted of the students all completing similar products using a 3D solid modelling CAD programme in a step-by-step fashion as the teacher demonstrated a step then the students completing that step. In the last few lessons the students were asked to use the knowledge they had learned to create a model of a robot using the software. At the end of this unit the students were given the same questionnaire as they had been given in the previous study; however questions that had been identified during the previous study as being irrelevant were omitted.

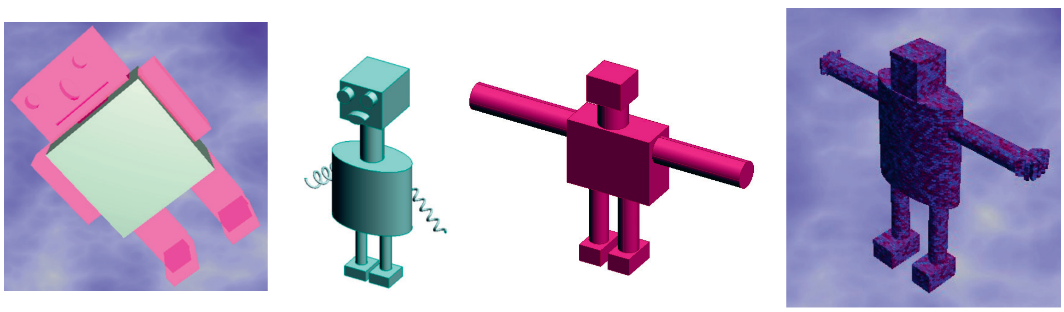

Fig. 1 Students' work in phase two

From this it emerged that 42% of students had indicated that their actual level of enjoyment had matched their expected level of enjoyment. 14% of students had enjoyed using the programme slightly more than they had expected and 10% had enjoyed using the programme significantly more than they had expected. 21% of students had enjoyed using the programme significantly less than they had expected and 12% of students had enjoyed using the programme slightly less than they had expected. This appears to indicate that if students *expect* to enjoy using the programme that they will actually enjoy using it.

To gain a deeper understanding of the students' feelings when using CAD, those students who either had the most extreme opinions of ease of use or enjoyment when using the program - or whose opinion had changed the most - were invited to attend a group interview of around 5 students at one time. The interviews were semi-structured in that some questions were prepared, however it was important that the interview was not so structured that the students weren't able to express themselves.

Findings from the interviews suggest that many of the factors shown to promote creativity may also be relevant to learning CAD programs. Students stated that they liked challenge and problem solving, although when taking risks the outcome had to be achievable as students who had not managed to complete the work were those who had enjoyed using the program least. Most students wanted to work at their own pace but also liked the idea of working in pairs as this appeared to reduce the risk as they could work through problems together.

Phase Three

Building on the results of the phase 2 study an alternative teaching method was created that focused on methods of promoting creativity. The resources for this method were presented to the students as a computer game in which the students needed to use CAD to create items in order to work through various levels and ultimately rescue a 'village elder'. The students were asked to work in pairs with one student in control of a set of information video clips and the other operating the CAD program. The students could work at their own pace and stop to review any points that they found personally difficult. The students were also awarded points both for getting it right or solving their own problems and also for attempting a creative design regardless of whether it worked or not. The intention was that this would encourage the students to take risks. Even if the final design didn't work, the pair would still gain points but more significantly would begin to develop an understanding of what CAD commands would or wouldn't work though play and exploration. When the students had finished the task they switched over roles and repeated the task and could improve their marks from their first attempt. Finally the students were provided with a booklet of common problems that they may encounter in each task to reduce the dependency on the instructor.

To test the effectiveness of this 'strategic' method of teaching compared to the traditional 'command-led' method, the game-based resources were used with classes of students who enrolled in the following school year. To maintain consistency, the students attended for similar activities as elementary school students as those had in phase one prior to them starting at the school. As before, by completing this task the students' answers regarding how they *expected* they would feel about using a CAD program could be compared to how they *actually* felt about using the program. The new teaching method was then used over a six week period involving three fifty minute lessons per week. At the end of this period of study the students were asked to complete the same questionnaire that had been given at the end of the phase two study and, as before, those students who either expressed extreme views or whose views had changed most dramatically were invited to attend semi-structured interviews.

Fig. 2 Students' work in phase three

The results of this study again highlighted that student attitude to using the program made a difference to how the students approached the tasks. Those students that had expected to enjoy using the program most often did then enjoy the program when they had used it. Those students who had expected the program to be difficult to use, but had also enjoyed using it, had seen the tasks as a challenge that they needed to work through. Those students who had thought the program would be difficult to use, and had not then enjoyed using it, had seen the challenge as a barrier that was just too hard to get through. Most students, even those that hadn't enjoyed using the program, had enjoyed the game aspect of the learning. Almost all of the students enjoyed working in pairs and had liked being able to work through problems together. This aspect had also been pleasing to the instructor who had enjoyed listening to conversations between the students in their pairs and felt that the students had learned far more from this experience, and by making mistakes, than by getting it right first time but by just following instructions. All students enjoyed being able to work through the tasks at their own pace; most students liked being able to revisit parts that they had found difficult, but others liked that they did not feel held back by weaker students and they could progress to the more difficult challenges. Most importantly the work completed by the students displayed far more variety and creativity either through the tasks with help from the explanatory video clips, or in the final task of the game by creating 'a castle' without a specific explanatory teaching video to follow (See Figure 2).

Phase Four To further test the alternative 'strategic' method of teaching CAD to students, the previous study was repeated with the next year's intake of students soon after they had enrolled at the school, but this time the students were taught by a different instructor who was equally experienced as a teacher but was far less confident in teaching CAD. A difference to the previous studies is that the study was undertaken with only one group and the new instructor was asked to keep a diary of their experiences after each lesson. The introduction and initial questionnaire was also completed at the start of the first lesson rather than before they had enrolled at the school.

Interestingly, more students had indicated at the beginning of the study that they expected to enjoy using the program, but fewer students had actually enjoyed using it. This perhaps confirms Pektas and Erkip's findings that instructor confidence may influence the students' attitude to the task (2006). The instructor also reported problems with some of the students working in pairs that had not happened before, although she also believed that this could have been due to the ability level of the class. A few of the students had some level of learning difficulties and this may have caused some problems with the pairings. Concerns raised by the students were that their partner wasn't following the instructions properly or that the students felt they weren't spending equal amounts of time on the program and the instructions. The instructor stated that she would use the method again but this time she would teach the students who struggled to work in pairs separately and guide them more closely. Again, however, the students produced a much better quality of work than others had when taught using the traditional 'command-led' method of teaching, and the work displayed a greater level of variation and creativity (See Figure 3).

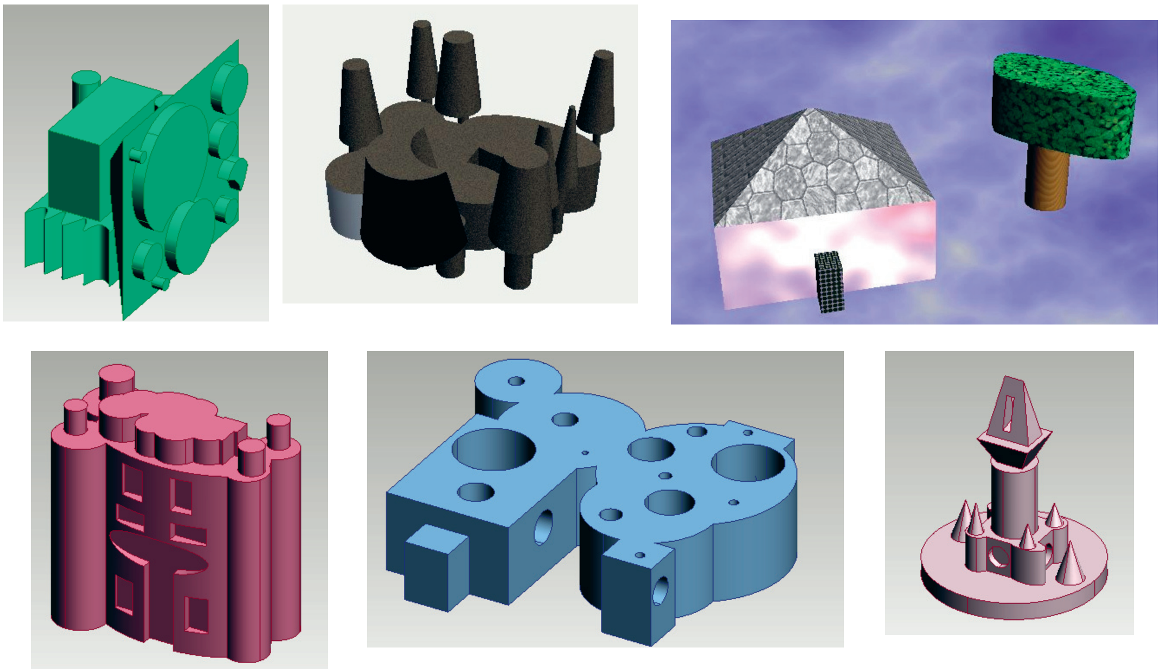

Fig. 3 Students' work in phase four

Phase Five

The final phase in this program of research tested the alternative 'strategic' game-based method of teaching CAD to students in a different school with a different instructor. The school had fewer resources for teaching CAD and only had one room of computers and no data-projector in the department. The instructor chosen for the study had also voiced a passionate personal dislike for the CAD program used in this study. Again a questionnaire and a demonstration of CAD were given to the students at the beginning of the first lesson and a second questionnaire was given at the end. The instructor was also asked to write a diary at the end of each lesson. In this study the diary was written in a more conversational tone and gave a deep insight into the level of concern, and even fear, which can be present when trying to teach using new and ever changing technologies.

Once the instructor had become used to the resources and how they should be used, a marked difference in tone became evident in the diary and the instructor reported that he had enjoyed some of the lessons and even looked forward to the lessons at times. One change from the previous studies is that when the instructor was stuck or saw the students getting into difficulties he reverted to old methods of teaching CAD for short periods. This made little difference to the study as the important aspects were adhered to and it made the instructor more comfortable.

At the end of the study, fewer students than in previous studies said that they had enjoyed using the program, however the instructor felt that this was due to the last task, which involved creating 'a castle' without the aid of specific instructional video clips to help (See Figures 3 and 4). He believed that this had over taxed the students which had changed their final opinion as during previous lessons the students had stated they had looked forward to the lessons. The instructor reported similar experiences as the instructor in phase three when considering paired learning. The instructor had enjoyed listening to the conversations between the pairs, particularly when the students were trying to solve problems. When asked whether he believed the students had been creative he replied, 'creative, - try gay abandon!' Once the students had realised they gained higher marks if they made their designs different to the designs in the video clips, they had worked hard to make their work novel and so the result was more creative. The instructor concluded that the method was valuable as it removed much of the pressure from the instructor, and by working through problems themselves provided a far more valuable learning experience for the students. He said that the students could see the point in what they were doing and didn't get bored as he had noted when teaching using the traditional 'command-led' method. He believed the game resource could be adapted to suit other CAD programs, and he would certainly use the resources again.

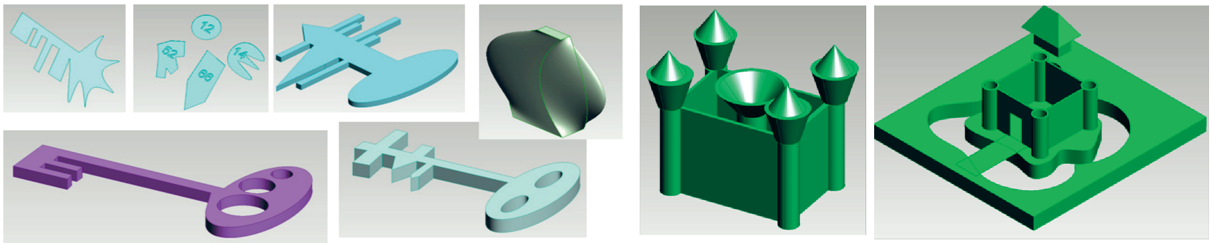

Fig. 4 Students' work in phase five

Conclusions

Some of the concerns raised in a review of the literature were not a significant factor. These included a possible difference in the way males and females approached using technology. Throughout these studies this was less of an issue than previous research has suggested. Male and female students gave similar levels of response to all parts of the questionnaire, and produced work that was of equal status and demonstrated similar creativity levels to each other. Spatial awareness also appeared to present little concern throughout the studies.

The issues that appeared to be more relevant to the studies were of instructor confidence, student attitude and lack of ability by the students to be creative. Surprisingly whether the student enjoyed using the program or not made little difference to the work outcome. Those that did well generally had the attitude that it was something they needed to do and get on with. By putting the work in a context, and through aiding the student to achieve even small goals, improved the students' confidence. Paired learning was pivotal to helping the students work through their own problems and the students gained an improved learning experience through discussion of their work as it progressed. By using known methods of encouraging creativity by providing rewards for taking risks, and not just for the actual final outcome, the students work showed a higher achievement and creativity level. Instructor confidence also appeared to be an important factor in influencing the students' confidence. By providing strategies for dealing with mistakes and solving problems the instructor's confidence improved, and through this the instructor was more confident to allow the students to take risks and work independently. The instructor was able to work through the problem with the student rather than giving them the answer each time, or not being able to help the student at all.

In short, the alternative 'strategic' teaching method based on a computer game is far more beneficial to both the students in terms of quality and creativity of outcomes, and also the instructor in terms of improving teacher confidence.

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