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*Explorations of best practice in technology, design and engineering education*

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Foreword

What constitutes good learning in Technology education? We know that in general, good learning occurs when you have appropriate content (what to learn), pedagogical knowledge (how to organize learning in general) and pedagogical content knowledge (how to organize optimal learning for specific content), however, for much of technology, design and engineering education we don’t have answers to what the correct combinations of the three aspects of the learning above should be.

Learning is of particular importance in TDE given that there are particular features of the learning environment that are specific to the areas. These include learning by doing, interacting with resistant materials, representing knowledge through words and 2 and 3 dimensional images, and engaging in problem-solving where both student and teacher do not know what the precise outcome will be at the outset of problem solving. These are the kinds of issues explored in the pages of these proceedings.

Contributors to the proceedings come from Australia, England, Japan, Kenya, New Zealand, South Korea, Sweden and the USA. The chapters cover a wide range of contemporary issues and themes in technology education including, curriculum, cognition, pedagogy, primary technology, teacher education, special education, information and communication technologies. As with previous conferences many papers could not be classified into single categories and displayed rich interconnections between a number of issues. What is both important and heartening to see is the range of research projects being undertaken to improve the quality of technology education.

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What constitutes good learning in technology education: how can we ensure that technology education graduates can provide it?

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This paper sets out to explain the author’s belief that transferable skills to be found in designing and making activities can provide the ‘good’ learning for pupils studying Technology Education. Firstly using references from relevant literature, the importance of, and difficulties inherent in design activity will be considered. Certain aspects of a teacher’s understanding of and thereby pupils’ understanding and ability to carry out the activity successfully will be discussed. The difference between physical skills and conceptual tools required whilst designing will be reflected upon. This will lead to a discussion regarding the differences between subject knowledge, pedagogical knowledge and personal subject constructs and the timeframe available to train teachers of TE that enables or hinders the ‘good’ learning from taking place. The author’s own research which has informed her thinking over the years on these matters will be used to support the points of view she has put forward throughout this paper.

Introduction
This paper has emerged out of the author’s life-long passion for what in the United Kingdom (UK) is called Design and Technology (D&T), her on-going research that has informed her practice as a teacher of D&T for nearly fifty years, and in particular her practice as a trainer of D&T teachers for the past twenty-five years.

Much has been written about the place that D&T Education should play in meeting the needs of society (e.g. Barlex, 2011; Kimbell & Perry, 2001). Researchers and educationalists from across the globe have called for every pupil to have high quality academic, social and physical skills, whilst of particular relevance to those involved in D&T, or as it is more widely known – Technology Education (TE), the need for a technologically literate society (e.g. Martin, 2007; Rauscher, 2007; Trilling & Fadel, 2009) to meet the demands of the 21st Century is rightfully emphasized. Although most would recognize that technological literacy could be developed across many aspects of a school’s curriculum, it is within TE that the opportunity for such learning abounds.

While it is acknowledged that not all pupils will use all the knowledge acquired in technology lessons during their working lives, the important transferable skills that can be developed through activities carried out in technology lessons are agreed to be of significant importance in the education of all pupils (e.g. Lawler, McTaminey, de-Brett & Lord, 2012). For example such overarching skills as being creative, thinking critically, being able to problem solve creatively, being motivated to find out for oneself, communicating in a variety of forms, taking risks and stepping outside one’s comfort zone, exploring practical uses of Mathematics and Science, exploring value issues and
understanding technological systems, to name but a few. For those who agree that this is the case, then the manner in which these skills are taught is important, for one cannot ignore the relationship that exists between ‘good’ learning and ‘good’ teaching.

In trying to answer what is implied by ‘good’ learning and ‘good’ teaching and how they can be achieved, this paper will not be referring to TE as a whole but homing in on one aspect that the author (Atkinson, 2009; 2011) and many others (e.g. Barlex & Rutland, 2004; Baynes, 2009; Lawler et al, 2012; Nicholl, McLellan & Kotob, 2009; Welch, 2007) consider to be important – the activity of designing.

Firstly using references from relevant literature, the importance of, and difficulties inherent in designing within TE will be considered. Certain aspects of a teacher’s understanding of designing and thereby pupils’ understanding and ability to successfully carry out the activity will be discussed. The difference between physical skills and conceptual tools required whilst designing will be reflected upon. This will lead to a discussion regarding the differences between subject knowledge, pedagogical knowledge and personal subject constructs pertinent to a teacher of TE and the timeframe available to train teachers of TE that enables or hinders the ‘good’ learning from taking place. Throughout the paper the author’s own research will be used to support her points of view.

The activity of designing

In 1989 in the first National Curriculum (NC) for England and Wales the reasons given for the inclusion of designing and making within a school’s curriculum were the recognition that ‘the capability to investigate, design, make and appraise is as important as the acquisition of knowledge’ (DES, 1989.1) and the acknowledgement that D&T was an area of the curriculum which could develop such capability. This support has continued. The latest NC states that D&T must provide opportunities for pupils to combine practical and technological skills with creative thinking while designing and making products and systems that meet human needs (QCA, 2007).

However, as early as 1986 the Secondary Examinations Council (SEC) spoke of their concerns about the rigid design process model that was being used in schools. This was followed in the early 1990’s by Archer and Roberts’ (1992) indication that designing was not a simple activity and their belief that it was problematic for learners because of “…obscure about what the requirements might be, ignorance as to what sorts of provisions might be suitable and uncertainty as to how well the one might fit the other” (Archer & Roberts, 1992, 3-4). From 1992-1997 the author’s own PhD researched key factors causing too many 16-year-old pupils to become de-motivated by design and make activities. Her findings concerned her greatly and led to a number of further small-scale research projects into why designing was so problematic. Evidence from many other researchers over the years supported these concerns. Some agreed that too often designing in schools was not taught as well as it could be (Kimbell & Stables, 2007; Norman, 2008; Ofsted, 1998; 2000; Spendlove & Rutland, 2007; Toft, 2007), that inadequate training of TE teachers impacted negatively upon their teaching practice (Bailey, 2012; Barlex & Rutland, 2004; Lewis, 1996) and that a lack of confidence in their own subject knowledge caused a major block in the development of quality TE in schools (Benson, 2012).
Most TE teachers would agree that pupils should enjoy the activity of designing and making and that they should be as enthusiastic about designing as they are about making. Some pupils are, although quite often the reason for their enjoyment is nothing to do with the process of designing itself and is more to do with an enjoyment of the individual physical skills they learn to use during that process (Atkinson, 1997). Pupils need to believe that although it can be a challenging learning experience, that if carried out successfully ideas will lead to products which when well made, they can be proud to own. Badly designed products however well made, and whatever new skills have been learnt along the way are a disappointment. Such outcomes are a frustration particularly to those pupils who are born with, or have developed tacit design intelligence that enables them to understand what is or is not well designed. Unfortunately these very pupils are the ones who become bored by the simple step-by-step models they are expected to follow during their design activity and end up becoming disenchanted with the whole subject (Atkinson, 1997). However, at the opposite end of the spectrum there are many pupils who do require a structure to follow. They need considerable help to understand what they must do, how they must do it and what they should be thinking about in order to achieve the level of designerly thinking that many believe is inherent in TE (Atkinson, 2009).

There are numerous complex entwined internal and external factors that influence a pupil’s designing (Atkinson, 1997; 2009). However this paper only concentrates on two: the design process models that teachers provide for pupils to use, and the teacher’s own knowledge and understanding of designing. This is not because the others are unimportant but because the author believes that the combination of these two provide a substantial challenge for many teachers of TE.

Designing can be broken down into two main sets of knowledge and understanding. It is essential that both sets are explained, thought about and taught if teachers are to provide the necessary support and learning required by pupils when they are carrying out the activity. There is a set of easily taught physical skills and there is a set of difficult, intangible concepts and intellectual thinking skills. The first set includes such areas of learning as drawing skills, presentation skills, CAD and CAM skills, researching skills, specification writing skills, 2D and 3D modelling skills and even tasks to encourage creativity. In this set there are also the plethora of practical skills concerning appropriate materials, components and processes that need to be understood enough to be used when turning ideas into reality. These tend to be straightforward to teach, time consuming but clear-cut. It is the second set, the intangible designerly thinking aspects of the activity that are difficult for teachers to provide a simple set of explanatory guidelines for pupils to understand and use, and yet not be constrained by.

Part of the problem has been that all the design process models produced over the years have been of necessity a simplification of the real process involved. A simplification that is useful as a set of reminders of what might be involved (SEC, 1986) but unhelpful in explaining the complex, interactive nature of the activity. Hennessy & McCormack provided a pertinent insight into what they called “a veneer of accomplishment” (Hennessy & McCormack, 2002) in which pupils appear to use a process (and hence have apparently learnt it) but in fact may not have understood it. As stated earlier, by comparison teachers and pupils have tended to find the knowledge and physical skills
required to support design activity straightforward to teach and/or learn although the sheer volume of knowledge and skill required and whether this should be learnt before or on a needs to know basis has attracted much attention and debate.

Many pupils without tacit design intelligence are unable to develop an understanding of the conceptual tools required during design activity without help. This becomes problematic if teachers themselves do not have that understanding either. In the UK there are many teachers who were not taught to design during their training. For instance craft teachers who were trained before the introduction of designing into the curriculum. This has had a knock-on effect over the past twenty years because of the cyclical movement of knowledge from teacher to pupils who then become teachers and lecturers training the next generation of teachers to design. This has inevitably resulted in many teachers in schools today still not displaying a deep understanding of the activity within their teaching. Whilst some have agreed that teachers with a lack of the necessary physical skills cause the problem, others have firmly laid the blame at the door of examination boards, citing the demands of imposed assessment regimes as the cause. The author believes that the shortfall in research discussing poor design process skills as a potential problem is because many do not recognise the deficiencies caused by a lack of in-depth understanding of the process involved. In 2000 the author (Atkinson, 2000) concluded that the linear assessment model imposed by examination boards was partially to blame although she believed that it was more to do with teachers feeling secure when sticking rigidly to the models of assessment provided for them. Thankfully there has been evidence from other schools indicating that the process did not ‘straitjacket’ their pupils’ examination projects, with design activity achieving top grades plus the ‘wow’ factor that well designed outcomes deserve. Unfortunately in recent years it would appear that the number of these ‘best-practice’ schools has not increased.

Evidence, from visits to schools, work as external examiner at a number of different TE teacher training institutions, and from applicants applying to study at the author’s own university, has indicated that many pupils are still not being encouraged to understand the complexities inherent in the activity or taught how they can design creatively within examination assessment models. As the author reported in 2009, the design process model used by older pupils has all too often been an inappropriate repeat of the simple model used earlier in a pupil’s education – re-enforced by the high mark awarded in the TE public examination taken by pupils aged 16. This then led these teachers to believe that their pupils must have been taught to design correctly as they had achieved a good mark, so a repeat of the same was all that was required in the final public examination that occurred just before pupils left school at the age of 18. Sadly once again the belief in the process used was often supported by another ‘good’ mark. Research by the author in 2010 indicated that once at University these students expected that the ‘successful’ design practice they had used at school would continue to serve its purpose, only to find that they had to spend time, firstly struggling to accept, and then coming to terms with, their misconceptions and poor design practice. Unfortunately the research also indicated that some students on shorter courses never even got as far as accepting that they needed to change their practice.

The author first researched this concern regarding the level of understanding about
designing by students on short university courses in 2007. The project emanated out of a student’s overheard comment ‘Why can’t I design as well as other people? I thought I understood the process and what was required’ (Atkinson, 2007). The study set out to discover how many students this statement applied to and to try to identify the challenges that such students faced. Results suggested a larger number of students falling into this category than was anticipated. The research also indicated an interesting link between a person’s preferred learning style and their style of designing (this relationship will be discussed in more detail later in this paper). The findings from the 2007 study led to the next year’s research (Atkinson, 2008). In this project the student’s design activity was interrogated in greater depth with the result that a clearer picture of designing style and the differences between those who had traditionally trained to become TE teachers (those studying electronics and resistant materials) and the relative newcomers to the subject in England, the textile and food technologists, was teased out. The data collected indicated that there were indeed significant differences between each group’s understanding and attitude towards designing. The data also continued to support the belief that the length of time the students studied, and their relevant prior knowledge were important factors in determining whether they were successful or not. The reasons for the existence of what appears to be problematic short university courses will be discussed in a later section of this paper.

The most recent piece of research carried out by the author and a colleague in 2011/12 (Atkinson & Sandwith, 2012) once again concentrated on design activity and how to improve a students’ understanding of the process. This time the study concentrated on teasing out the factors that appeared to enable some students to be passionate about their design activity whilst others from similar backgrounds and expectations, given the same brief, and in the same learning situation, did not reach that same level of enthusiasm. The importance of passion in terms of design activity is supported by the well researched links between creativity, intrinsic motivation and passion (e.g. Leonard and Swap, 1999). Teachers of designing 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 sometimes arduous and difficult process required to achieve outcomes of which they and their teachers can be proud. Information gained from the study provided an informed picture of the relationship that existed between ‘level of passion’ and successful design activity. The qualitative data also indicated that students who were passionate designers used language that was full of positives and that they were on the whole happy within themselves and relished challenging, unknown situations. Whereas students who were not passionate about their design activity tended to have a ‘glass-half empty’ and a ‘can’t do’ attitude towards their activity that placed a significant barrier between them and that activity. Their fear of not understanding the process appeared to prevent them from trying to improve their design practice (Atkinson & Sandwith, 2012). Unfortunately the research supported the author’s belief that it was an increasing proportion of students that appeared to fit in this category.

Although, as has already been pointed out not all students have difficulties with designing. There are students studying to become TE teachers whose design activity is excellent and whose skills are such that they are able to transfer that knowledge into an
appropriate form for use when they become teachers. However we must not be complacent about the group of students that do not fit this description, either for the sake of the pupils they will teach in the future or the prospect for the integrity of our subject in the years to come.

The relationship between learning style and designing style

Over a period of ten years the author researched and developed her understanding of the relationship between the ways people prefer to learn and the ways in which they prefer to design (Atkinson, 1997; 1998; 2002; 2003a; 2004; 2005). Individuals design and learn differently from one another. There have been many studies that have examined how people preferred to learn (e.g. Biggs & Moore, 1993; Entwistle & Ramsden, 1983). Riding and Cheema (1991) analysed 30 labels that other researchers had given to cognitive or learning style. They grouped them into a number of learning strategies and two principal learning styles or dimensions that were independent of each other. They referred to these as a Wholist-Analytic (W-A) dimension and a Verbaliser-Imager (V-I) dimension: defining the W-A style as the tendency for individuals to process information in wholes or in parts; and the V-I style as the tendency for individuals to represent information during thinking verbally or in images. The connection between the W-A dimension and designing can be explained when one considers that for designing to be successful the process should be a holistic experience (e.g. Kimbell, 1994), although the need to be analytical at certain times within the process is also recognised as essential. The connection between the V-I dimension and designing can be understood when one considers the fact that imagining has always been thought of as central to the generation and development of ideas. The author's interest in learning style and designing style began with the identification of a mismatch between learning style and teacher imposed design processes as one of the key factors in pupils motivation levels during her PhD (1997). This was followed as a lecturer in University with a study identifying the relationship between a university student's preferred ways of learning, past experience of TE and levels of success in their design activity, to see if the results replicated the findings of pupils in the PhD study (Atkinson, 2003a). The data did indicate similar differences in achievement within design activity in terms of gender and preferred ways of learning.

To develop a greater understanding of the significance of the findings a follow up study the next year looked at the relationship between a student's preferred learning style, attitude to learning, appropriate prior knowledge and achievement. In this instance achievement was in the context of computer aided learning (CAL) during an electronics module (Atkinson, 2003b). At the time there was external pressure on those in education to use CAL. The TE academic team wished to ensure that the CAL interface was a help not a hindrance to a students' learning and to know whether the CAL activity being trialled benefited students belonging to one learning style group more than others. The research findings highlighted the fact that preferred learning style was indeed an important factor in a student's attitude to learning and their ability to achieve when using CAL and that CAL was an appropriate learning tool in some situations and not others.

In 2004 once again using the school data collected for her PhD plus a new set of data collected from students studying TE at two universities, the author once again targeted the
relationship between preferred learning style, creativity and achievement within design activity (Atkinson, 2004). This research provided the author with a greater understanding of the link between learning style and designing style. Also of particular interest was the finding that there was a marked difference in terms of preferred learning style and conceptual understanding of designing between the two universities. Leading to a question as to whether this had anything to do with the very different average ages of the two university samples. The next piece of research teased out further the link between age and preferred learning style. The sample was made up of a mixture of mature students and students who had come directly from school and the results did indicate a significant difference between the two groups (Atkinson, 2005). The older the student the more able they were to cope with learning materials that did not match their learning style. The data also showed that the younger the student the more polarised his or her preferred learning style appeared to be. As a consequence of these findings the author re-designed the materials she used to teach students about designing, in an attempt to make them more palatable to all rather than just some of her students. The results were also used to inform the final year students who were preparing for their teaching practice placements, about the link she had found between learning style, teaching style and teaching materials.

**Content knowledge, pedagogical knowledge and pedagogical content knowledge**

Ever since the mid-1980's, in terms of teaching ones subject, there has been a growing understanding of the complex relationship that exists between subject knowledge and pedagogy. Shulman's (1986) contribution was to identify the overlap between two aspects of teacher knowledge, 'Content Knowledge' and 'Pedagogical Knowledge'. He named this intersection Pedagogical Content Knowledge, which he explained was the very important interplay between pedagogy and content.

In terms of mapping the teaching of designing onto this model, the cluster called Content Knowledge refers to a teacher’s personal conceptual understanding and knowledge of designing. The cluster called Pedagogical Knowledge refers to, what a teacher needs to know about teaching in order to deliver the subject of designing to a class of pupils. The third cluster, called Pedagogical Content Knowledge refers to the changes that the teacher must make to his/her personal knowledge of designing in order to turn it into a form that is appropriate for a specific group of pupils to understand.

In 2004 a model of professional knowledge from a TE perspective was developed (Banks, Barlex, Jarvinen, O'Sullivan, Owen-Jackson & Rutland, 2004). The model was based on Shulman's work. However, it referred to a teacher's 'Professional Knowledge' in terms of four rather than three interlinked clusters: Subject Knowledge; Pedagogical Knowledge; School Knowledge (which Shulman had called Pedagogical Content Knowledge); and at the centre of the three the researchers added a teacher's Personal Subject Construct.

In 2009 in a keynote lecture the author explained her thoughts regarding her own professional knowledge in the context of design activity. She suggested that over the years through practice she had increased her understanding of how to teach. The interplay between pedagogical knowledge and subject knowledge in terms of designing, had been
dynamic, and clarified her understanding of both, thus enabling her to think through the activity in a more appropriate form for her students (school knowledge). This had then led to a continual improvement of the subject constructs and strategies (personal subject constructs) that she used to aid her teaching. However she indicated that the important ingredient ‘thinking-time’ needed to enable this understanding to develop must be present. As Ken Baynes (2009) referring to the work of Jane Abercrombie said “… ‘we may learn to make better judgements if we can become aware of some of the factors that influence their formation’. In other words, we should think about thinking as well as thinking” (p8).

**Initial teacher training (ITT) for TE in England**
This need for thinking time brings the author to the next pertinent focus of this paper, that being the knock-on effect of the shrinking time spent studying to become a TE teacher in English Universities. TE secondary teachers used to study on four-year undergraduate courses with pertinent subject knowledge and how to teach being interspersed throughout the four years. In the mid-1990’s the government began removing their financial support for four-year courses once they had introduced a one-year Post Graduate Certificate of Education (PGCE) which relied upon first-degree courses to provide the subject knowledge required, while the PGCE course concentrated on teaching the students how to teach (more detail of these changes and their implications can be found in Atkinson, 2008). This erosion has continued. In 2012 the majority of universities now only provide PGCE courses. Indeed, with the government’s recent move to a ‘work-based’ model using teaching schools, the number of universities even providing PGCE courses is set to fall dramatically. Much research has been published decrying these changes particularly amongst the TE fraternity where the misalignment between subject knowledge gained on a first degree and what is required to teach TE is problematic (Tuffnell, 1997). As early as 1996 Lewis recorded concerns about the varied backgrounds of PGCE students whilst negatively comparing the subject knowledge that they possessed with the subject knowledge of those who trained on longer undergraduate courses (Lewis, 1996). Banks & Barlex (1999) specifically researched the lack of subject knowledge of PGCE students. While both Rutland (2001) and Zanker (2005) talked about the short length of time that PGCE students could devote to filling gaps in their subject knowledge to bring it inline with the requirements of a TE teacher when they had to spend 80% of the year in school, learning to teach.

In 2009 the author’s own research picked up on her previous findings concerning the problems of ‘length of time studied’. It targeted a student’s attitude to TE, to designing and to teaching TE. It used a student sample from TE courses of different lengths (1-yr, 2-yr and 3-yr) at the author’s university (Atkinson, 2009). The results provided more evidence to support the belief that the longer students studied the better their attitude became. The results added to the concerns of the TE academic team and their awareness of the need to plan better strategies to help develop a more positive attitude amongst the students on shorter courses. However the team wondered if this result only applied to its own institution. So in 2010/11 a project led by the author in collaboration with a second university and a series of secondary schools looked into the differences between TE.
teachers trained on Undergraduate (UG) and Postgraduate (PG) courses, both during their study and once they became teachers (Atkinson, 2011). The results suggested that during their studies PG students achieved slightly higher grades for teaching. Although, as teachers the data from the schools indicated that UG trained teachers were the better teachers, both in their early years of teaching and as established teachers. The findings once again provided support for the need for longer study time on TE ITT courses. However, there has been a pragmatic recognition across the UK that a return to longer courses is unviable in the current financial climate especially with a government that believes that a good first degree in an appropriate subject plus a one-year PGCE is the best way to provide first class teachers. This has proved to be the case in some subjects but all the research concerning TE indicates that it is not the case in TE where there is a misalignment between subject content of first degrees and what is expected of a good TE teacher.

**Conclusion**

This paper has not set out to provide a definitive list of specific topics that constitute ‘good’ learning in TE, for although there are technological issues and values that should be part of every child’s TE experience, it is also the case that each country’s priorities and expectation of what TE should provide, are different. Topics move in and out of fashion and the speed of the development of new technologies means that some subject content is quickly outdated. So to talk about specific content as being a must for ‘good’ TE learning fails to recognise the dynamic nature of the subject or its ability to take on different forms in different learning environments.

However, TE in all countries can provide important, distinctive, ‘good’ learning scenarios that are difficult to mirror in other areas of the school curriculum. Learning that allows for what Bronowski (in Barlex, 2011) called the important combination of the hand and mind in action, and which Leith in her support of TE as a ‘doing’ subject said “Tell me and I forget – show me and I may remember – let me do it, and I learn” (Leith quote in the National Curriculum (DES, 2004, 82)).

This paper has discussed important transferable skills that should be taught in TE. Ones that will provide appropriate opportunities for ‘good’ learning to take place that will benefit all pupils throughout their lives. In this paper the author has, with reference to her own research and that of others, explained that designing and making can provide an excellent vehicle for these transferable skills. Designing and making can also provide activities that are flexible enough to embrace different visions of TE, and appropriate means of teaching about and using new technologies as they arise.

However, the paper has also indicated that the key to whether learning is ‘good’ learning is the teacher, with research to support the belief that the development of sound skills, knowledge and understanding about the activity of designing and making for those studying to become TE teachers is paramount however difficult this might be due to changes in the ways in which TE teachers will be trained in the future.
References


Negotiating the Vacuum: constructing and applying assessment criteria to focus design learning

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Educators are currently required to conform to a model where learning and assessment are pre-determined, defined in a way that can negate the need for discussion and serve to create a ‘dialogic vacuum’ around assessment. This can be particularly problematic for Design subjects as they seek to engage in pedagogy that focuses on how we might live our lives rather than on known understandings. This paper draws on the findings of a two year small-scale research study conducted in a higher education Design context. Using a practice led approach, it examines how assessment criteria might best be constructed and applied in order to focus Design learning in desired ways. The research methodology is explained in detail, and the outcomes are analysed and discussed. The conclusions drawn from the evidence are that, by constructing and using assessment criteria in specific ways, differing stakeholder views of assessment can be validated, authentic problem solving opportunities can be negotiated and learners can be empowered through assessment. These conclusions are drawn together to offer a set of philosophical principals for developing and applying assessment criteria and insights are offered into ways these principals might be applied in other educational contexts.

Introduction and Theoretical Perspective

Higher Education (HE) assessment practice remains imbued with the principles of behaviourism (Brown, 2006). The use of learning outcomes and ‘constructively aligned’ assessment criteria are based on behaviouristic principles, requiring educators to conform to a model where learning is pre-determined, defined in a way that often negates the need for discussion and instead creates a ‘dialogic vacuum’ around assessment.

This can present a paradox for Design educators who seek a ‘pedagogy of possibility’ as a way forward for assessment practice (Mayo, 1999; Keesing-Styles, 2003; Bain, 2010), who seek to rethink assessment practice in a ‘sustainable’ way (Boud, 2002), that is from the perspective of autonomous, lifelong learning and who seek to integrate more contemporary theories of learning, such as Transformative Learning (Mezirow, 2000) and Expansive Learning (Engestrom, 2009), into their practice.

This paper seeks to examine this paradoxical dilemma by focusing on framing and using assessment criteria in ways that seek to empower learners through assessment. It draws on a conceptual model of assessment, ‘Assessment for Becoming’ (Bain, 2010), that offers an authentic approach to student voice in assessment practice and focuses on ‘how we might live our lives, rather than on known understandings’. The model outlines a pedagogy that endeavours to be transformative: educating students to take risks, to struggle with ongoing relations of power, to critically appropriate forms of knowledge that exist outside their immediate experience, and to envisage versions of a world that is ‘not yet’…
‘Assessment for Becoming’ is designed to promote the autonomous learner, who takes a pro-active role in the learning process, generating ideas and looking for learning opportunities, rather than simply reacting to the various stimuli of the teacher (Knowles, 1975; Boud, 1988; Bain, 2010). The features of Assessment for Becoming identified as pertinent to the paper are identified in figure 1 below.

- Student’s opinions on assessment are given space, epistemological, practical and ontological modes of voice, audience and influence.
- There are opportunities for students to negotiate what, when and how learning is assessed.
- Feedback from assessment is collaborative and reflexive.
- Students are active subjects, with assessment language that of the student. There is possibility for praxis.
- The approach to assessment includes lecturer-led, peer and self-assessment.
- Sustainable assessment practice is developed.

Figure 1: Pertinent Features of Assessment for Becoming

Research Methodology

This paper draws on a two year small-scale research study conducted in a higher education Design context. The overall aim of the study was to develop assessment practice that embodied a set of principles that might improve the consequences of assessment, or consequential validity (Messick, 1989; Boud, 1995; Boud 2007), which refers to the effect of assessment on learning (Messick, 1989; Linn, Baker and Dunbar, 1991).

Phase 1 of the study examined whether the consequence of current assessment practice was in keeping with the desired consequence of Assessment for Becoming, and whether this contributed to the creation of a dialogic vacuum around assessment. Practice trialled during Phase 2 was derived from Phase 1 findings. The primary focus was to examine how assessment criteria might best be constructed and applied in order to transform the dialogic vacuum of assessment into a rich and vibrant dialogic space in order to improve the consequential validity of assessment.

The most appropriate strategy for the research was deemed to be an exploratory single-case study, where the rationale for the single-case is revelatory (Yin, 1989). Accordingly, a theoretical sampling approach was used (Marshall, 1996). A sample of 112 UG and PG students from across a HE Design department was selected. The researcher then adopted a ‘purposive’ approach (Cohen, Manion and Morrison, 2003: 103), selecting three groups of 10 students for group semi-structured interviews.

Decisions around data collection were based on the need to build as rich and meaningful a case study as possible. It was felt that employing more than one research method would also enhance rigour and avoid invalidation (Robson, 2002). Questionnaires were given to participants at the beginning of Phase 1 and the end of Phase 2 in order to investigate changing perspectives on assessment. Observations and semi-structured interviews were considered appropriate in order to provide more focused empirical data (Cohen et al, 2003) by observing current practice, getting participants to talk about their
understanding, perceptions and experiences of assessment (Phase 1) and to investigate the impact of the pedagogy developed on the consequential validity of assessment (Phase 2).

Data analysis was concerned with organising and making sense of the data, noting ‘patterns, themes and regularities’ (Cohen et al., 2003:147). The research used a wider ethnographic stance to coding (Robson, 2002), using the key features of Assessment for Becoming to develop a list of categories prior to fieldwork, whilst incorporating a grounded theory approach (Glaser and Strauss, 1967), to allow for themes to emerge from analysis of data.

**Summary and Discussion of Relevant Phase 1 Findings**

Phase 1 revealed quite starkly the contradiction between the role of student voice in current assessment practice and that conceptualised by Assessment for Becoming. This was revealed by observations of practice and questionnaire data and backed-up by more in-depth interview discussion.

All programs were focused on the delivery of Desired Learning Outcomes (DLO), with evidence of assessment criteria aligned to the DLO (Biggs, 2003). However, application of assessment criteria was housed in a system of assessment characterised by a summative, lecturer-led approach. Findings confirmed that assessment criteria were exclusively pre-determined and lecturer-driven, with their generic nature problematic for students. There was some evidence that formative assessment activities supported critical thinking and resulted in a ‘pure learning effect’ (Dochy, Segers, Gijbels and Struyven, 2007: 91). In this, through the need to organise and refine knowledge, students learned during assessment itself, stimulating thinking of a higher cognitive level (Nevo; 1995; Struyf, Vandenberghe and Lens, 2001). Observation data indicated some evidence of sustainable assessment practice (Boud, 2002). However, the impact of this on empowering learners was again limited by a lack of exploration of assessment criteria and the consequence of this appeared to be that, even in a constructively aligned programme delivery, a ‘dialogic vacuum’ existed, where students struggle to understand what is being assessed, again dependent on the lecturer, seeking clues on how to succeed (Miller and Parlett, 1974), see figure 2.
In setting up an aligned system there are 4 major steps:

1. Defining the Desired Learning Outcomes (DLOs)
2. Choosing the teaching/learning activities likely to lead to the DLOs
3. Assessing students' actual learning outcomes to see how well they match what was intended
4. Arriving at a final grade

Based on Biggs (2003)

**Figure 2: The Dialogic Vacuum of Assessment**

Findings also indicated that the language used in student/academic dialogue and feedback appeared complex, judgemental and grade driven. This seemed of little use to students in helping them learn, as they struggled to find meaning in what was being said or written. The predominant use of ‘final vocabulary’ (Rorty, 1989: 73) appeared to leave little room for manoeuvre, ‘It has the final say. It classifies possibilities’ (Boud, 1995: 44).

In conclusion, from Phase 1 findings it was possible to assert that the consequence of the limited role of student voice in developing and applying assessment criteria, was to encourage learners to be dependent on their lecturers, disempowered in terms of assessment and with the potential to perpetuate social inequality (Giroux, 1989; Zgaga, 2005). It is also possible to assert that, when considering key features of Assessment for Becoming (see figure 1), the consequential validity of assessment practice across the Design department was low and Phase 1 data illuminated central issues that contributed to this, see figure 3.

- Lack of opportunity for student voice in assessment
- Generic ‘meaningless’ nature of assessment criteria, which were rarely used to focus learning
- Feedback predominantly focused on grades rather than learning
- Overly complex language which made feedback difficult to access and apply
- The approach to assessment exclusively lecturer-led
- Students remain dependent on trying to ‘please’ lecturers as a means to succeed

**Figure 3: Issues Contributing to Low Consequential Validity**

**Phase 2 Findings and Discussion**

Phase 2 of the research study centred on developing assessment practice consistent with the assessment features described in figure 1. Several headline findings emerged from Phase 2 data to support the assertion that the new approach to developing and applying
assessment criteria had improved the consequential validity of assessment, in keeping with
the stated aims of Assessment for Becoming. The findings were:
- Over time students attitudes to assessment became more positive
- Engagement with the dialogic approach to assessment appears to increase
  students understanding of the connection between learning and assessment
- Student and Lecturer judgements on quality of work became more consistent
- Students described being more in control of their attainment and became pro-
  active in developing assessment 'communities of practice’
- The dialogic assessment activities appeared to increase authentic ‘constructive
  alignment’
- The process provokes critique/evaluation of the DLOs and appears to
  compensates for broad or vague DLOs

Learning activities focused on developing and applying assessment criteria in order to
improve consequential validity were refined and tested over 5 terms of 2 academic years.
An initial development phase was followed by 3 single term cycles of trialling, evaluating
and refining the activities. Their effectiveness in improving the consequential validity of
assessment was evaluated through semi-structured interviews, analysis of feedback data,
analysis of summative assessment data and end of Phase 2 questionnaires. Pilot activities
were run as part of 8 courses, spread over 3 programmes. This section reports on the most
consistently effective approaches.

Early development of learning activities considered ways to provide spaces and
practices that nurture dialogue as integral practices of human learning and daily encounter
(Griffiths, 2003 and 2004; Leitch, Lundy, Clough, Galanouli and Gardner, 2005; Bain,
2010). Pedagogy centred on introducing, discussing and maintaining focus on assessment
criteria as central to and directly related to learning. Activities such as taught sessions,
seminars and tutorials were rooted in dialogic interactions so that the roles of teacher and
learner were shared and different modes of student voice were validated (Freire, 1973;
Keeling-Styles, 2003), with dialogue consistently focused on assessment criteria as a means
to focus learning. A particular emphasis was put on ontological voice so that ‘a student
need not force himself into the identikit model of a successful student …He (sic) can
discover his own individual way of being a student’ (Batchelor, 2006: 791). Student’s views
on assessment were given space, voice, audience and influence (Leitch et al, 2005), the
pedagogical approach assumed the students were intellectual performers rather than a
docile and compliant audience, and this appeared successful in supporting students to take
control of their learning and in encouraging critical thinking (Harvey and Burrows, 1992).

Assessment appeared particularly effective in focusing learning when students were
provided with ‘modelling’ opportunities, followed by scaffolding and fading activities
(Falchikov, 2007). These were refined over the 5 terms to include preparatory activities
that provided ‘base’ assessment criteria pre-written, which then supported students in
learning how to develop assessment criteria and encourage ownership of these criteria
(Falchikov, 2007). Scaffolding activities also focused on the selection and use of
assessment criteria, in a real rather than preparatory situation (Falchikov, 2007). Again,
provision of ‘base’ criteria appeared to support the learners in developing their
understanding of the links between learning and assessment and, as lecturers collaborated
with students to provide support, develop shared understanding. Fading activities involved lecturer support for developing and applying criteria being reduced over time (Fineman, 1981; Falchikov, 2007) and explored the degree of autonomy afforded to students in developing and applying criteria. Data revealed that students consistently required more modelling and scaffolding when introduced to the concept of student voice but this lessened over time.

It was considered important to explore what or who drives assessment and how it might contribute to the process of empowering learners. Data indicated that the dialogic approach described above was effective in lecturer-led assessment, but two approaches to assessment, peer and self-assessment, proved particularly effective in developing a collaborative approach to assessment (Hounsell et al, 1996; Black and William, 1998; Falchikov, 2005). Consistent with the key features of Assessment for Becoming, the consequence of implementing peer-assessment appeared to be to encourage ‘reflexivity, self-regulation, and active learners’ (Boud, 2007, p22). In addition, trials of the learning activities revealed a future-driven approach to be most effective in creating a climate for authentic student voice with ‘the power to sustain itself beyond completing the programme of study’ (Tan, 2007, p119). Activities were developed where the role of the academic was to work in partnership with students to develop their self-appraisal skills in constructing and refining assessment criteria. This process permitted students to focus ‘beyond the expectations of the teacher’ (Tan, 2007, p120). Data analysis showed that this collaborative approach supported students in reflecting more critically on assessment, presenting them with an effective opportunity to enhance their learning.

Careful consideration was given to the kind of language used in the dialogue of assessment. Boud (1995: 44) asserts lecturers must ‘choose our words carefully with an eye to the consequences …and provide something valuable which learners can use to change what they do, and not have to worry about defending themselves’. Development of learning activities focused on application of assessment criteria and feedback engaging students and lecturers in ‘reflexive and collaborative dialogue’ (Hounsell, 2007: 106). Data revealed this process to be most effective when it resulted in action, such as adjustments to teaching (Black and William, 1998). The approach to application of criteria and feedback was of one controlled by the student and driven by their needs (Mallett, 2004). Here data revealed that greater student engagement with assessment criteria appeared to generate rich feedback, particularly where this was supported by interactive learning conversations about assessment criteria, feedback, self-assessment and critical reflection (Robinson and Udall, 2006).

The most problematic issue for students and lecturers emerged early on in the data analysis. Both groups appeared to grapple with the relationship between learning and grading (or quality of learning) when developing and applying assessment criteria. Different approaches were trialled and literature around assessment criteria provided insights into different approaches (Rust, 2003; Price, 2005; Brown and Pickford, 2006; Bloxham and Boyd, 2007). Hughes (2010) reveals a way forward by making a clear distinction between criteria and standards, stating ‘It is important to understand the distinction between criteria and standards. A clear understanding of these terms will make the development task easier’. Sadler (1987) defines these terms as:
**Criterion:** a property or characteristic by which the quality of something may be judged. Specifying criteria nominates qualities of interest and utility but does not have anything to offer, or make any assumptions about, actual quality.

**Standard:** a definite level of achievement aspired to or attained. Standards are about definite levels of quality (or achievement, or performance).

Over the course of the study, data reveals that a separation of assessment criteria from quality descriptors allowed both students and lecturers to make sense of each, bringing them together to inform learning and make effective judgements around the quality of learning.

Data also revealed that, particularly during modelling and scaffolding activities, students struggled to make sense of criteria in relation to their assessed outcome. Over time, interview data reveals a simple solution was found.

Student 46: It was amazing really. The assessment criteria seemed, well, abstract... but as soon as we turned them into questions then we could ask the work questions.

Researcher: Could you explain what you mean by that?

Student 46: Yeah, instead of, say, a criteria that says something about being able to apply different Design methodologies – we just reworded it to a question. So it became ‘Do I draw on different Design methods and do I explain why each one was selected and ‘Bingo’ it (the criteria) was real and relevant.

Thus, framing assessment criteria as questions, using the language of subject proved most effective in supporting application of criteria in an independent way.

**Conclusion**

Consistent with the philosophy of Assessment for Becoming, this paper is not about prescribing an assessment methodology, but rather ‘...locally and contextually formulating practice within an integrated moral and epistemological stance’ (Simon, 1992: 58).

However, in bringing the Phase 1 and Phase 2 findings together, it is possible to speculate on the kind of practice around developing and applying assessment criteria that might be consistent with Assessment for Becoming and might improve the consequential validity of assessment practice.

Accordingly, drawing on methodology developed by Boud (1995) and (Falchikov, 2005; 2007), it is possible to offer a framework, consisting of sixteen philosophical questions, to inform development of assessment practice that might create a rich and vibrant dialogic space around assessment criteria, see figure 4 below. This framework is based on the main findings of this study and on the assessment practice revealed above, as such, it is consistent with the features and philosophy of Assessment for Becoming in embracing a number of principles that may not be familiar in generic HE assessment practice. It is proposed as relevant in informing assessment practice across HE subject boundaries and, particularly in terms of modelling and scaffolding assessment criteria, to other phases of education.

In closing, it is important to acknowledge that, whilst Phase 2 data revealed that 93% of students who participated in the study could see the benefits of being involved in
developing and applying their own assessment criteria, not all of them welcomed new and innovative ways of assessment. Students were initially concerned about the potential impact of the new systems of assessment on their workload and on their marks and grades. Some also considered the introduction of peer and self-assessment as a time-saving mechanism for lecturers (McDowell, 1995; Falchikov, 2005). Students also shared with academics concern over their competence in awarding marks (Fineman, 1981; Lapham and Webster, 1999; Connolly, Klenowski and Wyatt-Smith, 2012). It is also acknowledged that innovative assessment practices may call into question the value of academics’ judgements and render the powerful powerless (McGrath, 2001). Thus, the sense of disjunction felt by the student may be shared by the academic (Savin-Baden, 2000). However, it might also be argued, as highlighted by this study, that the role of lecturers in HE is changing to one of partnership with students (Falchikov, 2005) and that their roles in assessment must form part of the complex debate around accountability in grading student work (Bloxham and Boyd, 2012).
The framework of Philosophical Questions

Student Voice around Assessment Criteria

- Is development of assessment criteria seen as an integrated part of pedagogy (Watkins and Mortimer, 1999; Boud and Hawke, 2003) that promotes sustainable assessment (Boud, 2007)?
- Do academics work in partnership with students to develop and refine assessment criteria (Tan, 2007), thus encouraging meta-cognition (Harvey and Burrows, 1992)?
- Is student voice at the core of developing and applying assessment criteria?
- Does assessment practice help develop spaces and practices that nurture dialogue as integral practices of human learning and daily encounter (Griffiths, 2003 and 2004; Leitch et al, 2005)?
- Is student/academic partnership rooted in dialogic interactions so that the roles of teacher and learner are shared and student voices are validated (Freire, 1973; Keesling-Styles, 2003)?
- Are student’s views on assessment given space, voice, audience and influence (Leitch et al, 2005) with opportunities for different modes of voice (Batchelor, 2006)?
- Is careful consideration given to the kind of language used in the dialogue of assessment?
- Does feedback engage students and lecturers in ‘reflexive and collaborative dialogue’ (Hounsell, 2007: 106) resulting in action, such as adjustments to teaching (Black and Wiliam, 1998)?
- Is feedback driven by student needs (Mallett, 2004) and the impact of dialogue, language and feedback on student autonomy considered?
- Are there opportunities for interactive learning conversations about assessment criteria, feedback, self-assessment and critical reflection (Robinson and Udall, 2006)?
- Is consideration given to a sustainable system of feedback, where ‘students are encouraged to develop a greater sense of ownership of, and thus greater autonomy in, their learning (Hounsell, 2007: 108)?

Assessment Methods

- Is the range of assessment methods diverse enough to ensure that all students have the opportunity to demonstrate their potential (Race, 1999: 68)?

Assessment Approaches

- Are student-led assessment approaches considered integral to assessment practice?
- Does assessment practice around assessment criteria provide opportunities for modelling, scaffolding and fading (Falchikov, 2007)?
- Is assessment future driven allowing students to reflect more critically on assessment practice, and presenting them with an effective opportunity to enhance their learning (Tan, 2007)?
- Are students involved in the awarding of marks (Falchikov, 2005)?

Figure 4: Framework of Questions to Inform Dialogic Assessment Criteria
References


Engaging trainee teachers of science and design & technology in cross curricula collaboration – a case study

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Alison Hardy
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This paper explores the possibilities of developing innovative curricula by means of collaboration between teachers from different disciplines through the activities and outcomes of a one day workshop between trainee teachers in science and design & technology at a university in the East Midlands of England. The results of the collaboration are discussed in terms of collaborative creativity, the requirements of the Office for Standards in Education and the role of trainee teachers as stakeholders in education. The paper identifies further areas for research and development.

Introduction
This paper is in six parts.
Part 1 develops a rationale for the collaboration between design & technology teachers and science teachers during their initial teacher education.
Part 2 describes the courses at a university in the East Midlands of England by which graduates wishing to teach science or design & technology are trained.
Part 3 describes the one day workshop at this university in which design & technology trainees were able to work with science trainees in developing areas for collaboration.
Part 4 describes the collaborations developed by the trainees.
Part 5 discusses collaboration in terms of collaborative creativity (John-Steiner 2000), the feasibility/desirability in terms of inspection requirements for single subjects (Ofsted 2012) and the Ofsted report on design & technology (Ofsted 2011), and the role of trainee teachers as stakeholders in technology education (Layton 1992).
Part 6 identifies further areas for research and development.

The case for collaboration between design & technology and science during initial teacher education
In England the intimate and dynamic relationship between science and technology is rarely reflected in the school curriculum (Barlex & Pitt 2000, Barlex 2005) despite recent attempts through the National Stem Programme (NFER 2009) even though the nature of technology can be considered in terms of that relation as proposed by Arthur (2009).

Science appears to uncover novel effects while technology exploits these … (page 60

It should be clear that technologies cannot exist without phenomena. But the reverse is not true. Phenomena purely in themselves have nothing to do with technology. They simply exist in our world (the physical ones at least) and we have no control over their form and existence. All we can do is use them where usable. Had our species been born into a universe with different
phenomena we would have developed different technologies. And had we uncovered phenomena over historical times in a different sequence, we would have developed different technologies (page 66).

The rationale for any curriculum development that responds to this view of technology must be more than a simplistic mirroring of the world outside school in an attempt to provide authentic learning activities. The work of Janet Ainley and colleagues provides a justification in proposing the utility of one subject can be engaged in the pursuit of purpose in another subject such that the learning in both subjects is enhanced. (Ainley et al 2006). Barlex (2007a) has developed this idea with specific regard to the cross curricular links that can be forged between design and technology, arguing that pupils learning through pursuing purpose by means of designing and making technical artefacts in design & technology can be enhanced if they use what they have learned in science lessons in such activities. The science learning acquires utility outside the science lessons in which it was learned and simultaneously the use of science learning in this way enhances the pupils understanding of such science as they are required to use it to inform their designing and making. To justify the time and effort spent in orchestrating such collaboration it will be necessary to identify the sorts of enhanced learning that are likely to take place and to show that such enhanced learning has indeed taken place in both subjects. The difficulties of enabling teachers from different subjects to collaborate have been acknowledged (Royal Society 2007, NFER 2009) but seen as an important goal within STEM education (Holman 2011). Clearly conversations between science and design & technology teachers are a key starting point in the process of collaboration and the authors believe that it is important to enable such conversations between science and design & technology teachers in training.

The courses taken by the trainees in this case study
Trainees at this university in the East Midlands of England have different routes into secondary school teaching but they all study one common year known as the ‘professional year’. At the end of the year, if successfully completed all trainees are awarded both a qualification and qualified teacher status (QTS). The design & technology trainee teachers involved in the workshop were studying either for a BA (Hons) in Secondary Design and Technology Education or a postgraduate certificate in education (PGCE) and had already attained a relevant degree. All of the science trainee teachers were studying for a PGCE qualification.

The professional year is an intensive forty week programme with four distinct blocks (Figure 1): two six week blocks are spent in university and two blocks, seven weeks and fourteen weeks in length, are spent in schools on placement.

<table>
<thead>
<tr>
<th>6 weeks</th>
<th>7 weeks</th>
<th>6 weeks</th>
<th>14 weeks</th>
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<tr>
<td>In university</td>
<td>School experience 1</td>
<td>In university</td>
<td>School experience 2</td>
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Figure 1: Structure of professional year.

The time in university is primarily in taught sessions with university lecturers and
occasionally external speakers. The trainees study three modules during the year: Subject Application Studies, Education and Professional Studies, and Critical Reflection. For two-thirds of the time in university trainees are in subject groups learning subject knowledge and subject pedagogy. The remaining third is in mixed subject groups for the Education and Professional Studies module during which trainees learn about their wider role as a teacher outside of their subject. This is the only time during the programme where trainees interact with those outside of their subject specialism. Within university programme there is limited time for lecturers to involve outside speakers to give talks and run workshops due to the intensity of the course. Outside speakers tend to be involved within the Education and Professional Studies module sharing expertise related to generic themes such as teacher persona, classroom management, special education needs and child protection. The workshop which is the focus of this case study took place in the Education and Professional Studies module. Prior to this workshop there had been no planned sessions between science and design & technology trainee teachers with a subject focus at the university although there had been a workshop about STEM the previous year for design & technology trainees only.

The one day workshop
The trainees were engaged with the idea of collaboration between science and design & technology teachers by means of a whole day workshop. In the first session of the workshop 39 design & technology trainees attended an introductory lecture from which they developed ‘suggestions for collaboration’ with science. The start of the lecture emphasized the following important aspects of learning design & technology in schools:
- Pupils should make design decisions and ideally this decision making should be self directed. (Barlex 2007b)
- To enable pupils to achieve this goal a combination of four important teaching strategies can be used: making without designing, designing without making, designing and making and exploring technology and society (Barlex 2011)
Then the lecture presented the utility – purpose case for collaboration between science and design & technology and asked the question “What might pupils learn in science that is useful to them in design & technology?” Then the lecture presented the following designing and making arenas in which science learning might be useful:
- Utilising the Peltier effect to develop a product that heats or cools
- Devising a moving toy for an identified user
- Developing an alternative energy device
- Developing a lighting unit with the possibility of bioluminescence
- Developing a bread based product
- Devising a radio for a particular location
- Developing an item of protective textiles with the possibility of using spider silk
The trainees were then set the following tasks
- Decide which of the collaboration examples you find most interesting or think up your own example
- Develop a three slide presentation to use with the science PGCE students to convince them that it is worth developing some form of collaboration around
In the second session of the workshop the design & technology trainees presented their collaboration examples to 24 science trainees. After the presentations the science students were invited to choose which suggestions they wanted to participate in developing. New groups with a mix of science and design & technology students developed the detail of the collaboration between science and design & technology for a particular unit of work. In addition the trainees were required to consider how they would justify the collaboration to the school senior leadership team. The trainees were required to present their deliberations by means of a slide show with only six slides and a time limit of five minutes.

Collaborations and comments from the trainees
This section contains descriptions of three collaborations and general comments made by trainees at the end of the session.

The first group took the idea of materials with unusual properties as exemplified by smart putty (see [http://en.wikipedia.org/wiki/Viscoelasticity](http://en.wikipedia.org/wiki/Viscoelasticity)) as a starting point for science and design & technology working together. They identified the following possibilities in science lessons:
- Devising and implementing investigations
- Understanding the states of matter and particle theory explanations

They identified the following possibilities in design & technology lessons:
- Investigating products to reveal underpinning science
- Developing ideas for new products starting with underpinning science – a ‘we could use it for this’ approach

In terms of justifications they identified:
- Looking at ‘properties’ in both science and design & technology would scaffold learning
- The designing from science provided opportunity for wider design possibilities and differentiation
- Real world applications providing motivation

A second group took Olympic events as a starting point for collaboration and identified cycling, running and field events. They then identified a particular focus area in design & technology and science subject relevant to each event. Hence for cycling they identified textile and physics, for running food technology and chemistry and for field events resistant materials and biology. Within these areas they then identified the following particular topics: for science aerodynamics, velocity, genetics, gravity, trigonometry and nutrition; for design & technology healthy eating plate, designing, modelling, textiles and smart materials. Their justification was very broad indicating opportunities for enterprise activity and links with the wider community through further engagement with the London Olympics.

A third group took the starting point ‘designing for the other 90%’ focusing on the availability of purified water in the third world. The topic would start in science with some questions; what may be in contaminated water (why is this bad) and what is in water purification tablets and what effect does this have? This would provide a highly motivating
introduction to the conventional science topic of separating mixtures (filtration, evaporation, condensation, distillation). In design & technology pupils would use this science learning as the starting point for designing but not making items for water purification. This approach was justified as being useful because in science there would be purposeful practical work and an engagement with how science works and the possibility of assessment by means of the knowledge demonstrated in the design & technology lessons and useful in design & technology because there were possibilities for independent learning and opportunity to use learning to address real world issues. The group saw the activity as planting the seeds for STEM in that an understanding of filtration in science through mechanical, chemical, biological and other means could provide knowledge to inform technological developments of considerable use in the developing world. In more general terms they justified the approach as embracing four important features – applying scientific knowledge and approaches, understanding how science works, designing for society and enabling autonomous learning.

The session finished with trainees providing feedback on the day by responding to two questions about: ‘What went well?’ and ‘Better if?’. Trainee feedback about what went well focused on the long and short term benefits of the day. Long term students noted that what went well was ‘D&T and Science sharing points of view’, ‘broadening understanding of cross curricular’ and ‘practical collaboration’. The immediate benefits of the day were seen as helping them to attain their teaching qualification ‘[evidence for meeting the] Q standards’ and meeting new people (‘new friends’). ‘Better if?’ suggestions were either about the practical organisation of the day (‘Briefing about session’ and ‘More time’) or about the structure and content (‘science parallel morning’, ‘groups in D&T specialisms’ and ‘science as starting point’). The science trainees had not been briefed about the event and arrived to the afternoon session with no knowledge about what they were coming to, whilst the design & technology trainees had been briefed the previous week.

Discussion
The collaboration between science and design & technology trainee teachers can be viewed as an exercise in creative collaboration in that it requires the trainees to work together and develop new and useful approaches to teaching both subjects. Vera John-Steiner (2000) has written extensively about creative collaboration and argued that collaboration between individuals who share a common vision can lead to highly creative outcomes which in many cases far outstrips what could be achieved by those individuals working in isolation. She has developed a ‘family’ pattern as one possible means of achieving this. In this vision of creativity there is a dynamic integration of expertise achieved through a fluidity of roles fuelled by a common vision and underpinned by trust. This view of collaborative creativity is useful in considering the way in which the trainees from science and design & technology collaborated in creating a curriculum in which there was some synergy between the learning in each subject. The collaboration required that they revealed their ideas, some of which were tentative and unformed, and engaged in frank discussions of their worth. This required trust. The overall result required the efforts of all those contributing. Hence they will be dependent on each other. John Steiner
reminds us there is nothing to be ashamed of in such dependence. It is a dignified interdependence and the achievements of those who are dependent on each other in this way far out strips what they could achieve in operating independently (p.188). It seems unlikely that teachers working in isolation would be able to develop such engaging curricula as exemplified by the collaborations described above.

The report Meeting technological challenges? Design and technology in schools 2007 – 2010 (Ofsted 2011) noted that secondary schools should …

provide a balanced D&T curriculum that is well pitched to build upon the primary curriculum and includes the technologically challenging and more modern parts of the subject so that students can apply their scientific understanding and develop greater technical rigour in designing and making (page 7).

The collaborations developed by groups 1 and 3 definitely meet this suggestion. The broad sweep nature of the suggestions from group 2 make it unclear whether their collaboration suggestions would achieve this. The same report also noted …

The national programme for science, technology, engineering and mathematics (STEM) has the potential to contribute to tackling the challenges that face D&T and help schools to modernise their curriculum. STEM aims to develop support for schools in order to encourage young people to develop the skills needed to become the scientists, engineers, technologists and mathematicians of the future. The STEM programme predates this survey, but it is only within the last two years that the reach of its work has grown to the extent that it has begun to be reflected in the schools visited. (Page 48).

At the time of writing the National STEM programme no longer exists and related activities are unlikely to receive funding but as indicated by this extract from the STEM Cohesion Programme Final Report (Department for Education 2011) the Department for Education hopes that stakeholders will continue to remain active in STEM

As the programme contract comes to an end in March 2011, many of the stakeholders and lead organisations hope that participating organisations will wish to maintain and develop the relationships fostered during the programme, in order to reap the benefits of multi-agency working – namely, the possibility of achieving an even greater impact on teachers and schools, through more effective joint planning of STEM related information and provision. To encourage ongoing collaboration after the demise of the formal programme, some lead organisation representatives identify that it would be important to create opportunities for STEM stakeholders to continue to meet, for example, either at national conferences or as members of regional groups (page 48).

Hence, the government is leaving engagement with STEM in schools and by implication collaboration between design & technology and science in the hands of concerned stakeholders. It follows that the role of STEM in schools as a catalyst for such collaboration is likely to rest in the hands of committed enthusiasts. Engaging teachers in training with collaboration is perhaps one way of developing a cohort of committed, enthusiastic stakeholders.

Layton (1992) defines different groups socio-political stakeholders of school technology as follows: economic functionalists, liberal educators, professional technologists, women, sustainable developers. Although trainee teachers are not specifically identified as a stakeholder group in their own right it is not unreasonable to see them as within the liberal educator group although it is possible that some may align themselves with economic functionalists and take a highly instrumentalist view of
education which requires it to support economic competitiveness and wealth creation. Unpublished work by Hardy supports this. In attempting to characterize stakeholders who have differing values of design & technology Hardy (2012) has defined four different groups of stakeholders: influencers, users, shapers and holders. Influencers are group which through personal experience of design & technology can influence the curriculum time and uptake of the subject, parents, non-design & technology teachers and senior managers in schools are part of this group. Users are those whose value of the subject is determined by their use of the subject and includes pupils and employers; they might also be called consumers. Shapers are those who might claim to hold the ‘bigger picture’ of the curriculum and in the UK these people do not necessarily have direct contact with the subject but direct and inform policy about the curriculum such as politicians and heads of large academies. Trainee teachers are part of the ‘holders’ group, a group which includes subject academics, teacher educators/lecturers and subject teachers. The interpretation of ‘holder’ is someone who maintains the dynamic nature of the subject, rejecting a static view of both content and pedagogy and is concerned with and involved in shaping the curriculum through new practices. The session described here can to some extent be seen as an induction of the trainees into the ‘holders’ stakeholder group.

Further research and development
This short foray into the response of trainee teachers into collaboration between different subjects gives rise to the possibility of further research and development. These include the following questions.

To what extent do the trainees value the possibility of collaboration between subjects? Are there any patterns in trainee’s previous experience that indicate a predisposition towards valuing collaboration?

To what extent are those trainees who value such collaboration able to pursue this interest in their future careers? This requires some longitudinal studies which are demanding and often vulnerable to events outside the researcher’s control but identifying situations where positive attitudes towards collaboration lead to new and innovative practice would be useful.

To what extent do the organizers of the workshop value the possibility of collaboration between subjects? Are there any patterns in lecturer’s previous experience that indicate a predisposition towards valuing collaboration? Such research might call upon the work of Rokeach (1968) and the idea of derived beliefs in that the organizers might well influence the beliefs of the trainees.

To what extent do other stakeholders value such collaboration? Are there any patterns that indicate a predisposition towards valuing collaboration? Some of these stakeholders might well look to Ofsted for guidance and such guidance is available. Ofsted (2012) provides subject-specific guidance for inspectors on making judgements during visits to schools. For design & technology these suggest that outstanding practice requires …

Pupils to apply scientific, mathematical and engineering knowledge to create products which are functional. They exploit this well when making choices and taking decisions about all aspects of their work”. There is no similar statement in the science document extolling the virtues of links between design & technology and science. The possible effects of such a lack of balance is worth investigating.
The authors would welcome discussions with colleagues who are interested in the place of inter subject collaboration in initial teacher education so that an acceptable general approach may be developed and studies of its use and effectiveness be carried out in different countries.

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Ofsted (2012) Design & Technology (D&T) Survey Visits Generic grade descriptors and supplementary subject-specific guidance for inspectors on making judgements during visits to schools Crown Copyright
Some thoughts on the diseconomy of the NSW technology education curriculum

John Barlow
Australian Catholic University

Current reviews associated with the possible introduction of an Australian national school curriculum provide a timely opportunity for a critical reflection and evaluation of existing state based curricular across all academic disciplines. In New South Wales for example the technology curriculum has now expanded to include a wide range of subject options across both the primary and secondary school curricular which might be perceived by some technology educators and even members of the wider community as being a positive reflection on the richness, strength and diversity of this curriculum. However, a careful examination of the resourcing implications required to deliver, and service such a diverse curriculum might suggest otherwise.

This paper then presents an overview of enrolment trends in selected subjects of the NSW technology curriculum over the past century with an emphasis on the secondary curriculum and examines how the gradual development of such a diverse curriculum may ultimately impact on its effective delivery and influence the perception of technology as a significant learning area in schools and across the wider community.

Introduction

The term ‘diseconomy’ implies low efficiency or higher costs which result from the scale at which goods or services are produced and delivered. Economists in particular argue that the larger the business or enterprise the more prone it is to the impact of diseconomy. That is expansion in the depth and width - the scale - of a business or enterprise requires a consequent expansion in the systems required to manage, monitor and evaluate the delivery of the goods or services it provides resulting in increased costs and potential inefficiencies. In this context then this paper will provide a brief overview of enrolment trends in selected subjects of the NSW technology curriculum over the past century across the school curricular. This is followed by a short discussion which explores the how this might impact on delivery and management of such a diverse curriculum.

An overview of enrolment trends in selected NSW technology education subjects

The origins of technology education in NSW schools date from 1865 when technical classes were established at the then Sydney School of Arts (Mandelson, 1971a, pp. 4-5). By 1906 ‘educational handwork’ consisting of paper folding, cutting, and mounting, cardboard work and woodwork had been introduced in a number of schools.

Revised secondary school regulations and a new syllabus were introduced in 1911. This included the adoption of the Intermediate Certificate after two years of secondary school study and the Leaving Certificate after a further 2 years of study. Candidates for the 1913 Intermediate Certificate included 585 in the subject Manual Work. No technology subjects were presented at the first Leaving Certificate Examination in the
same year (Barcan, 1965, p. 212). The first formal syllabus in manual work for primary schools was introduced in 1914 and later revised in 1916 to include an official time allocation of 90 minutes per week for Art and Manual Work. (Mandelson, 1971b, pp. 136-137). Two of the major aims of manual work set out in this syllabus (and perhaps still relevant today) were to:

- make hands deft, and to train the eyes to be accurate and sensitive to beauty of form, and
- develop the habit of planning and orderly procedure in the prosecution of tasks.

(Mandelson, 1971b, p. 137).

The introduction of the Wyndham scheme reforms in 1962 saw the Intermediate and Leaving Certificates replaced by the School Certificate (at the end of 4 years of secondary education) and the Higher School Certificate (after a further 2 years of secondary education). During the Intermediate and Leaving Certificate/School and Higher School Certificate transition period (1964 – 1967) the number of secondary technology subjects and their candidature had significantly expanded. These are set out in tables 1 and 2.

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<tbody>
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<td>17</td>
<td>5</td>
<td>Art Metalwork</td>
<td>14</td>
<td>17</td>
<td></td>
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<tr>
<td>Bookcrafts &amp; Leathercrafts</td>
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<td>14</td>
<td>19</td>
<td>Bookcrafts</td>
<td>9</td>
<td>6</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
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<td>66</td>
<td>50</td>
<td>Farm Mechanics</td>
<td>164</td>
<td>408</td>
<td>376</td>
</tr>
<tr>
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<td>43</td>
<td>40</td>
<td>Graphic Arts</td>
<td>26</td>
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<td>3330</td>
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<td>1744</td>
<td>7874</td>
<td>8695</td>
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<td>Woodwork</td>
<td>6282</td>
<td>4126</td>
<td>5508</td>
<td>Woodwork</td>
<td>581</td>
<td>5446</td>
<td>6237</td>
</tr>
</tbody>
</table>

Table 1: NSW Intermediate Certificate – School Certificate transition 1964 – 1967

- Enrolments in selected technology subjects
- Source: NSW Board of Studies Statistics Archive

Following the introduction of both national and state technology education curriculum reforms (Williams, 2005), during the latter part of the 20th Century, a much broader approach to the study of technology beyond that of technical skill development was initiated throughout Australia. In NSW for example, Excellence and Equity the NSW Ministry of Education and Youth Affairs white paper was tabled in 1989. This resulted in
the introduction of Design and Technology, a subject emphasising the use of the design process in a broad based study of technology (McDonald & Gibson, 1995, p. 139) with 997 candidates presenting for the 1994 Higher School Certificate (NSW Board of Studies).

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</tr>
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<tbody>
<tr>
<td>Descriptive Geometry and Drawing</td>
<td>1445</td>
<td>2185</td>
<td>395</td>
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<td>Farm Mechanics</td>
<td>92</td>
<td>102</td>
<td>4</td>
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<td>22</td>
<td>22</td>
<td>26</td>
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<tr>
<td>Metalwork</td>
<td>362</td>
<td>562</td>
<td>103</td>
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<td>Home Economics</td>
<td>889</td>
<td>1091</td>
<td>65</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td>Home Science</td>
<td>262</td>
<td>338</td>
<td>397</td>
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<td></td>
<td></td>
<td></td>
<td>Industrial Arts</td>
<td>1293</td>
<td>1725</td>
<td>1555</td>
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<td>Needlecraft and Garment Construction</td>
<td>1112</td>
<td>1315</td>
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<tr>
<td>Needlework</td>
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<tr>
<td>Woodwork</td>
<td>545</td>
<td>781</td>
<td>115</td>
<td>Textiles and Design</td>
<td>216</td>
<td></td>
<td>408</td>
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</tbody>
</table>

- Enrolments in selected technology subjects
- Source: NSW Board of Studies Statistics Archive

In brief the introduction of Design and Technology was an attempt to align technology classroom pedagogical practices with contemporary developments in design and technology education particularly in the UK and Europe. It also provided a potential opportunity to rationalise technology subjects offered across the secondary curriculum. However, this attempt at curriculum rationalisation was resisted by classroom teachers and their professional associations. At the same time Agriculture, although a subject taught by and large by Science teachers, and Information Technology (computing) subjects such as Information and Software Technology, Information Processes and Technology and Software Design and Development were also added to the technology curriculum area.

By 2011 the number of technology subjects and candidates at the School Certificate and Higher School Certificate had further expanded. These are set out in table 3.
Table 3: NSW School Certificate – Higher School Certificate 2011

<table>
<thead>
<tr>
<th>Subject</th>
<th>2011</th>
<th>Source: NSW Board of Studies Statistics Archive</th>
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</thead>
<tbody>
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<td>Agricultural Technology</td>
<td>5248</td>
<td>Agricultural</td>
</tr>
<tr>
<td>Design and Technology</td>
<td>3118</td>
<td>Design and Technology</td>
</tr>
<tr>
<td>Engineering Studies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Technology</td>
<td>18123</td>
<td>Food Technology</td>
</tr>
<tr>
<td>Graphics Technology</td>
<td>2614</td>
<td></td>
</tr>
<tr>
<td>Industrial Technology</td>
<td>21075</td>
<td>Industrial Technology</td>
</tr>
<tr>
<td>Information and Software Technology</td>
<td>11149</td>
<td>Information Processes and Technology</td>
</tr>
<tr>
<td>Textiles Technology</td>
<td>4243</td>
<td>Textiles and Design</td>
</tr>
</tbody>
</table>

The subject Industrial Technology in particular continues to offer a wide range of options including Automotive, Building and Construction, Ceramics, Electronics, Engineering, Farm Maintenance, Leather, Metal, Multimedia/Photography and Timber at the School Certificate while at the Higher School Certificate Automotive Technologies, Electronic Technologies, Graphics Technologies, Metal and Engineering Technologies, Multimedia Technologies and Timber and Furniture Technologies are options in the senior course.

In addition to the subjects listed in table 3 there is a range of technology education aligned subjects, including life skills, Vocational Education and Training (VET) and non-board developed course offerings, which have expanded significantly. For example, selected technology education aligned VET NSW HSC courses and their examination candidatures are set out in table 4. While technology education aligned VET subjects may not necessarily be formally identified as part of the technology education curriculum they are however in the main taught by teachers who also teach technology education subjects.

Table 4: NSW Higher School Certificate 2011

<table>
<thead>
<tr>
<th>Subject</th>
<th>2011</th>
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<tbody>
<tr>
<td>Automotive</td>
<td>343</td>
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<tr>
<td>Construction</td>
<td>1643</td>
</tr>
<tr>
<td>Electrotechnology</td>
<td>210</td>
</tr>
<tr>
<td>Hospitality</td>
<td>5808</td>
</tr>
<tr>
<td>Metal and Engineering</td>
<td>746</td>
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</table>

Delivering the curriculum
Clearly then from a modest start in the latter part of the 19th Century the NSW technology
education curriculum has expanded to include a rich, diverse and commendable set of course options, supported by strong candidate enrolments as set out in tables 1 - 4, reflecting a significant contribution to the wider secondary curriculum. However notwithstanding the current discussions centred on the introduction of a national Technologies curriculum which includes both Design and Technologies as well as Digital Technologies, perhaps the issue that needs to be examined in the current NSW context is whether the subject options in the technology curriculum have now expanded to such an extent that the systems required to manage, monitor and evaluate their delivery have also inadvertently compromised the curriculum’s educative efficacy.

In this context three issues will be examined.
- Academic identity
- Community value
- Resourcing

It should be noted, however, that this list is not meant to be exhaustive, only an attempt to nudge a discussion.

**Academic identity**

The academic identity of technology education continues to influence its delivery and perceived educative value by technology and non-technology educators and members of the wider community. Unfortunately, there are still many individuals, often in significant education administration positions, who still view technology education as essentially craft based. This is a matter which is not restricted to NSW of course. For example Eggleston (1993, p. 60) writing in the UK context asked why technology education was not on a smooth and upward curve world-wide and why it is characterised by controversy, conflict and wide inconsistencies in its availability and efficacy. More importantly he asked the question:

Why are there still powerful groups that seem to seek to contain and restrict it?

(Eggleston 1993, p. 60)

Eggleston suggested that research and reform-driven change in technology education and its delivery to appropriate students, as well as the definition and nature of technology and the technology curriculum all contributed to this situation. He noted, for example, in the context of the delivery of the technology curriculum, that in every society the utilisation of technology varies resulting in different levels of status and prestige assigned to the user. More importantly though he observed that the wider community is

...familiar with an education that provides large numbers of skilled, semi-skilled and unskilled workers at one end and a few highly trained professional technologists at the other end ...

(Eggleston 1993, p. 61)

Certainly in contemporary Australian society with the efforts of the Australian government to broaden participation rates in secondary school and higher education this distinction is potentially diminishing. However, what might be important here for technology education is that the perceived academic identity of much of the content taught in school and university classes is still quite often broadly identified with mathematics and science rather than being attributed to technology learning experiences where theoretical concepts can and are more commonly applied and explored in a range of practical and problem solving situations. In essence, it is essentially a continued denial of the increasing intellectual
demands of the contemporary technology education curriculum.

However, it may be that this situation is fundamentally exacerbated by a curriculum discipline area that many non-technology educators and other observers incorrectly perceive as lacking a rigorous academic identity. There may be a number of issues that contribute to this perception, including the continued debate amongst technology educators about the fundamental nature of technology and technology in the curriculum as well as the wide range of subject options that continue to be provided. Further this perceived lack of identity also tends to diminish the academic status of technology as a cohesive whole and more importantly can often provide opportunities for compromising the direct control and management of the curriculum both in terms of the maintenance of evolving and relevant content and more importantly access to the provision of adequate and recurrent financial resources required for its effective delivery.

Community value

There is no doubt that technology as a school subject continues to be valued by students and the community in general. Significantly in a recent submission to the Australian Curriculum, Assessment and Reporting Authority (ACARA) on the Technologies subject area to be developed in the proposed national curriculum the Australian Youth Forum (2012) reported that over 96% of young people who participated in their consultation indicated technologies was an important subject because it:

1. prepared students for employment,
2. made the school learning experience more enjoyable, relevant and hands-on, and
3. made learning complex subjects easier.

(AYF, 2012, p. 9)

Put simply, Australian school students would seem to be continuing to enjoy and value technology subjects. Moreover however the provision of technology subjects has always been associated in part with the opportunity to provide for the development of skills and knowledge which could be useful for students in their future career aspirations as well as providing a means for meeting the labour requirements of an expanding industrial economy and more latterly that of the so-called knowledge economy required for international competitiveness. Notably Mandelson (1971b) observed that:

Manual work won acceptance partly because it seemed a useful study in an increasingly industrial world, partly because it was thought that general manual dexterity could be developed through a programme beginning in the kindergarten and culminating in technical schools and colleges, and partly because naturalists convincingly argued that constructiveness was an instinct which must be permitted expression if the child were to develop fully as a person.

Mandelson (1971b, p. 138)

Given these observations are about an emerging early 20th century NSW technology education curriculum they still have relevance for the modern equivalent, albeit one that embraces contemporary technological practices. Unlike VET which is intricately linked to the training needs of industry, proponents of technology education continue to argue that it is an integral component of a broad general education. Technology educators contend that the contemporary technology curriculum offers a much wider range of learning experiences for students than that of a VET competency based learning framework. Students in technology classes have the opportunity to explore learning through for example creativity, design thinking and problem solving activities, the use of
communication media and the development of project management skills as well as the more traditional practical skills and knowledge associated with the selection and use of materials and prototype production. Significantly the production of prototypes by secondary technology students in particular can now commonly utilise quite sophisticated emerging technologies including for example computer modelling, 3D printer rapid prototyping techniques, digital textile printing and also laser cutters to produce intricate profiles in a range of materials.

**Resourcing**

Resourcing the technology curriculum is complex involving a number of interrelated factors including but not limited to the provision of: accredited teaching staff, physical and increasingly virtual learning spaces, physical equipment and materials, and perhaps most importantly relevant and accessible on-going teacher professional development and training. Clearly these impose substantial burdens on any education system. This is a particularly significant consideration in NSW.

The ongoing provision of appropriately accredited teachers in the numbers required is an increasingly significant issue for delivering technology given both the broad nature of the contemporary curriculum and the age profile of current technology teachers. While there may appear to be an adequate number of students entering some NSW university technology teacher education programs there continues to appear to be a distinct disjunction between the expectations of many technology student teachers and their role as a ‘technology’ teacher. Notwithstanding the work reported by Green & Greive (2008) who found that many students decided to enter technology teacher education programs because they had been influenced by community encouragement, school based technology experiences and a desire to teach, many current technology student teachers do not identify as future ‘technology’ teachers at all. In essence many have a very narrow view of what kind of ‘technology’ teacher they want to be often influenced by their recent school and community experiences including significantly in recent years exposure to popular hospitality television programs. Essentially these student teachers, like many of their predecessors, often identify quite narrowly as either food, hospitality, materials or textiles teachers for example, not necessarily as the ‘generic technology’ teacher delivery of the contemporary curriculum ideally requires.

The provision of appropriately fitted out teaching spaces, both physical and virtual, is a fundamental resourcing requirement for supporting the delivery of the technology curriculum in particular. Increasingly though given the broad nature of the technology curriculum, these teaching spaces may need to be quite specialised and fitted out with quite specific equipment and materials handling facilities and may therefore not necessarily be utilised to their ‘maximum’ efficiency during the school teaching day. This is further exacerbated in many instances by the need to fit out teaching spaces for technology education VET aligned subjects to quite specific industry standards. For example the fit out requirements for a hospitality kitchen are far more rigorous than those for a food technology laboratory. While a hospitality kitchen for example can be used to teach food technology, the reverse is not necessarily the case.

The provision of appropriate, accessible and accredited professional development and training opportunities for classroom technology teachers are currently provided
throughout NSW by a wide range of qualified trainers under the auspices of registered training organisations (RTOs) including employers and professional teacher associations. This is becoming an increasingly important issue for classroom teachers given the inherently dynamic nature of technology where emerging technologies, new versions of existing equipment and new materials are constantly evolving while at the same time the requirement to maintain skills and knowledge about current equipment and material options remains. Further and perhaps more importantly the more rigorous demands and implications of harmonised national work health and safety (WHS) legislation, imposes safe workplace practice responsibilities on classroom teachers and their colleagues beyond that experienced by their predecessors. In essence the provision of on-going professional development and training for technology teachers is now obligatory for the adequate resourcing and support of the technology curriculum.

**Diseconomy**

Given the preceding discussion it might be argued that the NSW technology curriculum, given its complexity and diversity, might be subject to significant diseconomies of scale. It is certainly a curriculum that exemplifies both depth and width in the range of subject options available for students to choose as part of their secondary education. However, it is this very depth and width which supports the underlying strength and richness of the curriculum. Clearly by implication then the delivery of the NSW technology education curriculum requires that sophisticated systems are put in place to support, manage, monitor and evaluate its educative effectiveness. The continued success of the NSW technology curriculum would suggest this continues to be the case.

**Conclusion**

This paper has provided a brief outline of enrolments in the NSW technology education curriculum and its expansion during the 20th Century, followed by a brief discussion of some issues which might impact on the curriculum’s delivery in the context of potential diseconomies of scale required to support, manage, monitor and evaluate its educative effectiveness.

**Bibliography**


Conformity or diversity: developing creativity in design and technology in the early years

Clare Benson

Birmingham City University, UK

Design and Technology (D&T) has been an explicit part of the Early Years (EY) curriculum since the introduction of the first mandatory English Curriculum for children aged 3 - 5 years (QCA 1999). The 6 areas of learning within the curriculum were not subject specific (except for language and mathematical development); however the key elements of D&T could be identified within all six areas, but mainly were included within the Knowledge and Understanding of the World area. The most recent review places D&T within Expressive Arts and design (DfE 2012) and it is identified as a specific subject area. What then has been the impact of the inclusion of D&T in the EY curriculum for over 10 years on practice in Early Years settings? Previous research (Benson 2003, 2005, 2008) identified the lack of knowledge and understanding of D&T by EY practitioners. Practitioners in the main either left the children to ‘create’ whatever they wanted without intervention or taught specific skills or planned structured sessions during which the children produced similar products by following instructions. This paper will use the findings from the original research project – Designerly thinking in the EY – as a basis for a more detailed analysis of practice using 2 new case studies. From analysis of data collected from planning tools, observation schedules, outcomes and semi structured interviews, key strategies will be identified that may have supported or hindered the development of creativity within D&T activities.

Practitioner is used to identify any adult working with the young children in an EY setting.

Introduction

Since D&T was introduced as a new element in the EY Foundation Stage curriculum, it was felt important to ascertain what if any activity relating to D&T was being carried out in EY settings, particularly in relation to design. Therefore a large scale Early Years project funded by the Department for Education and Employment (DfEE)- Designerly thinking in the Foundation Stage (3-5 years) involving 400 practitioners - was carried out in 2003-4. From the analysis of the data collected after the project activities had been undertaken (Benson 2003, 2005, 2008) one of the key findings to emerge was the way in which designerly activities were carried out – they were different in nature in different settings despite the fact that all the practitioners had taken part in the same Continuing Professional Development (CPD) as part of the project. From an analysis of, for example, the planning, practitioners’ comments and the outcomes of the children’s activities it appeared that the outcomes from the children in relation to creativity linked to the differing ways of implementation. Further research was carried on from 2004-2010 involving a further 428 practitioners although this CPD undertaken was of a shortened nature. In trying to determine key factors that encouraged creativity through designerly activity in EY settings, two case studies were selected to look in depth at the different ways in which designerly activity was carried out. Factors that were taken into account when selecting the case studies are outlined in the Methodology section.
Effective pedagogy in the Early Years
It was felt important to identify key elements of effective pedagogy before making links to elements that might help with the development of creativity in young children. A useful study into the pedagogical effectiveness in Early Learning (Moyles et al 2002) identifies a number of effective teaching and learning practices including:
- ensuring time is available for children to fully explore concepts and ideas and complete tasks to their own satisfaction;
- enabling children to make choices, take measured risks, talk and think for themselves and have some responsibility for articulating and evaluating their own learning
- making full use of collaborative and co-operative ways of learning
- making full use of a range of open-ended, active, hands-on, multi-sensory learning experiences.

Another parallel study (Siraj-Blatchford et al 2002) also supported the above findings as well as identifying the importance of good subject knowledge of practitioners and adult-child interactions that involve open-ended questioning to extend children’s thinking.

Bruce’s work (2004) does not contradict these elements and in addition identifies the following as contributing to the creation of an effective learner – an ability to explore the world in an open, critical and creative way in order to extend their knowledge and understanding. It is possible to see the links between these elements and those that have been identified as supporting the development of creativity in children as well as adults.

Identifying key elements linked to creativity
Discussion relating to the definition of creativity has been wide ranging for many decades. There is no neat definition as the concept is so complex. Parker (1962) talks about a body of knowledge but using it afresh by presenting it in new ways and Schachtel (1962) identifies the importance of the individuality of the child. Woods’ seminal work (1995) suggests that during creative learning ‘pupils have control over their own learning processes, and ownership of the knowledge produced, which is relevant to their concerns.’

The ideas of ‘high’ creativity and ‘ordinary’ creativity (Feldman, Csikszentmihalyi & Gardner, 1994; Rhyammar & Brolin, 1999) and ‘Big C’ and ‘little c’ (Craft, 2003) were considered and it was decided to focus on the links with ‘little c’ for these case studies as it relates to all the children involved.

Questioning
From the original project questioning and task openness were two of the main factors that were identified that were supporting or hindering the development of creativity. Four positions with regard to questioning were identified:

a) transmission approach to questioning where teachers consistently asked basic closed questions which did not lead to extended or thoughtful responses e.g. what shape is it?
b) initial use of more advanced questioning techniques to engage the children was a new approach for this group of teachers and majority expressed shock at the thoughtful nature of the children’s responses i.e. these teachers were moving from the transition model of learning to begin to see children as thinkers (Bruner 1996)
c) the use of questioning that treated children as thinkers but not really as knowledgeable reflecting a limited understanding of the relationship between the personal and the social (Bruner1996).
d) social constructivist approach to questioning where the teacher treated the children as both knowledgeable and thoughtful. Dialogue and discussion were features of these teachers’ practice.

Tasks
The four categories that were identified were:

a) closed, focused on technical skills and materials;
b) less closed, where children were able to make some choices and reformulate tasks to some extent, but with little opportunity to make decisions and to work independently;
c) more open with children expected to work more independently;
d) open with children exploring issues as autonomous learners, reformulating tasks and deciding on how to approach them.

Torrance (1962) was more concerned with how to guide creative talent and his criteria certainly show links with effective EY practice including encouraging unusual questions. Foster’s (1971) analysis of links between good practice and encouraging creativity highlights the importance of involving children more positively in school experiences through questioning, listening, discussing, thinking and being actively involved in practical work with a wide variety of materials.

Based on the work of Benson and Lunt (2011) four key elements were identified that are not organised in hierarchical order. It was felt that these could be used as a framework for analysing the data to determine if practice was supporting the development of creativity.

- **Ownership and control**
  - links to Bruce 2004; Moyles 2002
  - links to questioning/tasks in original project

- **Relevance and motivation**
  - links to Siraj-Blatchford 2002; Moyles 2002
  - links to tasks in original project

- **Space and time**
  - links to Moyles 2002; Bruce 2004
  - links to tasks in original project

- **Interaction with others.**
  - links to Foster 1971; Siraj-Blatchford 2002; Moyles 2002
  - links to questioning in the original project

A detailed discussion of each element is included in Benson and Lunt (2011); the following are the main ideas for each element.

**Ownership and control**

By taking ownership, the child is able to think critically about his/her product and to start to innovate by introducing idea/s that are new to him/her (Woods, 1999; DfEE/QCA, 1999; Cropley, 2001; Nicholl, 2004).
Relevance and motivation
If a child cannot see the relevance of a task or assignment then he/she is unlikely to be motivated to investigate, to think around a problem or to develop his/her original thoughts (Woods, 1995).

Space and time
The meaning of space in this context is not just related to the classroom and school environment but to giving the child space to think (time) and to work in different ways. Time needs to be given to enable the children to finish their assignment, to make any modifications that they feel are needed, and to evaluate the finished product. Time and space are very much part of the Reggio Emilia approach to fostering creativity (Emilia, 1996) and one that is supported by Manning & Sharp (1979) and Benson (2004).

Interaction with others
The meaning is that children interact in a variety of ways with peers and adults. As part of the ‘talking’ process, the importance of encouraging children to ask challenging questions both to others and of themselves is set out in ‘Creativity: find it, promote it’ (QCA, 2003). Such questioning is one of the six key signs that QCA identified as being present when children are being creative and this is reinforced by the Office for Standards in Education (OFSTED) report (2010) ‘Learning: creative approaches that raise standards’.

These four elements will be used as a basis for the analysis of the data from the two case studies.

Methodology
Having gathered and analysed data from the large scale project, interesting issues arose that could be followed up through a case study approach. The large scale project provided a variety of general findings; it was decided to focus on a particular criterion – that of creativity. It is an issue that is of current interest in Early Years, especially as the new Early Years curriculum (DfE 2012) has at its heart the unique child involved in playing and exploring, active learning and creating and thinking critically. By exploring just two settings it was hoped that a greater understanding could be reached. Through the case studies the processes could be examined in detail; the settings already existed; the activities were part of the planned curriculum; and a variety of sources and different types of data could be collected. Questionnaires were given to all practitioners before and after the activities, planning tools were examined; semi structured interviews took place with the practitioners before and after the activities; observations of the 3 different types of activities were made; and the books were examined. The two settings that were chosen were similar in size, intake, environment and location but it appeared from the data gathered in the large scale project that these two settings had different approaches and that had led to differing outcomes. However both had similar Inspection reports in which parent satisfaction was high. It is possible to draw general principles from findings from such a study. The children involved were 4 years of age. As the children undertook similar activities over a four week period, clear boundaries were set in relation to the activities that were planned and undertaken. The main principles that researchers have identified (Cohen et al 2003; Creswell 2009; Denscombe 2005; Kumar 2011; Yin 1984) have been taken into account when setting up this case study research.
Throughout ethical considerations were taken into account. The practitioners 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 settings connected with the study was ensured. The parents were informed about the project and could have withdrawn their children from the activities; none did so. (Robson 1993; Gregory 2003; Denscombe 2005).

Case study activities
In these case studies the children were engaged in similar types of activities as undertaken in the original project but a different context was used. In both settings, the topic that the children engaged with was Toys. The children had been involved in a range of activities relating to Toys and the following activities came towards the end of the project. They examined a collection of books and cards that had moving parts (investigating and evaluating a collection of products); they took part in some teacher initiated activities to develop their practical skills in cutting and joining and their knowledge and understanding of mechanisms; and then designed and made a page with a moving part about their favourite toy to be included in a class book to go into their library to be read by the library users.

Findings and discussion
Case study 1
In CS 1 the practitioners talked with the children about the moving parts in the books in both sessions, using different books. They asked the children about which way the parts moved e.g. up/down, in/out. There was little focus on why the parts moved, why the different movements had been chosen e.g. up/down for an insect climbing up a tree, who might like the book, what materials the book was made from and why these might have been chosen Session 1 was with the whole group and the second session was delivered to small groups of children (6-8) and a similar format was used for both sessions.

Planning sheet for the activity
The planning showed that the activity would be very much teacher directed – read the book through; go back and then read, asking questions. Only 5 key questions were identified – does the … go up or down? does the … go in or out? Does the … go round and round? What moves in the picture? Do you like the picture that moves? Vocab: movement words e.g. up/down; in/out; round and round. There was no focus on giving the children time to investigate the movement or linking it to other things in e.g. the room, the playground.

Typical comments
Practitioner 2
I wasn’t sure what language to use or if the children would really understand about a mechanism even at a basic level so I thought it best to tell them about the mechanisms in the book.

Practitioner 4
It was nearly home time when I read the book so I told the children about the movement and things I thought important so we had done the book that day.
After this the children had little opportunity to investigate the books; they were put in the library corner but were not displayed prominently. There was little interaction between practitioner and children and questioning was limited mainly to a transmission model of questioning. One practitioner did encourage the children to ask questions as she read the book but moved on quickly when a question was not forthcoming. She felt that the children would not be able to formulate their own questions.

The sessions on joining were again set up as teacher initiated activity. Different joiners – glue, sellotape, masking tape, stapler and paper fasteners and simple mechanisms – slider, hinge and lever– were set out each day and in groups, the children were shown how they worked. The children were then given a template of a teddy's body and asked to join on his two arms with each of the joiners. There was little meaningful discussion and the interaction between adult and child was mainly about organisational or behavioural matters. The children looked at the mechanisms and then made up one themselves, using the pieces that had been prepared by the practitioners. Whilst the children appeared to like their end products, many left them behind on the desk before moving to a different activity.

Typical comments

**Practitioner 1**

The children need to be taught how to use the joiners so it is important to set up teacher directed activity.

**Practitioner 3**

Left by themselves the children will get in a mess and won’t end up with a neat Teddy to take home. They need to be closely supervised.

**Practitioner 5**

The children were able to make their own mechanism but they couldn’t have done it without the pre-cut pieces.

The planning sheet also indicated that it would be a 30 minute activity closely supervised with the practitioner directing the children.

The making activity was again practitioner directed. The adult identified how the part would move and intervened as the child was making the page to ensure that the page ‘looked good’ when finished. Whilst the children were able to decide which toy they would make it was from a limited selection that the practitioner had previously chosen. The practitioners felt that it was important to have a quality end product that the child could take home; it was something the parents expected. There was a selection of materials and joiners on the table but again the practitioners directed the children’s choice e.g. I think that paper would be best to use; that joiner will help the wheel to move.

The finished book was placed in the library and the practitioners said that some of the children enjoyed looking at it. They displayed it in an area where the parents waited so that they could see what the children had done. They felt that the project had been very successful with a quality end product. The children had learnt something about movement and joiners and the practitioners talked about trying to build on this in the future. Asked about the structured nature of the activities, almost all said that the children were too young to investigate and make without this structure and they could not have produced such a quality product if the children had been making many of the final decisions.
The children were given opportunities to try similar activities with joiners and paper/card to make different things but planning showed that most children had little interest in the activity and it was changed.

Case study 2

This did prove to be very different in organisation, interaction and end products.

Children were encouraged to investigate and evaluate the books before a practitioner initiated activity. Planning sheets showed that the books were placed on the Investigation table and practitioners were to comment/intervene with questions as appropriate. Different books were then read to groups of children before a practitioner read a book at Circle time to the whole class and encouraged the children to reflect on what they knew about the mechanisms, how they worked and why different mechanisms had been used in different pictures. Questions on the Planning sheet indicated that the children were being encouraged to develop their higher order thinking skills e.g. Why do you think...? What would happen if...? How does it move? Why has that mechanism been chosen for that picture?

The practical skills and knowledge and understanding sessions were practitioner initiated to start with after a display on the Investigating table. Different joiners were put on the table together with examples of how they could be used. After discussion the children were then encouraged to use the joiners and create the mechanisms using card/paper on the table. During these activities the practitioners intervened with questions/comments, trying to take each child’s learning forward. Planning sheets indicated that the questions were important; that the children should be encouraged to work on their own but also to have a discussion with others at the table and with the practitioner.

Throughout the children were being asked to think about what toy they might choose for their book page and parents were invited to discuss this with the children via a notice on the door of the class. This was a usual way of involving the parents.

The children discussed in small groups what they had chosen, why it was their favourite toy and how it might move. Different joiners and materials were placed on the table during the discussion so that the children could handle them and chose what they wanted. The children made their page whilst talking about it with their peers and several practitioners noted how much the children interacted with each other whilst making their own page. The children did take note of the comments that were made. From interviews and the planning sheet it was clear that the children were encouraged to make their own choices but questions such as: How might that work? What kind of movement do you want? What might give you an up/down movement? were identified as possible prompts to support a child if necessary. The pages were all different and had involved the children in making their own decisions and choices.

The book was placed in the library and the practitioners reported that both children and parents read the book frequently. Planning sheets and interviews indicated that at a child initiated activity table the children made different pages for several weeks after the topic was finished and enjoyed thinking of different ways to make things move.

It is possible to identify the four elements in the two case studies that Benson and Lunt (2011) highlighted in relation to encouraging the development of creativity.
Ownership and control
There was clearly an issue in Case Study 1 (CS1) in not allowing the children to have ownership of most aspects of the project. The practitioners controlled most of the activities as they did not feel confident in their own subject knowledge. By directing activities closely, they felt that they could steer the children along a path that they felt that they could control and that this would result in a quality end product. Practitioners in Case Study 2 (CS2) allowed the children more opportunities to make their own choices and to take control of their activities offering support when needed. This gave the children opportunities to think critically for themselves and ultimately introduce new ideas as they created their own toy page.

Relevance and motivation
Whilst there was evidence in both Case Studies of the children’s enjoyment of the activities, the children in CS2 were more engaged with their tasks, continued with them after the project was finished, and showed more interest in the finished book.

Space and time
The learning environment of CS2 was set up in a way that encouraged the children to investigate and ask questions with e.g. an Investigation Table. Time was given for the children to explore on their own and practitioners indicated that they were flexible in their planning; if more time was needed for an activity, then the planning was adapted.

Practitioner 3 CS2
Children need time to think, to explore, to fiddle, to go back to things as they built up their understanding

Practitioner in CS1 however felt that being organised and keeping to the original planning was important.

Practitioner 2 CS1
We need to keep pretty much to the planning so that we all know that we have covered what we set to do. Time is tight for all the different activities to be covered.

Interaction with others
In CS2 there was clearly more interaction with peers, parents and practitioners at a deeper level than CS1 and the CS2 practitioners indicated that they believed this to be an important part of the learning process. In CS1 the practitioners felt that at this stage of development it was important to lead the children and that discussion was limited in those kinds of activities as the children were given little opportunities to talk about e.g. mechanisms.

Conclusions and implications for classroom practice
Whilst the outcomes were different in each of the Case Studies, practitioners, children and parents in CS2 were not dissatisfied with the project; indeed almost all expressed enjoyment. There was a difference in values in the 2 Case Studies which was apparent in the way in which the project was carried out. In CS1 the more controlled implementation of the activities led to a ‘quality’ product i.e. it looked ‘perfect’ but the quality of the product in CS2 was manifested in the children’s thinking, questioning, opportunities to make decisions, and the individuality of the end product. Practitioners in CS1 identified
their lack of confidence in their own subject knowledge as a reason for the controlling of activities, whereas in CS 2 the practitioners supported each other if they were not sure and researched answers. More needs to be done in relation to supporting parents in understanding what constitutes good practice and the importance of developing thinking skills and creativity.

If it is considered important to develop and support creativity within the child, it is crucial that the children are engaged in activities that allow for more freedom; where practitioners are facilitators in many instances; and where practitioners have confidence in their subject knowledge or their ability to research for appropriate information.

It would appear that there is still a need for CPD for EY practitioners that supports not only the development of subject knowledge in relation to D&T but identifies key elements of creativity and how these might be translated into effective EY practice.

References


Analysis of a program to promote Design Education in rural Queensland Secondary Schools

Michael Berry
Griffith University

This paper describes and analyses the goDesign program undertaken within 6 Queensland schools in 2009-2010, the impressions and comments of the students, teachers and staff across the schools who participated, and various comments which provide evidence of the development of their design thinking as a result of the program’s implementation. It also outlines some of the recommendations arising from the program.

The program aimed to test a model for design education and immersion in secondary schools and its potential impact in helping to shape student’s dispositions and understanding of design thinking. It also sought to develop recommendations on directions for the greater implementation of design thinking within the secondary school curriculum. It focused on building conceptual understandings of design and practical hands-on knowledge in areas relating to artefact design, interior design and architecture.

Key words: Design and Technology education, design thinking, Immersion design projects, design in secondary schools.

Overview of the program
The project was implemented is six sites across Queensland by a visiting teams of personnel which included: academic and professional staff with a background or teaching role in design, various industry based designers, tertiary students drawn from the university who were studying design in areas such as interior, landscape or industrial design. It was undertaken as a three day intensive course with volunteer secondary students from across the school with a particular emphasis on industry technology and design as well as the Arts.

During the three days of the program teams of senior secondary students and staff were provided with a series of developmental, hands-on, immersive design activities. These were intended to engage and develop student’s understandings and depth of ‘design thinking’. They focused on team building and the processes of creative design and design thinking. The number of students from each rural school varied usually involving between 6-25 students together with one or more teachers. Other teachers and the school principal were often involved in some aspect of the three day program.

The model used was used as an ‘enrichment’ program, seeking to change student’s perceptions of the processes of design and themselves as potential designers. It required students to work in ‘design teams’ and use ‘design thinking’ in ways that parallel the types of activities they might undertake in first year university while also mirroring those processes used by expert practitioners from the commercial world. It provided them with opportunities to explore design concepts, exhibit their work and have their work
recognised and critiqued by peers, their teachers, lecturers and design experts.

Program overview

Day one - activities focused on three main activities;

- **Introduction and building trust** between the presenters and the participating students;
- **Postcard design** - developing an understanding of place and using this as a focus for creative design, each student used photos and digital images collected by themselves, other students and staff from their local area to generate a postcard that represent their space/community. This simple task was used as a catalyst to discuss the role and purpose of design as well as some of the key factors which influence the thinking of designers and their work.
- **Prototype T-shirt design** (using two pieces of T-Shirt shaped pieces of paper) - this task built upon the development of the 'post card' design activity and as well as drawing upon an important local issue for inspiration. The T-shirts were displayed in a short fashion parade and ideas as well as inspiration discussed across the class.

Day two - focused on the processes and practices of design and designers. High lighting the ways in which they work to;

- **Memento and product design** – The students documented, shared and refined their design ideas to generate plans and 3D prototypes and test these with potential customers and clients. Students were asked to work in design teams to generate a series of product ideas for mementos that could be sold at a local fete or shop. The notion of 'inspiration from the local community' was used with the artefacts each being designed based on ideas from the local area.
- **Selling their ideas and communicating with others** - In the afternoon they were asked to produce a sales pitch for their ideas and share them with the class for critique and discussion. The viability, creativity and form and function of designs was discussed and evaluated by their peers with prompting questions from their teachers, the principal, and utilising the guest lecturers.

Day three - involved two types of guest speakers;

- **Working with a professional designer** talking about their practice and how their passion for design was developed including information on their current business. This provided the students with an authentic view of the processes of design thinking and enabled them to consider their paralleled use in the classroom and workplace. It also provided them with an understanding of the professional pathways available to the designer and the tertiary study which they might undertake. Each professional designer showed a range of design artefacts, plans and diagrams. They spoke in detail about a range of product design projects which they had undertaken and showed examples of the products created for the community.
- **Working with university students** studying in design also addressed the students. During this discussion they outlined their career aspirations and
described some of the activities which they had undertaken at university which studying design.

- **Designing Outdoor design installations** - The final design task involved the secondary students and guest speakers working together to design, create and collaboratively critique a temporary outside structure using a combination of cardboard, plastic, cloth and found materials.

**Program aims**

“Designers spot potential and how to work with a client or space”.... “there’s a process that designers go through for each project and this process isn’t linear.”

Student, Spinifex State College – Senior Campus Mt Isa

The program sought to develop three key concepts with students and school staff. To broaden their:

- **understandings and capabilities of ‘design thinking’** and their awareness of various vocations and learning pathways which may lead to careers in different design related fields.

- **knowledge and understandings** of the processes and practices of real designers by enabling them to meet professional designers, design staff from the university and by gaining a better understanding of the courses available to them for tertiary study in design.

- **design confidence** and ability to apply the design process and have them demonstrate and share their knowledge with peers, staff and the community though the display of their work in the local art gallery with the work of award winning young Queensland designers.

**The program’s key features**

The program was characterised by the following six distinct features:

1. **Place Based learning** – the design tasks drew on the student’s personal interpretation of issues and inspiration from their local area. This helped to contextual the students learning, making it meaningful. Howard Middleton(2005) in his article *Creative Thinking, Values and Design and Technology Education* notes the importance of ‘meaningfulness’ and contextual knowledge to students stating that

‘A key feature of any good design and technology classroom is that the activities that students engage in are meaningful. They are meaningful because they have a contingent relationship with the real world that is both inside and outside the classroom.’ That is, the ideas and processes that the students engage with are connected to the lived world rather than abstracted from it. (Middleton, 2005, p67)

2. **Interdisciplinary Practice** – knowledge from the students local communities, personal lives, as well as knowledge and skills from across the curriculum were drawn together to help generate creative and often dynamic solutions. The program aimed to be immersive, engaging teams of students in design thinking through practical and developmental appropriate activities with a range of designers, tertiary design students and lecture staff over three days.
3. **Utilising Real Designers** – Real design practitioners were incorporated into the program – usually drawn from the local community. Sharing their stories and providing a model for students in rural areas. The descriptions of their practice in local industry validated the student’s activities and the processes which they undertook. They also provided an authentic audience for the student's designs providing feedback to the students and offering suggestions.

4. **Exploring career and learning pathways** – Real world learning was emphasised with students as was the range of pathways which people can follow to pursue their interest in design. This helped to contextualise the learning as meaningful and valid, allowing the students to potentially see themselves as pursuing one of these alternatives in the future.

5. **Authentic audiences** – At the same time as the program was being run at the school, leading design winners from the DIAQ awards were displayed at the local gallery. This enabled students to visit the local gallery, peruse the winning designs and participate in the local DIAQ event. Moreover it provided a display space enabling the design solutions of local students to be displayed alongside those of accomplished designers. This provided students with an immense sense of pride and accomplishment as well as providing an opportunity for local community members to see the design work of both local students and innovative young designers from across the state.

6. **Product development through design thinking** – students were expected to collaborate to develop a product based on a broadly defined and locally contextualised design brief. The notion of a tangible product provided an item which could be shared across the class and evaluated and commented upon by the students themselves and their peers. The students were provided with opportunities to document their ideas and create models or prototypes of their designs.

7. **The projects academic underpinnings**

   The project commenced with a literature review which considered; senior and junior secondary syllabuses across Queensland; prior programs on school based design projects undertaken across the world; and literature on design related learning in schools. This process sought to build links between the proposed program and existing syllabus programs and enable the development team to consider the learnings of previous landmark programs.

   Clear curriculum linkages were identified with Design and Technology syllabus documents and the Arts.

   **Five other key documents were used to shape the theoretical base of the program.**

   1. The IDESIGN model of design thinking, developed by Dr Charles Burnette in 1989 (see attachment) and was utilised to inform the process model. This program was originally developed during a Design Based Education K-12 Program at the University of the Arts in Philadelphia by Dr. Burnette entitled, *Design With Kids*. This placed tertiary design students in classrooms to help teachers undertake design projects related to their educational goals. In
partnership with Dr. Janis Norman, Director of Art Education at the University, a national pilot program was launched in 1990.

2. *The Shape of the Australian Curriculum* (2009), a scoping paper from the ACARA, identified ten important general capabilities which it endeavours to develop. Aspects of five of these principles were naturally incorporated into the program. These included: Thinking skills, Creativity, self management, teamwork and social competence. Each became an important process element to the implementation and operation of the program within the classroom.

3. *The National Framework for Rural and Remote Education*, developed by MCEETYA, provided some reflection on issues facing rural and remote students including lower participation rates in higher education and a need to recognise that country communities are often places of great innovation, expertise and resilience. They stress the need to consider the following essential enablers for the provision of quality education in rural and remote locations:
   - Personnel- teachers, administrative and classroom support, specialists
   - Relevant curriculum
   - Information and communication technologies
   - Multiple modes of delivery
   - Environments formed through effective community relationships and partnerships
   - Resourcing

Each of these areas was considered in the programs development and implementation.

4. *The Educational Goals for Young Australians*; goal 2, developed as a part of the Melbourne declaration describes successful learners in terms of eight key characteristics. A summary of these includes aspects of active participant in their own learning, development of essential skills, ability to think deeply and logically, being creative, innovative and resourceful problem solvers, being able to plan activities independently, collaboratively and in teams to communicate ideas, making sense of their world, being motivated to reach their potential and understand pathways to continued education. Each of these elements was explicitly developed and fostered through the program through the hands-on problem based learning activities and the negotiation and customisation of the student’s learning within each design task.

5. *The Intellectual and policy foundations of the 21st century skills framework* provides insight into the importance of the learning and innovations skills, critical thinking and practical problem solving. ‘In a world in which good design is increasingly used as a means of differentiating objects of mass production, creative design skills are highly desired in the labour force.’ Furthermore they state that ‘it is important to see problem solving as encompassing a set of skills. To successfully solve a problem, we must first be able to formulate it as a problem that is, understand what makes up its essential elements. Thus critical thinking skills are key.’

**Data gathering, workshop samples and outcomes**
The program gathered information and data through;

- informal video of learning activities in the classroom,
video interviews (Students, teachers, staff and program presenters) and student work samples specifically relating to development of design projects.

- student diaries that were kept progressively over the three days and in which students recorded their personal reflections.
- Still photos were also taken progressively through-out each day of the three day program

Analysis of these and the personal reflections of the facilitators have provided a range of data and some interesting findings which are outlined below and have been used to generate the summary and recommendations for this paper.

**Views of the program by participants**

**Student impressions and comments**

“This program has helped me widen my thinking on design. This will help me not only in my art subjects, but many other aspects of my schooling. It encourages me to ‘think outside the box’, to try many methods before deciding one path and the vital necessity of teamwork.”

Student, Spinifex State College – Senior Campus Mt Isa

“There was a lot more thinking and brainstorming and it actually got me thinking more about the world around me and how certain things or products come about. Thanks guys.”

Student, Spinifex State College – Senior Campus Mt Isa

Three days of intense design thinking, even with a focus on fun and active engagement can be challenging for students. Certainly the comments of the students indicate the significant impact that the program had on their understandings about themselves as potential designers, the role of designers in society and the complexity of the design process. The student’s comments reflected a changed understanding of the build environment and the design products around them. They could see how they could potentially play a role as a designer and felt empowered to make changes in their designed world. They enjoyed working in teams and felt satisfied that they had generated, refined and shared a range of creative design ideas which appeared viable and potentially feasible at a commercial level. They enjoyed the opportunity to meet designers and design students and talk to them about their work. They were generally appreciative of the opportunity to display their work at the local gallery and share it with peers, the school community and the local community including their parents.

1. **Staff and principal's impressions and comments**

“The students have broadened their horizons so that they’re looking at different opportunities that they may not have thought of previously.”

Principal, Chinchilla State High School

Often, due to the pressures of school management, principals don’t have the opportunity to work with students and consider their learning at an activity and curriculum level. Rather they tend to see students activities in terms of discipline areas. This program gave them the opportunity to see the students undertaking tasks in an interdisciplinary way, integrating knowledge and building deep understanding while being actively engaged in the project.
“This kind of teaching that you guys are doing is exactly what teachers should be doing. Giving it over to the students, students develop their own learning as well as learning a bit more independence, so that they are not relying on the teacher or their parents... that is the way I think classrooms should be run”.

Teacher, Emerald State High School

This program provided teachers with the opportunity to reflect on the nature of learning and the ways in which interdisciplinary, problem based tasks can engage students in group problem solving. Its activities provided students with the opportunity to think creatively about problems which are meaningful to them and become self guided learners. They could see that real practitioners don’t work within subject defined boundaries and that the narrow nature of learning within ‘subject areas’ often contributes to student’s disengagement and lack of interest.

2. **Visiting Design Practitioners**

The visiting practitioners often commented on the richness of the students imaginations and the thoroughness of their design processes given the limited time within which they had to conceptualise and develop their ideas. They obviously enjoyed the notion of working with young designers and sharing their experience and knowledge of the commercial world of design and its challenges. Their real world perspectives helped students contextualise the work they were undertaking, making it more authentic and meaningful.

3. **Community Impressions**

While community feedback was not directly recorded individual comments from parents and general members of the community were very positive. These particularly related to the public exhibition of the students work and the way in which the students were able to work so well in creative teams to generate highly creative and yet very meaningful design ideas and solutions.

**Reflections on the value of program**

Clever design is the catalyst, the oil, which lubricates the wheels of the manufacturing industry, providing the opportunities to value add to raw resources and generate real jobs in new and emerging industries. It makes Australia more inventive, creative and competitive, enabling us to tackle the demands of a changing world and respond effectively to major challenges like climate change and rising population pressures through the development of new and improved products and systems. Through design thinking students are empowered to generate new solutions, see new connections, and create the next generation of smart technologies that are needed to be economically and successfully build our place in an increasing competitive international market. Simply put, design thinking = clever thinking and opportunity for students and this will translate into new opportunities for rural and remote communities if properly fostered within the educational community.

This program found that design thinking is a critical way for students to holistically understand, and be able to actively participate, in the build environment. That it enables them to understand how products are conceived, designed and manufactured, leading to an increased appreciation for the designed world and the role they, as active designers,
may play shaping future products and their community.

Summary and recommendations

Design activities are interesting and engaging for students, enabling them to incorporate their own ideas and creative thinking and utilise that together with other learning to create meaningful and useful products. The ‘soft skills’ fostered through these programs are as important to the students as the practical design based knowledge which they develop. The following recommendations be considered for incorporation into school based curriculums to support the greater uptake of design thinking within the curriculum.

1. **Design thinking** programs should be introduced as a pedagogical tool, supporting practical, problem solving methodology in our schools though integrated STEM (Science, Technology, Engineering and Mathematics) related learning materials and those of the Arts. Integrated learning opportunities for cross-curricular problem solving activities should be encouraged between classes particularly in the Technology and Arts domains with a common focus on product design, development and prototyping.

2. **Opportunities for students to meet and work, either directly or indirectly, with real designers and industry representatives** should be fostered in secondary schools. Such programs develop student’s self-image enabling them to see themselves as potential designers and creators within their local community, increasing the likelihood that they will pursue design related fields of study in tertiary education and employment in this area.

3. **Problem based curriculum with hands-on, practical design activities** should be implemented to foster creative thinking, practical program solving, esteem and literary and numeracy skills of students. Such multidisciplinary projects enable students to see learning as meaningful and authentic, linked to the real world.

4. **Teacher professional development** should be implemented for key teachers from across the disciplines of Industrial Technology and Design, Science and the Arts. It should be developed in such a way as to assist teachers in developing and implementing creative, problem based learning activities for students.

In a world of rapid change much of the content knowledge developed by students will be obsolete even before it is taught to them. They must develop ‘process’ related skills and design thinking which will enable them to understand and actively participate in shaping the designed world in authentic and meaningful ways. Such programs are intuitively more engaging and interesting for students enabling them to develop a balance of social, cognitive and intellectual skills and capabilities for the 21 century.

“A designer’s role in society is huge, impacting on everything around us. Beyond this, a designer’s role can be one of fun, interesting and innovative designs.”

Student, Chinchilla State High School
References

I would like to acknowledge the efforts of the program coordinator, Natalie Wright FDIA, from the School of Design, Faculty of Built Environment & Engineering – QUT, and the staff from the school who assisted in the implementation of the program across the six schools. I would also like to acknowledge the staff and students of the schools involved Chinchilla, Mount Isa, Quilpie, Emerald, Gladstone and Bundaberg and their local galleries for their support. Thanks to the members of the design community who participated in the activities and helped to inspire the students.

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Integrating technology and science– an opportunity missed!

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Every second year in Malaysia, The “Search for SEAMEO Young Scientist Congress (SSYS)” is held at the Regional Education Centre for Science and Maths (RECSAM). Students (aged 12-16) from twelve ASEAN countries present their scientific solutions to pressing local and community problems. “SSYS aims to encourage young learners to apply scientific and mathematical knowledge into technological problem-solving activities to address sustainable development.” (SSYS Information booklet, 2012).

Independent judges from Australia, and several other countries make assessments on the students’ written solutions (academic report), their presentation of their scientific approach and any subsequent models the students produce. The projects represent a technological approach to solving a community need/problem, with the construction of a device or model to illustrate the students’ solution. Deakin researchers, Wendy Jobling and Coral Campbell will present examples of some of these projects and discuss the possibility of assessing the technological aspects of the project, drawing on research into the relationship between science, technology, engineering and problem-based learning.

Introduction

The SEAMEO young scientist awards have been running biennially beginning in 1998 with the 2012 congress the eighth (the idea was initiated in 1997). Although the themes change subtly from year to year, the overarching focus is on the needs of local communities and sustainability. The rules of the congress encourage students to make use of mentor teachers and university academics (the latter can also give students access to some specialist equipment). Depending on the students’ location this help is variable and in some cases the teacher is the only available mentor.

During the congress the students present their work in three formats: a written report; power point presentation to the judges and fellow delegates, and students from local schools; a display where a poster is presented – the judges interview teams about their work. This exhibit is then open to the public.

It should be noted that three of the eleven special awards do relate specifically to technology. They are:
- Special award for commercial potential development of a product for society and the environment;
- The special award for the application of Science Principles and Processes;
- The special award for application of technology in relation to the congress theme (SSYS, 2012, p.5)

The congress themes give an authentic context for the problem solving involved and lend themselves to technological solutions. We posit that the technology (design technology) is the driving force in these projects, which the students were so passionate about. Additionally the students have met a design brief and their application of technological skills and knowledge can be assessed.
Technological Knowledge – reviewing the literature

In the past, technology was frequently viewed as applied science as Fensham and Gardner (1994) discussed in their paper, which gave four different views of the relationship between the two. Rather than viewing technology as subservient to science, it can be argued that the partnership between the two is equal in terms of both the motivation provided and the cognitive skills needed. Early research by De Vries (1996) indicates that we need to look beyond the ‘technology as applied science’ and actually look at the specific skills and types of knowledge that are contributed by technology and its application. In his studies, De Vries found that scientific knowledge had only a limited influence on the development of a design task. In fact, he found that projects were often a result of ‘a combination of scientific-technological know-how’ and ‘know-how of social phenomenon’ (1996, p1).

More recent research (De Vries, 2005) has indicated that there is no clear academic equivalent to technology education in other school subjects. He discusses that students need to understand both the aspects of conceptualisation in technology and the role of technology in culture and society. In terms of the conceptualisation of technology, students need to realise that the technology process, technological knowledge and technological objects are all part of technology. He indicates that in practice, students need to make judgements about effectiveness – the effectiveness of their solution or construction. Students make judgements relating to the function and functioning of their products with respect to the original design brief. In this way, technology knowledge is quite different to science knowledge. Technological conceptual knowledge aims at understanding how concepts from disciplines such as science apply across a range of biological, mechanical or electrical systems. Barak and Shakkar (2008) argue that there are aspects of knowledge which are unique to technology. The term ‘qualitative knowledge’ used in technology cognition (taken from McCormick, 2004) refers to the way a person can make evaluations about a technological aspect in a task without needing to understand the underlying mathematics or physics.

Compton (2004) discusses technological knowledge at the point of application in teaching and curriculum. She discusses Baird’s research (2002) which concluded that the epistemological aspects of technological knowledge extend beyond content “justified true belief” to that of a knowledge of functionality – that materials or artefacts have a function in which knowledge elements such as detachment, efficacy, longevity, connection and objectivity can be explored. Compton then moves on to define tacit and explicit knowledge, wherein tacit knowledge is often embedded in the unconscious. Tacit knowledge can be recognised in the way a person “knows how” to undertake a task, but is not confined to this one elaboration. Barbeiro (2004) recognises that tacit knowledge can be both procedural (knowing how) and conceptual (knowing that – factual) and can, under some conditions move from tacit to explicit forms, becoming accessible.

Research by Meijers and De Vries (2009) also examined both normativity and non-propositional knowledge in technology. Whilst in other content areas, normativity usually only features as norms for knowledge: in technology there is also normativity in the content of certain types of knowledge – for example knowing that a hammer is used for
inserting nails in wood is normative knowledge – it relates to a knowledge of the function of an item. The importance of this type of knowledge lies in the fact of its practical reasoning or means-end reasoning – the item has a purposeful use. In terms of non-propositionality, technological knowledge is the ‘skill’ knowledge – knowing how to use an item or artefact. This knowledge is frequently complex and tacit. Often technological drawings exhibit non-propositional knowledge as the visual aspect is often in the eye of the viewer.

One other form of tacit knowledge exists in technology education – that of systems. More than just a knowledge of how things work, it is the knowledge of how all the components of a system operate together to achieve their purpose. This knowledge allows a technologist to be able to isolate various components to enhance the ability of the artefact to solve the problem or issue (Kelley & Kellam 2009). …in short, systems thinking is about synthesizing together all the relevant information we have about an object so that we have a sense of it as a whole. (Kay & Foster, 1999, p2)

**Knowledge in teaching**

In 2009, Kelley and Kellman proposed a theoretical framework to guide the teaching of technology. They moved past the old ‘academic versus vocational’ debates to focus on the attributes of technological literacy. This they saw as learners having the knowledge, skills and abilities in technology to live, function and work in today’s technological society. A significant element of their theoretical framework was problem-solving along with critical thinking and reasoning. They (Kelley & Kellman, 2009) indicated that context and problem-based learning are key elements in technology education and learning. They extend this thinking to include project-based thinking.

Contextual learning/problem-based instruction and project-based instruction….provide meaningful learning through a real-world context. (Kelley and Kellman, 2009, p38)

Savery and Duffy (2001), when discussing problem-solving argue that a problem needs to be real for the student to really engage with it. An authentic problem allows students to ‘own’ the problem, and to believe that they can have input into a solution. Real problems are not necessarily easy to solve. They are often a complex mix of social, scientific, technological issues which all need to be considered in the development of a solution – frequently they are ill-defined problems with unresolved boundaries. In addition to problem solving, students in authentic projects also learn group collaboration, communication and information sharing.

In the Science Congress, where many of the projects have a design basis, we can look for the key elements of technological thinking as indicated above. In summary these are:

- making judgements about the effectiveness of their design and solution - requires both reasoning and critical thinking, problem-solving and awareness of the role of the ‘solution’ in culture and society.
- consider functionality, purpose, and apply ‘qualitative’ knowledge which is often tacit (the knowing of how to do a task).
- Systems knowledge
Presenting the Four Projects

A case study methodology is used to support the development of 4 ‘cases’ from the 4 projects viewed. The researchers were involved in viewing the presentation of each project, reading the final report and talking with the ‘young scientists’ (technologists) Yin (2009, p2) states that “Case study research arises out of a distinctive need to understand a complex social phenomena or situation allowing the researchers to retain the holistic and meaningful characteristics of real-life events”. Since the description of each project was interpretive in nature, involved a ‘system’ that was ‘bounded’ in both time and space, we identified case study as the appropriate methodology.

Case One – Project HF-Autotrap

The HF-Autotrap is a device for catching common household flies. It uses a trapping chamber and a hole at the top of the chamber through which the flies enter. Up to 80% of flies which enter will be unable to escape. At the base of the device is a form of lure and a vibrating table which forces air through the trapping chamber and out the hole at the top, which in turn attracts the flies into the hole. The base of the vibrating platform has an automatic time-delay switch which turns the platform on during the day and off at night. It can be built for household use or commercial use. It consists of a lure made from local waste materials which can be recycled for use at little or no cost.

In developing this device, the students identified the problem of excessive flies near homes and factories which could spread disease. They designed and built three prototypes which were tested by varying different components in an attempt to improve the machine’s effectiveness.

Technological knowledge displayed - The built device highlighted students’ problem-solving skills in systems analysis and in mechanical engineering in the construction of the device. They exhibited systems knowledge and materials knowledge. They understood the idea of functionality and purpose in their design. They displayed an understanding of electronics in the design of the switch, and aesthetics appreciation in the symmetry and pleasant appearance of the finished product. Finally they exhibited an understanding of the role of their solution within a socio-cultural framework.
Case Two – Aerated *in vitro* Culture system as a tool for Rapid production of Plantlets and Plant conservation.

This was a scientific enquiry into using an aerated *in vitro* system for enhanced plant growth. Students investigated what changes they could make to the rapid multiplication of plantlets to further increase numbers over a short time. The introduction of air into the standard *in vitro* culture system was one possible investigation. Students already had knowledge of the growth medium used for enhanced growth of the plants and recognised that time limited the number of possible variables they could investigate – hence their selection of an aerated system (possibly suggested by the laboratory they were working with). They learnt the techniques of tissue culture and medium preparation, working in a bio-hazard hood and aseptic techniques to minimise cross contamination. However, at the point of starting the project, they realised that they had a technological problem to be solved. The apparatus required to aerate the plants did not exist. They need to invent it. This required close examination of the existing apparatus and a number of considerations about where air could be introduced into the system. The young scientists had to design their own aeration equipment in glass and have it professionally constructed to be able to complete their science experiments. To design the glassware, the students needed to have an understanding of what they expected their new equipment to do and how it would fit with the other material and equipment in use.

The medium can be used in a variety of containers, including culture tubes and jam jars/vessels.

Technological knowledge displayed – students displayed strong problem-solving abilities. They had to consider the way their apparatus needed to function so they considered functionality, purpose, and displayed qualitative knowledge - which is the knowing of how to do a task. In being able to design a new aeration system within the apparatus, they demonstrated systems knowledge.

Case Three – Renewable energy

The third case examines an authentic need for affordable and accessible electrical energy in
small communities. During the 2010 congress students from Cambodia (Chen Sophal, Phal Songhak et al) presented their solution for the problem of providing small villages with a source of renewable energy for generating electricity. Their solution was a low wind speed generator for use in villages not connected to the ‘national’ grid. Its production involved the use of scrap materials that were readily available in such communities. The process not only involved the reshaping of materials to form the turbine’s blades but also the re-use of parts, such as an alternator from a car, to allow energy storage in a battery.

Although the science knowledge exhibited was impressive, as a technological product to solve a problem it excelled. The students’ use of recycled materials was significant not only in terms of the congress theme but also for if the product is eventually to be made and used by local villagers. These people will need to be able to use local tools to shape the metal as well as having the knowledge to maintain the machine. A small-scale prototype was presented at the congress allowing the students to demonstrate its use and to explain how it was designed, made and the science principles involved. (There is potential for this model to be used at the village level for a similar demonstration.)

**Technological knowledge displayed** - What can be assessed in terms of technology is the students’ knowledge of the properties of materials and how these were considered and influenced the design. This includes the techniques and tools used for shaping and joining. Another area for assessment is how the components are put together to form the system, which is where scientific knowledge is integral. The importance of feedback during each stage of the product’s development is vital and can be in the form of the teacher’s or mentor’s specific questioning as well as peer and self-assessment which help focus students’ attention on specific problems to be solved (Black, 2008).

**Case Four – Eco filter**

The final case is that of a water filter, which the students designed and built to fulfil several authentic needs in the community. The first was the on-going problem of water purity in many villages and rural areas, the second the need for a simple easily made product to use in the aftermath of natural disasters and finally as a way in which to educate primary aged students about the excitement of learning science (the students did not think of their project as being in the two areas).

The product designed and made by this team, Poh Jian Zi and Joshua Ling En Sheng (who presented it) was described as an eco-filter. It comprised an outer casing
made from discarded mineral water bottles with replaceable compartments. These compartments contained organic matter (Neem leaves, egg shells and husks from rice production) these were to remove heavy metal ions prevalent in most water samples taken from around the island of Penang but also a common problem in many locations throughout the region. Additional materials used to remove large sized impurities were sand and gravels while activated carbon, wood based carbon and volcanic rocks addressed odour removal and colour from the bio-absorbents. The final ingredient to be used was silver granules to kill bacteria. A feature of this product is the use of predominantly waste materials from agriculture. This makes it low cost as well as readily made by members of local communities.

Technological knowledge displayed - In terms of what can be assessed with this product are the sources of information used during the investigating phase before designing began: Materials knowledge - Why were the various materials selected for the filter, (evidence of their efficacy) Systems knowledge - how was the order of their placement decided and the evidence for their efficacy (science knowledge integration)? Problem-solving - What modifications were made during the project and why, and what if anything would they change in the future? Through answering questions such as these the product can be further improved.

Conclusion

The evaluation of the four cases, ostensibly science projects, highlights the intrinsic technological knowledge masked within the broader science agenda of the projects and the congress. The projects demonstrated students' knowledge in many of the technological thinking skills and ways of operating. The four examples highlighted thinking related to:

1. problem-solving, mechanical engineering, systems thinking and materials knowledge, functionality, purpose aesthetics, and socio-cultural awareness (HF-Auto Trap)
2. problem-solving, functionality, purpose, qualitative thinking, and systems thinking (Aerated In vitro culture system)
3. problem-solving, materials knowledge, systems knowledge, process knowledge, and socio-cultural awareness (renewable energy model)
4. problem-solving, materials knowledge, systems knowledge, and socio-cultural awareness (Eco filter)

These are clear instances of technology actually dominating the science or as indicated by De Vries (1996) earlier, little science is required for students to be able to develop the technological aspects of their projects. There is the possibility that other projects at the Science Congress could be evaluated for their technological knowledge or, better still, in future, technological knowledge could be one of the evaluation criteria for the projects.

The cases presented here are a small sample of those from the eight congresses held since 1998. Fifty projects are submitted each congress, so over 400 student projects so far have been evaluated for scientific content and applied science methodology. What does stand out in each is the motivation that authentic problem-based projects provide for students as they address problems faced by their local communities.

The examples we have provided illustrate that the opportunities for assessment of technological knowledge are clear and can potentially assist students with the development of their future technological skills and knowledge.
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Student understanding of the relationship between fit for purpose and good design: does it matter for technological literacy?

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Fit for purpose and good design are common terms in technological discourse and therefore should be of importance for technology education. While fit for purpose has been a key concept in technology education in New Zealand since 1993, the concept of good design has only relatively recently entered technology education documentation by way of the newly aligned achievement standards (Ministry of Education, 2012) and the revised Nature of Technology strand (Compton and Compton, 2010a). As part of the Technological Literacy: Implications for teaching and learning research currently underway in New Zealand (Compton, Compton and Patterson, 2011) we began exploring student understanding of fit for purpose and good design, and the relationship between them. In this paper we report on initial findings and discuss our developing ideas about how this may provide a useful descriptor of student technological literacy as it progresses as a result of technology education.

Introduction
Fit for purpose and good design are common terms in technological discourse and therefore should be considered as important in technology education. Fit for purpose has been present in technology education in New Zealand since 1993 and has been explicitly emphasised as a key concept in technology in the current New Zealand Curriculum (NZC) (Ministry of Education, 2007). For example, fit for purpose is a concept in all three technology curriculum strands being specifically mentioned in achievement objectives related to Characteristics of Technological Outcomes from NZC Level 3, Technological Modelling from level 2, and Outcome Development and Evaluation from Level 4 (Ministry of Education, 2007, Levels 2-7 pull-out section of the NZC). In the national curriculum and in the additional support material known as the Indicators of Progression (Compton and Compton, 2010a, Compton and Compton, 2010b; Compton and Harwood, 2010), fit for purpose is presented as the means to judge the ability of a technological outcome to serve its purpose within the intended location, where the requirements of the outcome are clearly defined by the specifications in the related brief. When fit for purpose is described as being 'in the broadest sense' (Compton and Harwood, 2005), the concept is extended to include the determination of the 'fit' of the practices involved in the development of the outcome (including such considerations as the sustainability of resources used, treatment of people involved in manufacture, ethical nature of testing practices, cultural appropriateness of trialing procedures, determination of lifecycle and ultimate disposal) as well as the 'fit' of the outcome itself. This extended
concept underpins the focus of the NZC Level 8 technology achievement objectives for Brief Development and Outcome Development and Evaluation (Ministry of Education, 2007, Level 8 pull-out section) and explained in the Level 8 Indicators of Progression for Brief Development, Outcome Development and Evaluation, and Characteristics of Technological Outcomes (Compton and Harwood, 2010; Compton and Compton, 2010a). Fit for purpose is also a key concept underpinning the newly aligned technology achievement standards at Level 1 and 2 of the New Zealand Qualification Framework (NZQF), and fit for purpose in its broadest sense is captured in a number of the NZQF Level 3 technology achievement standards (Ministry of Education 2012). (Please note: The NZQF runs from Level 1-10 and provides pathways into the tertiary sector up to Doctorate level. There is an overlap between the NZC and NZQF frameworks with NZC Level 6 equating to NZQF Level 1, 7 to 2, and 8 to 3.) The achievement standards provide assessment tools for teachers to validate student learning in technology at senior secondary school as part of the National Certificate in Educational Achievement (NCEA).

The concept of good design however, has only recently been given an explicit emphasis within technology education in New Zealand. This has been by way of the revised Indicators of Progression for Characteristics of Technological Outcomes at NZC Level 3 (Compton and Compton, 2010a) and the development of a new achievement standard at NZQF Level 3. This concept is based on a contemporary understanding of good design that begins with the view of ‘designs as arguments’, which ‘frees us from the art world’s tendency to evaluate on aesthetic criteria alone’ and ‘insists on contextual evaluation’ (Hall, 2009, pg 1). Hall (2009) goes on to explain that in this sense, ‘design is not just about how a thing looks or how it works; it is also about the assumptions on which it rests’. Ten criteria have been suggested for evaluating design arguments as ‘good’ today - that is, in the ‘troubled economic, ecological, and political climate of the early 21st century’ (Hall, 2009, pg 1). The criteria identified by Hall are: sustainable, accessible, functional, well made, emotionally resonant, enduring, socially beneficial, beautiful, ergonomic, and affordable (2009, pg 1). Viewed in this way, good design becomes a central tenet in the stance of technology as a worthwhile human endeavour.

We argue therefore that the concepts of fit for purpose and good design are both important to explore in technology education, and could be important elements in an informed and critical technological literacy. Our initial thinking is that these concepts, as described above, have an interesting relationship and can be mutually informing. Fit for purpose can be thought of as the mechanism by which to judge a specific technological outcome by considering whether all the technical and social acceptability requirements as defined in the brief have been met when the outcome is placed in situ. A technological outcome can be judged as fit for purpose – or not. Fit for purpose therefore is a concept which only has meaning when applied to a specific technological outcome in its unique physical, sociocultural and temporal location. Good design on the other hand, is a concept which sits at a somewhat more ‘utopian’ level. It is not about any specific technological outcome but rather is clearly positioned as a set of criteria reflective of the socio-political climate of an era and may be applied to any technological outcome in order to make a normative judgement of ‘goodness’. Such a judgement could be usefully viewed as a placement on a continuum rather than as a ‘good/bad’ type of decision. This notion of a
design continuum built upon multiple and often contesting criteria could provide a very rich context for students to critique and discuss their own and others’ designs. The concept of good design is not just useful for end point judgements of technological outcomes. Developing student understanding of the concept of good design and encouraging them to be aware of the criteria upon which it is based during their technological practice would be a good strategy for enhancing their practice.

What then, of the relationship between the two concepts? We would say that given ‘functional’ is one of the contemporary criteria of good design, and all technological outcomes must be ‘functional’ to be fit for purpose, it follows that fit for purpose can be seen as an integral part of good design. The closer the relationship between the specifications for any particular technological outcome and the criteria of good design, the more likely a judgement of fit for purpose will be accompanied by placement near the ‘good’ end of the design continuum. However, in practice all technological outcomes are the result of compromises required to resolve tensions that arise between the opportunities and constraints surrounding their development and have additional motivating forces influencing design-decisions. That is, ‘good design’ is rarely the only driver! These forces often serve to prioritise particular good design criteria over others. It is therefore common for technological outcomes to be judged fit for purpose (against the specifications that have resulted from these compromises) than it is for them to be clearly placed at the ‘good’ end the design continuum. As the concept of fit for purpose is extended to include the fit of the practices as well as the resulting outcome, the relationship to the concept of good design strengthens further. This reflects the similarities found between the criteria of good design and the considerations underpinning what are thought of as ‘fit’ practices.

Earlier findings have indicated that students’ ability to act on ethical, environmental economic and legal considerations during their critique and/or development work in technology education tends to be limited. Developing a better understanding of the concepts of fit for purpose and good design may help rectify this tendency and thus aid in the progressing of students’ overall technological literacy from foundational to citizenship, and through to a more comprehensive technological literacy. As discussed elsewhere (Compton, Compton and Patterson, 2011) we see these three phases of technological literacy as useful descriptors whereby foundational technological literacy refers to the expected transformation of students as they work from NZC Level 1 to Level 3 of the technology curriculum, citizenship technological literacy refers to the expected transformation of students as they work up to NZC level 5 and a comprehensive technological literacy refers to the expected transformation of students as they work up to NZC Level 8. As part of the Technological Literacy: Implications for teaching and learning (TL: Imps) research currently underway in New Zealand (Compton, Compton and Patterson, 2011) we began exploring student understanding of fit for purpose, good design, and the relationship between the two. In this paper we report on our initial findings and discuss our developing ideas about how this focus may be useful in providing a description of how technological literacy may progress.
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 this 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 in the NZC (Ministry of Education, 2007). 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 the TL:Imps project, students in years 1-13, ranging from age 5 years to 18, will be interviewed about technological outcomes, both known and unknown to the student, to identify their understanding related to fit for purpose and good design. A series of three interviews will be conducted over a two year time period. The Round 1 interviews collected baseline data between March and April 2011. These interviews included a question around fit for purpose but not good design and therefore will not be included in this paper. Round 2 interviews were undertaken between October and December 2011 after the completion of the first year of a technology programme. The interviews included questions around fit for purpose and additional questions about good design and its relationship to fit for purpose. These interviews provide the data used in this paper. A third round of interviews, to be undertaken after the completion of the second year of the technology programme, will also include these additional questions and will be compared with the Round 2 data at a later date. Whenever possible the same students will be interviewed in each round. The participant makeup and prompts used are provided below.

Interview participants and prompts

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 in 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 (59.3%) than male students (40.3%) have been interviewed reflecting the overall cohort of students involved (55.8% female and 44.2% male). During Round 1 a total of 392 students were interviewed. The majority (74%) 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 second interview. An additional 43 students were interviewed. Therefore the number of students interviewed in the Round 2 was 333. All students involved in the research have been assigned a nine digit identification number to maintain their anonymity when presenting any direct quotes as in the findings section below. The first two numbers refer to the school, the third, fourth and fifth numbers refers to the number assigned to students within each school, the sixth number refers to the type of data collected from that student,
the seventh and eighth numbers denotes the year group (where 01 = year 1 through to 13 = year 13), and the final number denotes gender (where 0 = male and 1 = female). The distribution of students interviewed in Round 2 by year group is shown in Table 1.

Table 1 Participants by year group

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The technological outcomes used in Round 2 are presented in Figure 1.

Bobble (known) Gaiter (unknown)

Figure 1 Technological outcomes used in Round 2.

Using these technological outcomes as prompts, the students were asked to explain their understanding of fit for purpose, good design, and the relationship between the two. Data was collected regarding fit for purpose understanding from all 333 students, and 326 of these students also provided data related to good design.

Findings

Student understanding of fit for purpose
When asked what they thought fit for purpose meant 135 of the 333 students (40.5%) showed they did not understand the concept at all, while the remaining 198 students (59.5%) demonstrated some level of understanding of the concept. A breakdown of these percentages is shown in Figure 2 and described below.
Of the 135 students showing a lack of understanding of fit for purpose, the majority (101 students or 30.3%) had ‘no idea’ and 34 students (10.2%) held the wrong idea. For example:

It makes you fit if you do something with it. 210223030

Of the 198 students showing some understanding, the majority (129) exhibited a simplistic understanding. For example:

If you design something… is it able to be used for what you wanted to use it for. 180193081

Understanding of fit for purpose as related to specifications was demonstrated by 60 of these students. These students linked being fit for purpose to a range of needs/requirements related to the outcome’s ability to function and be acceptable to people. For example:

Fit for purpose is whether or not something meets the requirements of the situation that it has been designed for. So a chair that it supports your weight comfortably, if it’s got wheels on it, whether they roll freely… for a garment that it fits well and doesn’t break down in the first wash… if its sportswear that it enhances your performance – like lets your body cool down… 170553131

A more sophisticated explanation of fit for purpose was only demonstrated by 9 students. These students referred to the fit of the practices as well as the outcome and often made reference to the need for evidence to support a fit for purpose claim. For example:

It means it has met all the needs for what they were creating it for and all the people are generally happy with it and its doing its job well. The world’s trying to ‘go green’ so making products in a caring way and creating healthy and environmentally caring products … like recyclable… is all part of it. So it (the bobble) is probably fit for purpose ’cos most people want environmentally safe stuff –and it looks like it would work well and be easy to use. (Why do you say probably?) To say ‘yes’ it is fit for purpose, you would need everyone to agree that it is environmentally safe… it would need to be tested by lots of scientists and stuff to prove it is safe. 260203080

When this data was explored by year group it was apparent that there was an overall trending up of student understanding of fit for purpose as year group increased. However this was disrupted to some extent in years 9, 10 and 11 where more students than might be
expected still held a simplistic understanding of fit for purpose. It is also interesting to note some students as early as year 3, 4 and 5 showed they were beginning to form an understanding of fit for purpose related to specifications.

**Student understanding of the relationship between good design and fit for purpose**

When asked about the concept of good design and how it might relate to fit for purpose, 120 of the 326 students (36.8%) stated they did not know what good design meant. The remaining 206 students (63.2%) explained a view of good design and could discuss its relationship to fit for purpose. A breakdown of these percentages is shown in Figure 3 and described below.

![Figure 3](image.png)

**Figure 3 Student understanding of the relationship between good design and fit for purpose**

Seventy two students (22.1%) stated good design related to a ‘quality’ factor (often aesthetic, although good materials used/made to last were also mentioned), but did not see any relationship between good design and fit for purpose.

A typical response was:

Good design means it is made to last and fit for purpose is about can it actually do the job it is supposed to. 210193031

In contrast to this view, 38 students (11.7%) felt that good design meant the same thing as fit for purpose. Their view of good design therefore varied as related to their understanding of fit for purpose, but all felt they were different names for the same concept. For example:

Fit for purpose and good design… they are just the same thing 140223081

The remaining 96 students considered the concepts to be different but related. Of these, 31 students (9.5%) thought that good design related to ‘looking good’ and was part of being fit for purpose. These students would often go on to explain how something could be a good design but it may not be fit for purpose. For example:

Good design is when something looks good, and fit for purpose is when it looks good and does the job it was meant to… something can be a good design – it can look good but is might be useless, it might not work properly so it is not fit for purpose. 150183090

The other 65 students (19.9%) thought that fit for purpose was a part of being a good
design where good design reflected a range of associated factors such as being easy to use, made from quality materials/long lasting, affordable, environmentally friendly, as well as looking good. These students would often go on to explain how something could be fit for purpose but may not be a good design. Examples of student responses included:

For something to be a good design it would have to be able to do what it is supposed to, but it would also have to be comfortable and easy to use. Something that does what it’s supposed to but isn’t easy to use and it doesn’t look so good or doesn’t seem to be thought out that well… then you could say it was fit for purpose but isn’t a good design. 170183101

It would need to be really strong – like that drink bottle, you wouldn’t want it to break after a few uses – that wouldn’t be a good design… it has to last and I think now with the whole economy and global warming and that… it has to be affordable and… and it has to be efficient ‘cos we don’t want to you know ruin the world. (So what do you think the difference between good design and fit for purpose is?) I think they have similarities because like a good design should be fit for purpose… ‘cos fit for purpose means you can use it – and so you can actually sell it… but a good design – has those other things as well… 240173081

When this data was explored by year group it was apparent that there was an overall decrease in the number of students who had no idea what good design might mean as year group increased, although this was somewhat disrupted at year 9 where almost half of the students (29 out of 61) still stated they had no idea. There was also an overall decrease in the number of students who felt there was no relationship between the concepts of good design and fit for purpose as year group increased. However, there was no clear trend by year group noticeable across the remaining three categories.

Discussion
From these initial results it would seem that the majority of students from year 6 and above have developed some understanding of the concept of fit for purpose and that this concept generally strengthens and becomes more sophisticated as the number of years at school increases. This suggests that the technology programmes of learning these students are currently participating in are providing opportunity for many students to develop their understanding of fit for purpose. This reflects the current emphasis on the Technological Practice components generally and on Outcome Development and Evaluation specifically. However, such a trend with year level is less clear in relationship to understanding of what good design may relate to, and its relationship to fit for purpose. Notions of good design are not a key focus until NZC Level 3 of Characteristics of Technological Outcomes and early data on student achievement related to this component shows that only 15 of these students (14.7%) were found to be working at NZC Level 3 or above. Therefore it can be surmised that the understanding of good design coming through this data are largely intuitive and reflective of personal views of what constitutes ‘good’. This would explain the variation of views about good design and its relationship to fit for purpose.

Implications for technological literacy
Based on these early findings we consider it is worth continuing to explore shifts and relationships associated with these concepts, along with other aspects such as student ability to ‘read’ technological outcomes (Compton, Compton, and Patterson, 2012), as we begin to develop holistic phase descriptions of the nature of transformation that occurs as students become more technologically literate.
Based on the findings to date, and the positioning of concepts within curriculum, assessment documents, and support material, we consider the concepts of fit for purpose and good design may be usefully linked to the phases of technological literacy as follows:

**Foundational technological literacy** might be evidenced by student ability to:

- explain the concept of fit for purpose as a means of judging whether a technological outcome ‘does the job’ it is supposed to do
- employ this concept in their own evaluations of whether their outcome has successfully included the attributes they felt were most important
- make and explain a judgement of an outcome as being a good or bad design, although their concepts of good design may be both personal and partial.

**Citizenship technological literacy** might be evidenced by student ability to:

- explain the concept of fit for purpose as a means of evaluating a technological outcome as based on whether it has met the specifications of its brief,
- employ this concept in their own evaluations of prototypes and when analysing the technological practice of others
- make and justify a judgement of an outcome along a continuum good design as based on an understanding of good design criteria.

**Comprehensive technological literacy** might be evidenced by student ability to:

- explain the concept of fit for purpose in its broadest sense
- employ this extended concept of fit for purpose in their own evaluations of prototypes and when analysing the technological practice of others
- explain the concept of good design and the nature of its relationship to fit for purpose
- apply the criteria from good design in their design decision making and evaluations of their own and others technological outcomes in an informed and critical manner.

In order to explore the potential of this focus in the descriptions of technological literacy, we require data from a greater number of students working at level 3 and above across all the eight components of technology than was the case in the Round 2 data. We are hopeful that during the second year of their technology programme many older students will have progressed to this level, and therefore their teachers would have explicitly focused on good design and used aligned strategies to widen the considerations that students take into account in their own practice and critique of others technological developments and outcomes. If this is the case, our Round 3 data should provide us with the opportunity to continue this exploration.

**References**


Development of a new high school instructional material for engineers’ moral education: Introducing Science and Technology communication

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In recent years, activities that involve science and technology communication are conducted as a kind of technology education. In this study, we develop teaching material that integrates these activities with our previous studies. First, we conducted engineers’ moral education at our technical high school. In 2011, the Fukushima Daiichi nuclear disaster took place. At that time, engineers in the company were asked to explain the accident. However, citizens and politicians distrusted of their explanations because they did not provide sufficient information as expected. As the result, people changed the attitude toward the atomic energy policy. Therefore, we developed material for engineers’ moral teaching that introduces science and technology communication as the setting in order to increase its effect. Second, we propose that science and technology communication be considered not as an activity for scientists and engineers to persuade citizens but instead an occasion for citizens to address consensus-building on effectively utilizing science and technology in our society. In our definition, an important role of scientists and engineers is to provide accurate information so alternatives can be discussed and evaluated. Therefore, our teaching material supports collaborative learning between citizens and experts in the field of science and technology.

Introduction

Today’s highly technological society relies heavily on engineers to solve technical problems. Most of these engineers work for companies that are usually locked in stiff competition with other companies. Because company managers are oftentimes compelled to come out ahead of the pack, they push their engineers to develop products of superior performance at the lowest possible cost. Meanwhile, cost and safety are in a perennial tug-of-war: more safety usually requires a bigger budget. The dilemma is thus passed on to the engineer, who must find a balance between cost cutting and safety. If an engineer yields to a manager’s demand to slash costs by sacrificing safety, it could create serious trouble.

Recently, many institutions have introduced an engineers’ ethics subject in all engineering degree programs, as stipulated by the Washington Accord (International Engineering Alliance). However, not all engineers come from such programs; some enter the field via vocational education at the upper secondary level. Therefore, we considered that an ethics subject is absolutely necessary in the technical high schools to develop future engineers’ moral education (Endo & Matsuda 2008).

In our past study, we found that some students could not understand why engineers’
ethics education was necessary. Since they had yet to work in companies, they were unable to connect it to the possibility that engineers could commit harmful acts by cutting corners, and that the engineers need not be evil by nature to do such things. In short, the students’ questioning was not necessarily grounded in high morality, but in their inability to grasp the resulting engineer’s dilemma.

Therefore, we believe that students should be made to understand workplace climates, human relationships, and the pressures of performance that employees experience. We call it “knowledge of situations,” derived from Murai’s “Three Types of Knowledge” for moral judgment (Murai 1990). Endo and Matsuda (2007) revealed that when they asked students to draw a concept map of the elements of an engineer’s moral judgment, those who had attained higher educational levels were able to create more complex and fulfilling maps. This supports our hypothesis. For this purpose, we developed some instructional materials that provide students with knowledge of situations and confirmed the effects of the materials to achieve our purpose (Endo & Matsuda 2008).

We also found other issues in the students’ responses to the question of what they should do when faced with a case requiring their ethical judgment as engineers in a company. Their responses were centered on how they could sidestep or gloss over their responsibilities for the trouble they caused. We need to consider the reasons for such responses and devise methods of prompting them to recognize their roles.

Gregory and Miller (1998) said, “In a democracy people make decisions about scientific and technological policy matters every time they vote.” Indeed, such decision-making should be done by consumers—the taxpayers—not by the scientists or engineers. Gregory and Miller (1998) also stated that “science communicators could bear in mind that people find most useful, and most readily retain, information which is relevant to their lines and which is set in real, everyday context rather than in the abstract terms of formal science.” As we understood it, they emphasized the need to take into consideration the understandability of the topics from consumers’ perspectives. Scientists and engineers ought to fully explain the details of a technological problem to the consumers, who do not have professional knowledge to draw from; they should present consumers with enough data to allow them to pick an alternative.

According to these suggestions, we considered that our program and instructional material lacked sufficient support in prompting students to consider what the role of engineers is. The right to choose the desired technology belongs to consumers. We need to teach students that the responsibility of engineers should be focused on providing consumers with adequate information. For this purpose, we agreed that it would be effective to include the scene of science and technology communication in our instructional material.

**Purpose**

In this research, we intended to provide technical high school students with simulations of engineers’ moral dilemma by developing game material. We introduced scenes wherein a student, being an “engineer” in a company, has to explain technical problems to the stakeholders or consumers. We expected the exercise to inspire the students to take the role to heart. For this purpose, we picked up the real case of an automobile maker as the
motif of our scenario to develop game-type e-learning material. In addition, we conducted practice lessons using our game material to examine its effectiveness.

Plan of the Practice Lessons
Our practice lessons were planned for 39 students who comprised one of five classes at the 9th grade (ages 15-16) of the Tokyo Tech High School of Science and Technology. Because of the constraints of our yearlong plan, the engineer's moral program had to be conducted in four 50-minute lessons.

The purpose of the first three lessons is to provide knowledge of situations, i.e., promoting students' understanding of the pressure of achieving both high performance and low costs, as well as human relationships in the company. In the fourth lesson, we deviated from previous practice.

Figure 1 Plan of practice lessons and the instructional materials used in each lesson

In the first lesson, the students were asked to judge two practices involving moral issues: “Heinz’s Dilemma” (Kohlberg 1971) and Meat Hope Corporation’s “Mislabeling Scam of Meat Case.” The former case was used to measure their general level of morality and the latter, their moral judgment level against that of a member of the company—from consumers’ viewpoints. We collected the data using e-learning materials and utilized them as the pre-test in the last section.

In the second lesson, we let students play the “Company Manager” game (Endo & Matsuda 2009), which was designed to help them understand why a company manager put pressure on his/her company members. In the third lesson, we asked them to play the “Engineer in a Company” game (Endo & Matsuda 2010) to show them the interaction between company members who have different roles. In this game, each student played three different roles in a personal computer manufacturing firm: an engineer, salesperson, and complaints officer. These games were developed as e-learning materials for individuals.

At the end of the third lesson, we conducted a mid-term test to examine the effect of the lessons so far. For this purpose, we made a simplified judgment practice about the “Ford Pinto Case” (Birsch and Fielder 1994), which was used for judgment practice in the fourth lesson. The students were asked for a written answer (in essay form) to this question: “What do you think of the company’s decision from the viewpoint of an engineer in the company?”

In the fourth lesson, we used the new game material to explain the next section below. In the past, as we mentioned above, we have used our e-learning judgment practice about Ford Pinto Case and our paper-based judgment practice about “Whistle-blowing” (Endo & Matsuda 2008). Although the materials were meant to make the students aware of an
engineer’s need to exercise moral judgment when considering the consumers’ standpoint, they were not enough to change the students’ attitudes.

When all the lessons were completed, the students chose any case in conjunction with engineers’ moral judgment, and they had to answer the following questions within a week: (1) “What’s the matter?” (2) “Should an engineer in a company blow the whistle or not?” (3) “Being an engineer in a company, how should you behave when technological trouble occurs?” and (4) “How should a company manager make decisions?” The answers were used as the post-test data.

**New Instructional Material Introducing Science and Technology Communication**

Our new instructional material was game-type e-learning, played individually. The reason we did not make it a group game was to make each student’s sense of responsibility apparent. The new game was developed to change the students’ tendency to rationalize or gloss over their responsibility for the trouble that arose. We concluded that a group decision would make individual responsibility ambiguous and thus encourage undesirable attitudes. Since we established a one-to-one setup for decision-making and its result, no student would be unable to escape from his/her responsibility for the result. The game scenario was a fictitious case, but it was patterned after the “Mitsubishi Motors Recall Case” of 2002.

Our scenario consists of four scenes: (1) the occurrence of trouble is reported to a complaints officer, (2) a meeting with other engineers, (3) a meeting with members from several sections of the company, and (4) a press conference. As mentioned previously, we had been using the instructional material of the Ford Pinto Case for judgment practice, which has many commonalities with new one; e.g., both caused by the car company and producing casualties by the troubles. On the other hand, they are decisively different as regards the clarity of the learner’s responsibility for the result. In the old game, although learners were asked for their decisions, the game itself instilled adequate acts as feedback and the results did not change regardless of what the student chose. In our new instructional materials, the results change according to the learners’ decisions, which heightens authenticity and makes them feel their responsibility. Following is the scenario of our new game.

In the first scene, some users file complaints about the hub damage and parts that fall off. The company’s complaints officer reports it to the engineer (player). At this point, the game asks the player, “Which do you choose: recall or passing the responsibility to the users?” After storing his/her choice in a variable, the game gives the feedback, “It is important to act with integrity.”

In the second scene, the player has a meeting with other engineers. The complaints officer reports that users have been lodging complaints in each division in the company, including the office of the company manager, and that the complaints have become too many to ignore. The purpose of the meeting is to determine how to explain the next scene to members the company’s divisions. Because the company manager and others are not specialists, they do not have sufficient technological knowledge about the trouble. They thus entrust the whole thing to the engineers, but the engineers cannot identify the cause
of the trouble. Therefore, the engineers may opt for the convenient choice that is advantageous because they do not want to assume the responsibility for a misjudgment that would place needless strain on the company. After prompting the student to recognize this dilemma, the game lets him/her make a decision as the professional leader.

In the real case, young engineers claimed that the trouble of the hub had practically no relation with the accidents, and the report promoted concealment activity. The purpose of our instructional material is, as mentioned in the Introduction, to foster the integrity of students, who otherwise tend to shirk or gloss over their responsibility. Therefore, in our instructional material, we made the scene require data to persuade others scientifically even if the engineer’s opinion is respected. Though it is absurd to fabricate data, students are asked to consider several possibilities and present scientific/technological data to support their judgment. However, Japanese high school students did not learn methods of statistical analysis in mathematics; rather, they learned the definition of terms. Therefore, our instructional material provides examples wherein two opposite conclusions can be deduced from the data: (1) a case of public opinion poll to which they could understand “agree” if the number of poll to “don’t care” was added to “agree” but could understand “no” if it was not added; (2) a graph that blew out of proportion the differences between choices by not using zero as its base value; and (3) the data used in the speech of Buchanan (1996) to appeal the inequity in the Japanese car market by showing that U.S.-made cars did not sell well in Japan, without explaining that German-made cars sold well because they were right-hand drive.

The choices at this point are constructed as two factors: decision (concealment or recall) and data for a report (only data favorable for the decision or unbiased data to support executive decision).

The third scene is a meeting in the company, which can be construed as science and technology communication. In this scene, professionals should put their heart and soul into showing objective data, and trust the judgment of nonspecialists. The purpose of this scene is to help the student understand his/her role—that of not using arbitrary instruction to persuade others to agree. However, at this point, the problem has not yet been settled, and there is pressure from others in the company. It is possible that the engineers will quibble or misjudge and recommend a recall. In choosing recall, the engineer must confront the pressure brought on by the heavy repair cost, influence on the market, decline of trust in the company, damage on the brand image, influence on employees and stockholders, and so on. For a company, both recall and procrastination in accepting responsibility have risks. It is important for students to feel this dilemma realistically for them to be able to improve their moral judgment as engineers. When a student recommends a recall, it affects the executive decision. Otherwise, the consensus of the meeting will incline towards concealment.

In the fourth scene, a press conference is held; the decision that was reached and the data that was chosen in the previous scene are presented. After that, the game shows the results according to the log recorded in the first scene, and the decision and data chosen in the third scene:
FB1: You lost trust, but according to the support from the main bank, the company can release a new car after five years.

FB2: You and the company manager were caught by the police; the company faced criminal charges, too.

FB3: Although you were caught by the police because of a fallacy in the report, you avoided prosecution. The performance of the company deteriorated, and it is now going bankrupt.

FB4: The declining performance is slight and short-term, and is not serious. In real cases wherein recall and accidents were concealed, the smaller companies were often driven into dissolution and bankruptcy. Only the massive ones with a strong economical base survived. Therefore, we emphasize that an engineer ought to offer sufficient information from the beginning, and to be truthful every time. However, the truth should not yet be revealed at the time of decision-making. In our instructional material, the data recommending a recall does not contain causation between the trouble and the accident, and the company was not put at a disadvantage. The reason for this is that we gave priority to raising the students’ judgment level from 3 to 4.

Results and Discussions
In this research, we obtained three data sets—pre-, mid-, and post-test—from the students. In order to examine the effects of the program, we interpreted each reason for a student’s judgment and evaluated his/her decision level corresponding to the developmental stage of moral judgment proposed by Kohlberg (1971). Before we show the results, we would like to stress a point. Originally, the developmental stage was premised on not falling in a low-ranking stage. However, in the following evaluation, we only classify the students’ responses in each level corresponding to Kohlberg’s stage. We considered that Kohlberg’s theory discussed the “Ethical Code Knowledge” of Murai’s Three Types of Knowledge for moral judgment. We also took into account that people cannot make an appropriate moral judgment without having sufficient knowledge of situation, even if they have sufficient Ethical Code Knowledge. This is the reason we considered that levels of judgments change in a short period or among different problems.
Figure 2 Summary of the number of students, classified according to each level in each test

The results are shown in Figure 2. Columns (1) and (2) are the results of the pre-test conducted in the first lesson; column (3), the mid-test; and column (4), the worksheet submitted after one week of lessons. When compared with Heinz’s dilemma, which can be inferred from general morals in daily life, the responses evaluated as level 2 in the “Mislabeling of Meat Scam Case” greatly increased because of insufficient knowledge of situation; and in level 3, out of sympathy to the company. Thorough analysis revealed that those who were level 2 in Heinz’s Dilemma were still level 2 in the “Mislabeling of Meat Scam Case.” Because many students evaluated at level 4 in case (1) fell to level 2 in case (2), the number of students at level 2 grew substantially. The purpose of our engineer moral education was, notwithstanding the limited number of lessons, to prompt students to apply general moral judgment in daily life to engineers’ moral judgment cases. Therefore, the goal of our program was to raise students’ judgment levels from situation (2) to situation (1). In addition, the above results of (1) and (2) were similar to those of last year.

We considered that students evaluated at level 2 step up to level 3 by their knowledge of situation in the company. In fact, the number of students evaluated in level 3 swelled in the mid-test—case (3)—by the end of the third lesson. As to the individual responses, most of students at level 2 in case (2) rose to level 3 in case (3). The above result of case (3) was similar to that of last year. However, letting the students understand the situation in the company is the interim goal, not the final goal. At the end of the lessons, students turned in their homework. The results showed that the number of students evaluated as
level 4 increased, but those at level 3 decreased. Because the result of the post-test conducted in the last year was similar to that of case (3), it can be concluded that our new instructional material could successfully change the students’ judgment.

Our new instructional material saves the responses of each student in the game as logs. Table 1 shows a summary of students’ decisions: “concealment or recall” in the first and third scenes, and “only data favorable for the decision or unbiased data to support the executive decision,” in the third scene.

Table 1 Summary of each student’s decisions in the first and third scenes

<table>
<thead>
<tr>
<th></th>
<th>the first scene</th>
<th>the third scene</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>concealment</td>
<td>recall</td>
<td></td>
</tr>
<tr>
<td>showing data</td>
<td>7</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>not showing data</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>showing data</td>
<td>11</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>24</td>
<td>38</td>
</tr>
</tbody>
</table>

In the first scene, 20 students chose concealment, four more than those who made the same choice at level 3 in the mid-term test. Some students were evaluated at level 4 in the mid-term test. One reason for this increase may be the characteristic of the individual learning game, which hides a student’s choice from other persons. On the other hand, the number of students insisting on recall in the third scene was 24, less than the 33 students evaluated at level 4 in case (4) of Figure 1. Nevertheless, in the fourth scene, 35 of 38 students chose that the engineer should submit unbiased data to support the executive decision. This number was close to 33, the number of students evaluated at level 4 in the post-test.

Summary and Future Perspectives

The results of the practice lessons suggested that it was effective to introduce the science and technology communication scene into engineer moral education to prompt students to discern the role of professionals. In our instructional material, we considered that a professional should uphold the trust of stakeholders by showing sufficient and objective data at a science and technology communication scene—not to sway them but to support their decision.

However, since the boundary between “explaining” and “inducing” or “entrusting the judgment to others” and “influencing others’ judgment” is not always clear, engineers need to have a high level of morality. Moreover, emphasizing the importance of entrusting the judgment to others may prompt students to gloss over their responsibilities. Therefore, we have to improve their attitudes not only as far as “providing sufficient data,” but also in “exploring various alternatives and solving the problem in cooperation with other members of the company.”

We plan to add a mode that provides students experience of consumers’ standpoints.
In that mode, students need to learn that there is a large variety of consumers, who have different interests. Just as consumers choose companies, companies choose consumers. We believe that it is better for a company to provide consumers with sufficient data to cultivate good consumers. This game will evolve into a game for all students, instructing them on why technology education is necessary for everyone if good citizens are to be cultivated.

References
The development of an educational compact computer for programming learning

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The purpose of this study is to develop and research the utility of an educational compact computer for programming learning. The authors developed the educational compact computer. Then we organized the experiment. As a result, we confirmed that "the students learn quite easily to create simple programs". Therefore we judged that "programming learning using the educational compact computer is possible".

Introduction

According to the new course of study “Section 8 Technology and Home Economics” for junior high school that became effective from school year 2012 in Japan, programming learning (content of technology field) is one component. It is described as follows: Technology of information processing. The following items should be targeted in the instruction with regard to automatic measurements and controls via computer programs: (a) To understand the basic mechanisms for automatic measurements and controls using computers. (b) To deliberate the procedures for processing information and be able to create simple programs.

The authorized textbooks for the technology field are published by three publishing companies, which are: Tokyo Shoseki (Kato et al., 2012) = the textbook A, Kyoiku Tosho (Satake et al., 2012) = the textbook B and Kairyudo (Mada et al., 2012) = the textbook C.

First, concerning “(a) To understand the basic mechanisms for automatic measurements and controls using computers”, Three textbooks are written “sensors, actuators and input/output devices only using the personal computer (PC)”. In addition practice examples, which are “the sensor car and the greenhouse of plant in the textbook A”, the line trace car in the textbook B” and “the line trace car, the sensor car and LEGO in the textbook C”.

Secondly, concerning “To deliberate the procedures for processing information” of “(b) To deliberate the procedures for processing information and be able to create simple programs”, Three textbooks are written “ flowchart structures and flowchart symbols”. About flowchart structures, the textbook A is written “sequence structure and decision structure” and the textbook B & C are written “sequence structure, loop structure and decision structure”. Moreover about flowchart symbols, the textbook A is written “terminator, process, decision and predefined process”, the textbook B is written “terminator, process, decision, loop, input and output” and the textbook C is written “terminator, process, decision and loop”.

Thirdly, concerning “To be able to create simple programs” of “(b) To deliberate the procedures for processing information and be able to create simple programs”, Three textbooks are written programming language of the intermediate language. The textbook A is written “the graphic language” and the textbook B & C are written “Basic".
However, according to the reports 2008-2010 of “All Japan junior high school technology and home economics association”, it is pointed out that programming learning using PC is “there is a limit of the use to PC in some schools”, “there are not enough teaching materials” and “the method of the teaching is difficult”. Therefore, the purpose of this study is to develop an educational compact computer for programming learning.

The development of the educational compact computer for programming learning has not been reported in recent years. However there are some precedent studies on programming learning (Moriyama&Kirita, 1997; Yamaguchi, 1998; Yata&Ueda, 2006; Harigaya, Isukawa and Yamasuka, 2010), and learning using the pocket computer (Akiba, 2002) and the development of a programming language by Visual Basic (Miyazaki, 2006).

**Development of an educational compact computer**

In 2008, the authors started to develop an educational compact computer “iProx TX (Figure1)” that concept was “to be able to create simple programs not using PC”, and finished in 2011.

This educational compact computer is united the 8bit MCU (STC90LE514RD+LQFP44 3.3v) that students can create simple programs with a maximum of 30 steps and save 3 files. In addition the iProx TX has three functions, which are “the infrared ray remote control function for the sensor robot”, “the programming function for the sensor robot” and “the programming function for the sensor light”.

![FIGURE1 Educational compact computer (iProx TX).](image)

In a previous study about programming learning, there was the conclusion that: “Programming the computer appeared to be the most difficult and frustrating for students (Jarvinen, 1998)”, “A visual programming language based on icons makes programming easier than with text-based languages like Visual Basic and Logo (Lavonen, Meisalo and Lattu, 2001)” and “It is programmed in C using a PC. Perhaps the use of C remains questionable. Pupils had no problem with this (Price, 2000)”. Therefore we developed a programming language of iProx TX, called “i-language” like
“the icon” and “Basic” for students making program easily without frustrating. In addition each command of i-language is equal to each flowchart symbol (Refer to Figure 3-5).

The details of commands of i-language is the followings, FW (runs forward), BW (runs backward), TR1 (turns right), TL1 (turns left), TR2 (rotates to right), TL2 (rotates to left) to the above for the sensor robot, 1OP, 2OP, 3OP, 4OP (active output port 1-4) to the above for the sensor light, FOR (for loop), NXT (end of for loop, work in pair with For command), IF (check condition, If---Then---Else / 1RS, 1LS, 2RS, 2LS = input sensor for the sensor robot / 1IP, 2IP, 3IP, 4IP = input sensor 1-4 for the sensor light), STP (stop, all out put inactive), GTO (go to, Jump to the line address in a program), END (end of the program) and 00-99 (range for time and FOR loop, 00 is infinite, 01-99 is the no. of loop).

Development of controlled devices and tutorials
We developed two types of controlled devices and tutorials (Figure 2). Controlled devices are included “sensors, actuators and input/output devices”. One type is a sensor robot which has input sensors (the micro switch sensor and the infrared ray sensor) and actuators (two motors). The sensor robot is controlled by the iProx TX’s infrared ray remote control function. Eight students can control their individual robot at the same time. In addition the sensor robot is controlled by a program of the input/output devices. Another type is a sensor light which has sensors (a light sensor, a sound sensor, a touch sensor and a passive infrared ray sensor) and actuators (a full color LED, a blight light LED and a siren).

FIGURE 2 Controlled devices and tutorials.

We edited two types of tutorials for the sensor robot and sensor light of programming learning. The learning time of programming learning on the tutorial is four school hours. The contents are as follows, operation, commands, flowchart and symbols, program’s input – transfer – run, the learning about sequence, the learning about loop, the learning
about decision. Moreover students learn the making programs in order of the first “sequence (Figure3)”, the second “loop (Figure4)”, the third “decision (Figure5)” using the learning sheet which is divided into three parts of human language, flowchart and programming language (i-language).

First, concerning the programming learning of sequence in the case of the sensor light, students input commands to iProx TX according to the example of sequence in the learning sheet of the tutorial (Figure3). They select the command of icon from command area on LCD screen while moving the cursor by the operating key, input the output1 “1OP 00” into 01 step, then the time zero “00” changing to the time one second “1OP 01”, in the same way, the output2 “2OP 01” into 02 step, stop “STP 01” into 03 step, the output3 “3OP 01” into 04 step, the output4 “4OP 01” into 05 step, end “END” into 06 step. After programming, students transfer programs by infrared ray to the sensor light from the iProx TX. Finally students make the sensor light working the output1 “turn on the red LED for one second”, the output2 “turn on the blue LED for one second”, “stop for one second”, the output3 “turn on the green LED for one second” the output4 “turn on bright light ten pieces LED for one second”. Then students created their original program.

FIGURE 3 Sequence learning sheet.

Secondly, concerning programming learning of loop, according to the example of loop in the learning sheet of the tutorial (Figure4), students input commands of “For—Next (FOR and NXT)” based on the existing program “1OP 01, 2OP 01, STP 01, 3OP 01, 4OP 01, END”. Students press the “add key” then insert a new empty line into 01 step and input “FOR 00” into 01 step, then range for FOR loop 00 changing to 05. In addition students press the “add key” then insert a new empty line into 07 step and input “NXT” in to 07 step. Students make programs of loop “FOR 05, 1OP 01, 2OP 01, STP 01, 3OP 01, 4OP 01, NXT, END”. After programming, students transfer programs by infrared ray to the sensor light from the iProx TX. Finally students confirm the sensor light is repeated five times as programs of sequence. Then students created their original program.
Thirdly, concerning programming learning of decision, according to the example of decision in the learning sheet of the tutorial (Figure 5), students input the command of “IF” based on the existing program “FOR 05, 1OP 01, 2OP 01, STP 01, 3OP 01, 4OP 01, NXT, END”. Students press the “add key” then insert a new empty line into 01 step and input “IF 1IP ON TH 02 EL01” into 01 step. Students make programs of decision “IF 1IP ON TH 02 EL01, FOR 05, 1OP 01, 2OP 01, STP 01, 3OP 01, 4OP 01, NXT, END”. After programming, students transfer programs by infrared ray to the sensor light from the iProx TX. Finally students confirm the sensor light is worked as “when input sensor 1 is working, the sensor light turned on as programs of loop. Then students created their original program.

<table>
<thead>
<tr>
<th>Human language</th>
<th>Flowchart</th>
<th>Programming language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn on output1 for one second</td>
<td>Start</td>
<td>01 FOR 05</td>
</tr>
<tr>
<td>Turn on output2 for one second</td>
<td>Loop begin 5 times</td>
<td>02 1OP 01</td>
</tr>
<tr>
<td>Step for one second</td>
<td>On output1 1 second</td>
<td>03 2OP 01</td>
</tr>
<tr>
<td>Turn on output3 for one second</td>
<td>On output2 1 second</td>
<td>04 STP 01</td>
</tr>
<tr>
<td>Turn on output4 for one second</td>
<td>Stop 1 second</td>
<td>05 3OP 01</td>
</tr>
<tr>
<td>Repeat five times</td>
<td>Loop end</td>
<td>06 4OP 01</td>
</tr>
<tr>
<td>End</td>
<td></td>
<td>07 NXT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>08 END</td>
</tr>
</tbody>
</table>

**FIGURE 4 Loop learning sheet.**

**FIGURE 5 Decision learning sheet.**

**Methodology**

The experiment was organized at a junior high school located in Kobe, from February to December, 2011. A total of 128 second-grade students (male 53, female 75 / 13-14 years old) in four classes attended the technology course. We designed the syllabus for the
experiment class 1-13 and the test 1-3 (Table 1).

Table 1 Schedule of experiment class

<table>
<thead>
<tr>
<th>Date</th>
<th>Experiment class</th>
<th>Learning contents</th>
<th>Method for measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb 2011</td>
<td>1 Programming 1</td>
<td>Test 1 (Questionnaire : 10 minutes)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Programming 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Programming 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Programming 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring vacation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>5 Production of the sensor light 1</td>
<td>Test 2 (15 minutes), Questionnaire(5minutes)</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>6 Production of the sensor light 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>7 Production of the sensor light 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>8 Production of the sensor light 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td>9 Production of the sensor light 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td>10 Production of the sensor light 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec 2011</td>
<td>11 Programming 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct 2011</td>
<td>12 Programming 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov 2011</td>
<td>13 Programming 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec 2011</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Experiment class 1: Operation, commands, flowchart and symbols, program’s input – transfer – run.
Experiment class 2: The learning about sequence, the learning about loop.
Experiment class 3: The learning about decision, create simple program for the sensor light.
Experiment class 4: Create simple program for the sensor light and the sensor robot.
Experiment class 5-10: Production of the sensor light for technology of energy conversion.
Experiment class 11-13: Create simple program (Figure 6&7)

The teacher has the experience of the technology field for 36 years. In addition students learned the content about “technology of materials and their processing” at the first grade. We prepared the iProx TX, the tutorial and the sensor light for individual student, the sensor robot for each group of class, the document camera and the projector for the teacher.
Results
In the investigation before the lesson, nobody had the experience of programming (test1). After the lesson 1-4, we carried out the test 2. And after the lesson 5-13, we carried out the test 3, where we asked students to describe the program (around ten steps) on sheet.

After test 2, we checked their programs by the sensor light working, as the result, we confirmed the following things, students who were able to describe something program was 86.7% (111 students) and students who were able to describe complete program was 53.9% (69 students). The complete program means that the sensor light is worked by their program. We classified theirs at six levels afterwards.

Level 0: The student who is not able to describe program.
Level 1: The student who is not able to describe complete program.
Level 2: The student who is able to describe complete program of sequence structure (include GTO).
Level 3: The student who is able to describe complete program of loop structure (include combining with sequence structure).
Level 4: The student who is able to describe complete program of decision structure (include combining with sequence structure or loop structure).
Level 5: The student who is able to describe complete program of combining structure (include combining with sequence and loop structure).

We analyze test 2 according six levels, the result was Level 0 - 17 students, Level 1 - 42 students, Level 2 - 23 students, Level 3 - 4 students and Level 5 - 24 students. Average of level was 2.21. Moreover, the result of test 3 was Level 0 - 5 students, Level 1 - 66 students, Level 2 - 2 students, Level 3 - 4 students, Level 4 - 0 students and Level 5 - 51 students. Average of level was 2.63.

The results of a one-way ANOVA using each factor displayed significant main effects F(2, 381)=139.486, p<.0001. The result of a multiple comparison using the Ryan’s Method showed that there are significant difference between “test 1 and test 2”, “test 1 and test 3” and “test 2 and test 3” (Figure 8).

These results suggest that the programming learning using the compact computer is effective.
The purpose of this study is to develop an educational compact computer for programming learning. We developed the educational compact computer “iProx TX” that concept was “to be able to create simple programs not using PC”. In addition we developed two types of controlled devices “a sensor robot and a sensor light”.

After development, we organized the experiment at a junior high school from February to December, 2011. We designed the syllabus for 13 school hours. A total of 128 second-grade students in four classes attended the technology course. After the lesson, we carried out the test 2 and 3, which we made students describe program. Then we analyzed test 2 and 3. These results suggest that the programming learning using the compact computer is effective. In other words we confirmed that “the students learn quite easily to create simple programs”. Therefore we judged that “programming learning using the educational compact computer is possible”.

References
Yasuhiro Mada et al. (2012), Technology and Home Economics (Technology), Kairyou.

FIGURE 8 Ability of creating program

Conclusion

FIGURE 8 Ability of creating program
TPCK: What happens when the ‘T’ is also the ‘C’?

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The Technological Pedagogical Content Knowledge (TPCK) framework developed by Mishra and Koehler has received ongoing attention since its introduction in 2006. It is seen by many as most useful when considering teaching practice, and the development of pre-service and in-service teachers. The intention of this paper is to make a contribution to thinking around and understanding of the TPCK framework, particularly in relation to technology and teaching in the technology discipline.

An aspect of this is the definition and conception of technology presented in the framework. It is suggested that especially in the case of technology education, there is benefit in considering and exploring broader and specific notions of technology to gain a fuller conception of what the ‘T’ in TPCK might include. Considering features and differences of the range of areas within the technology teaching area is a useful way to examine possibilities and implications of such.

Also viewed as important and of interest in relation to the technology discipline is the potential of the ‘T’ also being the ‘C’ within the TPCK model for technology teachers. It is suggested that these points have relevance and raise possibilities and implications for pre-service and in-service technology teacher training and development.

Introduction
Teaching with technology has received a great deal of attention in the community, schools, and academic literature. Since its introduction in 2006, the Technological, Pedagogical, Content Knowledge (TPCK) framework developed by Mishra and Koehler has played a useful part in its consideration. This paper examines teaching of the technology discipline through the lens of the TPCK framework alongside broader and specific notions of technology, and considers the implications of this for pre-service and in-service teacher education and development.

TPCK
In a Presidential Address at the 1985 annual meeting of the American Educational Research Association, Lee Shulman, Professor of Education at Stanford University, illustrated and questioned some striking contrasts between teacher evaluation standards of the time and those of the latter part of the preceding century. The change over the 110 year period that he identified and examined was from teachers being assessed with an almost exclusive focus upon requisite content knowledge in 1875, to one in the 1980's that only evaluated their pedagogical knowledge (Shulman, 1986).

Shulman (1986) argued that knowledge of both areas was “needed by teaching professionals” (p. 13), and with a focus on student teacher development suggested for these knowledge areas to “blend properly”, equal attention needed to be given to the “content aspects of teaching” and the “elements of the teaching process” (p. 8). The identification of the two areas and their ‘blending’ was important as it both highlighted...
and specified an interrelationship between the domains. Shulman (1986) described the area of overlap as “knowledge of the structure of one’s subject, pedagogical knowledge of the domain, and specialised curricula knowledge” (p. 13). In a subsequent paper in the following year, Knowledge of teaching: Foundations of the new reform, Shulman further developed these conceptions and posited that if it was “to be taken seriously” a revision of teacher education and scholarship would be required. In this revised approach, “an emphasis on pedagogical content knowledge would permeate the teacher preparation curriculum” (Shulman, 1987, p. 20).

Nine years later, building on this concept and challenge, and responding to the increasing availability of technologies for teaching, Punya Mishra and Mathew Koehler presented the technological, pedagogical, content knowledge (TPCK) framework (Mishra & Koehler, 2006). The TPCK framework presents relationships between the pedagogical and content fields of knowledge identified by Shulman (1986), and introduces the element of technology knowledge. These fields of knowledge are presented as overlapping circles to emphasise “the complex interplay of these three bodies of knowledge” (Mishra & Koehler, 2006, p. 1025).

The figure below is a later iteration of the TPCK framework which was renamed TPACK for the sake of convenience in discussion. It has been included in place of the original diagram as it acknowledges, and indeed communicates, that “teachers operate in diverse contexts of teaching and learning”, a point which is especially pertinent to the focus of this paper (Mishra & Koehler, 2009, p. 62).

![TPACK framework](image)

**Figure 1 TPACK framework (Mishra & Koehler, 2009, p. 63).**

Within the TPACK framework, Mishra & Koehler (2006, pp. 1026, 1027) define Content Knowledge (CK) as “knowledge of the actual subject matter that is to be learned or taught, Pedagogical Knowledge (PK) as generic, but “deep knowledge of about the
processes and practices or methods of teaching and learning, and Technology Knowledge (TK) as knowledge that includes the “skills required to operate particular technologies” and knowledge about ‘standard’ and ‘more advanced’ technologies used for teaching. Mishra and Koehler (2006), argue that “productive technology integration in teaching needs to consider all three issues not in isolation, but rather within the complex relationships in the system defined by the three key elements” (p. 1029). They suggest, and it follows that in order to do so, there is a need to examine these components “in pairs: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and all three taken together as technological pedagogical content knowledge (TPCK)” (Mishra & Koehler 2006, p. 1027). Examining all of these relationships is beyond the scope of this paper, the focus and topic of interest in this case is the pairing of technology knowledge and the content knowledge (TCK) of the technology discipline.

The ‘T’ in TPCK and conceptions of technology

Repeating and then expanding on the definition provided above, to elucidate their conception of Technology Knowledge (TK), Mishra and Koehler (2006, p.1027) present TK as knowledge about what they describe as “standard [teaching] technologies”, and “more advanced [teaching] technologies”. Examples provided of the former include “books, chalk and blackboard”, and of the latter, “the Internet and digital video” (Mishra & Koehler, 2006, p. 1027).

Despite this somewhat inclusive conception of teaching technologies being presented, the discussion in much of the literature in response to the TPCK model and TK more specifically, tends to focus on ICT alone (see Angeli & Valanides, 2009; Archambault & Barnett, 2010). Perhaps this is not surprising as many when asked what they consider technology to be, they will provide examples of the latest ICT related technologies such as smart phones, iPads, or cloud computing. The requirement of teachers to use ICTs, the challenge being experienced with such a shift, the increasing prevalence of ICTs in schools, at home, and in the workplace, as well as the expectations of students, parents, schools, education departments and governments across the world are other and significant likely reasons (AITSL, 2012; Baskin & Williams, 2006; BECTA, 2004; Enochsson & Rizza, 2009).

Angeli and Valanides (2009) justify their separation of ICT from other technologies suggesting that if the TPCK is to be of greatest use “as an analytical framework for guiding and explaining teachers’ thinking about technology integration in teaching and learning”, there is a need for it to have greater specificity. They assert that the TPCK model, essentially the conception of ‘TK’, is ‘too general’ in its current form, and propose the introduction of a strand they describe as ‘ICT-TPCK’ (p. 157).

While the author sees potential value in distinguishing ICT from other technologies for some purposes, and welcomes this distinction because it invites and creates a space for a discussion about broader notions of technology, it is suggested that much of the power and beauty of this framework is its inclusiveness, and that this is necessary because of the complexity and diversity that exists in education, this latter point being highlighted by Shulman (1986). Many teachers use both digital and non digital technologies in their
teaching, and to treat them separately would seem less than ideal. Also, this inclusive definition and holistic conception of technology maximises the flexibility and applicability of the framework. These points are particularly important for those involved in technology education because ‘TK’ can include a very broad range of technologies, as many technology key learning areas are focussed on, and use for teaching purposes, other technologies, such as those defined by Arthur (2009).

**Conceptions of technology**

In his well-cited book *The nature of technology: What it is and how it evolves*, Brian Arthur provides us with three definitions of technology which can be used to satisfy and purposefully meet a range of circumstances and needs including teaching and writing about technology education. Arthur’s first definition would be familiar and compatible with many others’ notions, identifying technology as a “means to fulfil a human purpose”, including a “method or process or device”. Secondly, he defines “technology as an assemblage of practices and components”, as “collections ... of individual technologies and practices.” This presents technology in a plural sense and examples of this type including “electronics or biotechnology”. Thirdly, he presents technology in a general sense, “as the entire collection of devices and engineering practices available to a culture”, the whole collection of all technologies that have ever existed past and present” (Arthur, 2009, p. 28).

These definitions and their arrangement are helpful for this discussion because they illustrate the extent of what can be and is considered technology, and they provide a frame which affords a clearer examination of technology and more specifically teaching technologies in relation to the TPCK model.

**Identifiable and specific TPCK knowledge set for technology teachers**

As stated previously, Mishra and Koehler (2006, p. 1026) define Content Knowledge (CK) as “knowledge about the subject matter that is to be learned or taught”. For the technology discipline at secondary school level in NSW, this subject matter includes a set of subjects grouped under the banner of Technological and Applied Studies (TAS). The TAS discipline areas are varied and include studies of Agricultural, Design, Food, Graphics, Industrial (e.g. Wood, Metal), Information and Software, Marine and Aquaculture, and Textiles Technology. In the senior years this list expands to include specific strands of Engineering, Software Design and Development, and a range of Vocational Education and Training (VET) subjects (NSW BoS, 2012).

If we consider TK in the technology teaching discipline given the great range of learning areas listed above, many questions arise. What conception of technology is useful for technology teachers? Do technology teachers have and/or need an identifiable and specific TPCK knowledge set? If so, what might the differences be between each of the areas within the discipline? What are the implications for pre-service technology teacher education?

It is suggested that all teaching areas should be thought about as specific cases in reference to the formulation of the TPCK as each have unique features. It is also suggested that there is value in considering each of the discipline areas within and under
the technology banner separately, as although they are bound together by the common theme of technology, each has foci and characteristics that makes teaching them quite distinct.

**Differences between each of the areas within the technology discipline**

The following excerpts from a sample of NSW year 7-10 TAS syllabi intend to provide a sense of each discipline's content knowledge (CK), and for clarity and simplicity, do not include the many other generic skills and foci that are part of these subjects.

“The study of Agricultural Technology … develops knowledge, understanding and skills in the management of plant and animal enterprises, the technology associated with these enterprises and the marketing of products” (NSW BoS, 2003a, p. 4). To satisfy syllabus requirements students will engage in practical experiences for at least 50% of class time, some of these require certification, permits and licences (p. 17).

An example of core content is students will “Learn to: use agricultural equipment, machinery and techniques correctly and safely” and “perform procedures in the management of plants and animals” (p. 21).

![Figure 2 Tractor driving](image1.jpg) ![Figure 3 Renmark High School ABC, 2010](image2.jpg)

Dapto High School, n.d.

Another example to consider is that of Industrial Technology in which “students develop knowledge relating to current and emerging technologies in industrial and domestic settings…[including] the interrelationship of technologies, equipment and materials used in a variety of settings and develop skills through hands-on interaction with these in the design, planning and production of practical projects” (NSW BoS, 2003b, p. 8).

In this case it is expected that practical experiences will account for the majority of class time (p. 151). Amongst a range of objectives students “learn to: safely use hand and power tools, materials, finishes and equipment” (p. 154).
What happens when the T is also the C?
The examples above present cases where technology content (C) being taught can also be the technology that is used for teaching (T). That is, taking the example in Figure 2, it can be assumed that before the student operates the tractor, the teacher would teach how to use this agricultural machinery, a technology, correctly and safely, by demonstration. In so doing, the tractor/agricultural machinery is the technology used for teaching (T). Similarly, in Figure 4, students working with and learning about the technologies of plywood and a hand saw, would be taught using these technologies.

The situation where the teaching technology is part of the subject matter is not unique to the technology discipline. For example in a similar case, McRory (2008, p. 196) cites an observed instance from science teaching where Niess (2005) argues that the technology of a computer based laboratory pH probe “is part of the science itself...[and that] “students could learn [and be taught] science both by using the tool and by learning about the tool”.

The point is, however, that many if not most disciplines do not feature the matching of the T and the C. In many disciplines the teaching technology used might be a whiteboard and marker, presentation software, a learning management system, a classroom, each of these potentially having no relationship with the content. These teaching technologies are readily identified, drawing on Arthur’s inclusion of ‘methods or processes being technologies, others that could be considered include teaching methods/approaches. In this case, an example where the T is also the C could be where an approach such as role play is used for teaching drama. In fact, in this instance, one might argue that the T is the C and the P as well. Some might say that a framework where everything can be the same is without value. The inverse is argued as the framework reveals these instances and provides a mechanism for their explanation, and a lens through which we might examine them.

Implications for pre-service and in-service technology teacher training and development
The implications for pre-service teacher preparation and in-service teacher development from this discussion are potentially numerous. The usefulness, and/or perhaps the necessity of viewing, designing, and building these programs, even conceiving teaching itself using the TPCK framework is one of these. Particularly in the case of technology teaching, having a mechanism, a framework, a lens, to consider the elements of TPCK,
especially where they may match, would seem very valuable for gaining and constructing understanding, and explaining what technology teachers do.

Support for this suggestion comes from Schmidt et al (2009, p. 125) who suggest that the TPCK framework is useful for both “thinking about what knowledge teachers must have to integrate technology into teaching and how they might develop this knowledge”, and “for measuring teaching knowledge” in given content areas. An example to consider this is in relation to the Australian National Professional Standards for teachers. It is suggested that being able to apply the TPCK descriptors to the standards could be a helpful way to categorise, analyse, and organise them for development programs and other purposes.

To exemplify, within these standards, under the heading of ‘Professional knowledge’, the first item is “know students and how they learn” which can be described as PK. The second is “know the content and how to teach it, this covers all three areas and is therefore TPCK. Under the heading, ‘Professional practice’, the next group of standards is “Plan for and implement effective teaching” which is TPK (AITSL, 2012). The AITSL standards include other items which have not been included in this example, however, the notion is illustrated, the TPCK framework can easily be applied and used to categorise, examine, and explain teaching related matter. Harking back to Shulman (1986, 1987), it is assuring that both pedagogy and content knowledge have their place in the Australian teaching standards.

The Teaching Teachers for the Future (TTF) project, an Australian government funded initiative involving all 39 teacher education institutions is an example where the TPCK framework has been deemed valuable for teacher development. Its aim is to enable all pre-service and in-service teachers, as well as school leaders, “to become proficient in the use of ICT in education” (DEEWR, n.d.). The digital resources produced as a part of the project have been “created following the TPACK learning framework.” Also, the Project has found that “TPACK provides a schema for thinking about and implementing in classrooms the complex relationships between these three elements of the learning program and helps teachers to ensure that their planning is comprehensive and integrated” (DEEWR, n.d.).

Recognition of the three areas of knowledge and their pairs is important for pre-service technology teacher preparation. Just as Angeli and Valanides (2009) found with ICTs, being technology savvy does not automatically equal teaching with technology savvy, it is suggested that possessing content knowledge of other technology areas does not automatically equate with being able to use these technologies effectively for teaching. The implications for pre-service teacher preparation become obvious when viewed through the TPCK lens. Preparation must include consciousness of the three areas of knowledge, and development of the three areas as linked and related bodies of knowledge and skill.

**Conclusion**

The TPCK framework has been shown to be useful for examining, considering, and conceiving teaching and teacher education and development, and more particularly the identification of the character and needs of teaching the technology discipline and
preparing for such. While it is not a unique case, teaching the technology discipline is suggested to be the most common instance where the T is also the C, and given this, warrants specific investigation and treatment for pre-service and in-service teacher education and development. Broader and holistic conceptions of technology are suggested as ideal and appropriate for the TPCK framework and considerations of teaching with technology.

References


Developing flexible, adaptable and self-regulated students in the technology classroom

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Most if not all technology teachers concern themselves with two main types of knowledge, declarative and procedural. They do so because these forms of knowledge are reflected in the syllabi they teach to as “learn about” and “learn to” statements. Studies of adaptable and flexible expert students across all domains of knowledge and walks of life raises questions about the types of knowledge that are missing from school curricula and consequently, from teaching and learning experiences in the technology classroom.

Self-regulated expert students always possess conditional, strategic and metacognitive forms of knowledge in order that they can solve problems in authentic contexts. Yet technology classrooms rarely if ever acknowledge and nurture the development of these forms of knowledge.

In the technology classroom teachers focus their attention on declarative and procedural knowledge forms because they exist as “learn about” and “learn to” outcomes. For the purposes of this paper declarative knowledge is defined as facts, concepts and principles. Procedural knowledge is defined as rules, scripts, algorithms and procedures. This paper addresses some of those knowledge forms necessary for developing flexible, adaptable, and self-regulated students by considering the design of a simple chair. Space limitations preclude any consideration of the role of the teacher in developing these knowledge forms in students in the technology classroom.

Knowledge outcomes from the technology classroom

Many technology teachers when asked to describe what they would like their students to be able to know and do as a consequence of their technology studies would say the following:

- Recognise that a design problem(s) exists and characterise the types of design problems they are being confronted with i.e. represent them in particular ways
- Know how to solve those common design problems in context
- Understand what knowledge is necessary to solve the design problems they encounter and then use that knowledge to solve those problems
- Demonstrate skill in manufacturing artifacts that solve or resolve specific design problems
- Understand how to judge that their solutions are successful i.e. what criteria delineate successful completion of a design project/problem solving effort
- Transfer their skills to analogous problems
- Recognise when they do not understand the problem(s) in part or whole
• Flexibly adapt their thinking and work processes according to the unique circumstances of a particular design/problem solving context
• Seek help when necessary to improve understanding of design problems and potential solution processes

A detailed exploration of these outcomes reveals a complex and interrelated range of knowledge types that go well beyond the learn about (declarative knowledge) and learn to (procedural knowledge) forms listed in syllabus documents and which are commonly the focus of activities in the technology classroom. By ignoring certain knowledge forms or by focusing only on a specific sub-set of knowledge within a general category (procedural knowledge for example), the processes that are necessary to develop flexible and adaptable thinking are greatly constrained and devalued.

Recognising, finding, and representing problems

Many technology classrooms do not require students to recognise that a problem exists. That is, they do not use the procedural knowledge concerned with recognition. Recognitional dimensions include but are not limited to situation assessment skills (Endsley, 1995), building mental models which are memory representations that explain or make more concrete a specific artifact or environment e.g., notions or concepts of a “chair” (Gentner & Stevens, 1983), or making sense of situations or events (Klein, Moon and Hoffman, 2006a, 2006b; Weick, 1995). Teachers do this by either assigning a task where the problem is easily discerned; or explicitly given in the form of a well-defined problem that loads on the specific knowledge and skills that are the focus of the outcomes for the task. Here the task could be to “design a chair to be used in an outdoor setting”. In this example there is general clarity in regard to the type of problem the students are being asked to solve, even to the extent that the solution must be a “chair”. In other cases, materials, joining methods and so on are defined beforehand. The aforementioned preliminary brief might be expanded to include constraints on the types of materials (e.g., western red cedar), joint types (e.g., mortise and tenon joints) and so on. Pragmatic considerations often guide teacher’s thinking in these situations.

Forcing students to identify and delineate specific and often complex, context-bound problems slows down the production phase that is often the focus of teacher efforts. In these circumstances teachers make a value judgment about what knowledge (or even parts of knowledge forms) is more important: well defined and easily taught declarative and procedural knowledge on one hand, or complex and difficult to teach problem recognition, problem finding and problem representation skills on the other. When simplifying the task so much it becomes far more difficult to set challenging but achievable goals (important factors in powerful learning according to Hattie, 2009; Marzano, 2007; Schunk, 2005 and others). Learners’ focus on the obvious surface features of tasks rather than the underlying abstract structures and consequently, deep learning cannot take place. In this setting, powerful cognitive and metacognitive processes remain dormant and underdeveloped. Students practice what they can already do (often reflecting practice exercises conducted immediately prior to undertaking a task) rather than the things they cannot do. More importantly, they are not encouraged or required to set themselves learning goals and monitor their progress towards those goals. Setting goals requires that
metacognitive and self-regulatory processes be set in motion. Goal setting also engages student motivation by ceding some degree of control and autonomy (Deci & Ryan, 1987) to students over their own learning.

Besides recognizing that a problem might a companion skills is to find those problems in complex environments. It therefore involves recognitional processes as well as representational processes. On first inspection problem finding appears to occur at the beginning of designing but actually occurs throughout a design task as students interact with the problems and redefine them in order to resolve emergent problems and eventually complete their assigned task. Students undertaking their major design project in Design and Technology (NSW Board of Studies, 2003) at the Higher School Certificate must undertake problem finding in order to establish their project though the quality of problem finding is inconsistent and highly variable in quality when project documentation is closely examined. In contrast, other syllabi in years 11-12 such as Industrial Technology emphasise the procedural dimensions of manufacturing more heavily in submissions for the same award.

Problem finding is marked by vision, insight, curiosity and challenge, on one hand, and risk, anxiety and doubt on the other. Much schooling seeks to take away these dangers because they can take too long to address and resolve and the results of the efforts of students are not certain. This issue in turn makes it harder to confirm that a student has met one or more outcomes or standards defined in the syllabi. Problem finding necessitates the representation of a problem and problem space (a form of declarative knowledge). These representations reflect the understanding that a student holds of the problems to be solved. They can be described as a form of mental model (Gentner & Stevens, 1983). In an ideal situation, an optimised representation is made that reflects extensive experience in a domain (such as that possessed by an Industrial Designer) but for ill-defined problems of the type common in technology classes, representations by students are simple, often crude approximations (they are in effect novice designers). Experienced designers continually adjust these representations throughout design efforts in response to feedback they receive from their efforts and subsequent reflective processes judging their progress against established goals. For technology students, representations tend to remain as relatively fixed entities in order to facilitate completion of a design project.

Few students will have experience in our example of designing a chair. The mental models they hold will reflect their lived experience and so their representations are stereotypical in nature (chairs have four legs, a seat base and a back). To develop an ideal representation or framing of a problem requires a high degree of knowledge of the relevant subject mater (facts, concepts, principles, and procedures), and familiarity with that particular type of problem in a variety of contexts (Bransford, Brown, & Cocking, 2000). Designers become better able to represent problems with greater experience in solving those problem types because they can build cases and formal representations of the types of problems and solutions that will work. Having extensive background in solving a particular type of problem allows the designer to recognize salient elements and cues in the problem, and then recalls them on demand. This recognition will in turn activate one or more relevant solution schemas. Perhaps most importantly, more
experienced problem solvers will represent the problems they are facing at a more abstract and primitive level rather at a surface level. Lest the interested reader think that being a designer guarantees efficient designing one needs only look at the early examples of the design task seating of the type used in offices. Four legs in a fixed seat were translated into four arms on a swivel base chair. The instability that resulted from this arrangement was not recognised by many designers until they received feedback from the field. Five arm swivel bases are now the norm and are far more stable because the five arms extend the overturning moment are further out. Even today most chair designers are not fully conversant with the underlying principles of supporting the human body comfortably and correctly in a seated position, despite research on this topic over the last forty years (anthropometric data and biomechanical issues such as correct pelvis angle/tilt as well as neutral pressure on the fourth lumbar vertebrae are some of those principles and can be seen in such chairs as the Bambach Saddle Seat and the Balens chair). In both examples, there is no need for a seat back at all! Other examples of seats that address these underlying criteria include Recaro automobile seats, Humanscale office chairs, and Ekornes Stressless brand home furniture. The clear message from the existence of these examples is that there are many cases that can be used to help delineate essential features of “chairs” and thus guide design efforts. Declarative and procedural knowledge of this type is to some extent, distributed in the environment (Fagin, Halpern, Moses, & Vardi, 1995) but readily available for use in new designs, even in a school context. There is no reason why students in technology classrooms cannot survey the existing state of the art to extract common elements and contextual adaptations that are made by designers. Exploring many cases in a variety of contexts makes it easier to develop a “suite of representations” (Bransford, Brown & Cocking, 2000, p.62) and then delineate underlying principles. As we shall see subsequently, abstracted representations enable classification of problems at a deeper level, thus making them easier to adapt in transfer contexts. Abstracted underlying principles also make the high-road transfer of learning (Salomon and Perkins, 1989) possible. Greater cognitive flexibility is the outcome (Spiro, Feltovich, Jacobsen & Coulson, 1992). These underlying principles can, in turn be used to guide design goals and establish performance criteria in a more flexible way.

A we shall see subsequently, abstracting problems into underlying forms is essential for transfer of knowledge form one context to another. Inexperience in a domain makes it harder for students to activate the relevant schema-they may not even possess any relevant schema. The knowledge they have may remain inert and therefore of no use. The decision of teachers to limit or even remove the requirement to find and represent problems can be explained in these circumstances. In an effort to simplify and focus the task, and promote the successful completion of the manufacturing process, teachers make it much more difficult for students to see into problems i.e. at a more abstract level, and adapt their designing skill in future learning events. Flexible learning cannot take place because the students are not required to think or act in that way.

**Manufacturing knowledge**

Demonstrating skills in manufacturing dovetails neatly with procedural knowledge and technology teachers spend much time developing them. Each skill set is designed for a
specific context and/or material and teachers remind students to use specific techniques, often through demonstrations prior to manufacturing an artifact. Constraining procedural and declarative knowledge means that students develop skills in solving design problems of a specific type and the design processes they use can become ritualized (McCormick, 2004). They learn to design a chair for an outdoor setting in the given example. They learn a restricted skill set by working specific materials using specific tools and techniques. Some automation of those skills might eventually occur though there is little evidence of this occurring in school technology settings since there simply isn’t enough time to build automaticity. How well do these specific skills sets prepare them for other chair problems e.g., a chair for use in a cocktail bar, or a chair for a high-class office, or an aircraft. Since there is only one chair designed and manufactured, there are few opportunities to develop a more comprehensive skill set.

Evaluation knowledge
Judging the success or failure of a design demands in the first instance that specific goals have been set for a task that guide design and subsequent manufacturing efforts and which will enable the development of appropriate judgmental criteria associated with those goals. Goals for a chair might relate to its seat height and back angle, stability, anthropometric suitability and so on. Criteria are derived from the goals established and refined for the design problem interactively during the design and manufacturing process. In professional settings comparisons with existing designs are commonly used to judge one artifact. Both the Australian and British Design Awards make use of ratings made against the existing state of the art using specific criterion measures. In order that students (as distinct from teachers) refine goals and determine appropriate judging criteria demands, deeper cognitive, metacognitive and self-regulatory resources must be brought to bear in a deliberate and focused manner (Zimmerman, 2008). Having teachers do this removes the requirement for students to acquire this important declarative, procedural, and contextual knowledge, and reduces both the effort required for learners, and the long-term benefits that might accrue. Students will not develop the knowledge of how to judge success or failure against one or more standard(s) or other extant examples.

Transferring knowledge
Transferring knowledge (declarative knowledge) or skills (procedural knowledge) from one domain or context is one of the most cherished and valued outcomes from learning in a technology education setting (and in all education – see Bransford, Brown and Cocking, 2000) and requires conditional knowledge (knowledge of when, where and why to apply specific knowledge). Yet design contexts are constrained for students for a number of pragmatic reasons in the classroom. Little automation of skills can take place because there are few opportunities for varied and challenging practice (note the emphasis here) in different learning contexts. Complex problems become simplified and students are guided at every step of the design and production process to the extent that little powerful learning can take place. Knowledge can become context bound and cannot be transferred other than in very similar contexts. Low-road transfer (Salomon and Perkins, 1989) between similar contexts is reasonably straightforward since there are many analogous
declarative and procedural knowledge requirements in the task.

Yet transfer to widely differing contexts demands that teacher provide learning experiences in many contexts that help build a repertoire of cases and representation, and in a form that permits knowledge to be generalized. This in turn demands that that knowledge become abstracted into underlying principles of the type I revealed is necessary for designing a properly functioning “chair”. We can therefore focus on finding broad similarities across contexts in terms of the knowledge required to solve problems. Transfer thus requires the use of conditional knowledge. Conditional knowledge demands effortful engagement and deliberate control over ones cognitive and metacognitive knowledge (Schunk, 2005). The learner needs to know what they do and do not know in order that they define and represent the task at hand, and initiate and sustain appropriate solution processes. This process is not automatic.

**Self-regulated learning and help seeking**

Our discussion so far has highlighted the necessity for students to be aware of and in control of their thinking processes in order that they are strategic and goal directed in their efforts. Zimmerman (2008) argues that self-regulation involves self-generated thoughts, feelings and actions for attaining academic goals. Self-regulated students are proactive in seeking out information and are metacognitively, motivationally and behaviourally active participants in their own learning (Schunk, 2005). They set goals, organise their thinking and acting and self-monitor and self-evaluate themselves continually (see Figure 1 below).

![Figure 1: Dimensions of self-regulation (cnmtl.columbia.edu)](image-url)
They structure their environments to facilitate new learning and exercise choice and control over when to participate, what methods and processes to use, defining outcomes, and choosing social and physical settings. For our student designer this translates into setting and monitoring the achievement of goals, self-efficacy (can I do this), values (is this worth doing), strategy use (which knowledge and process or processes should I use and why), self-monitoring (how am I going in terms of the processes I am using and the cues I am paying attention to?), self-judgment (to what extent am I meeting the criteria I have established for successful completion of this task?), and structuring the environment (am I making best use of the available physical resources? If not, what can I change to improve achievement), and help seeking (am I making best use of the available human resources to provide help when it appears necessary or desirable?). The long-term goal of building self-regulated students in technology classrooms is to help them develop self-regulation as a generalized capacity (Lombaerts, Engels, & Vanderfaeille, 2007). This cannot occur spontaneously so technology education experiences must address this dispositional complement to declarative, procedural, conditional, and strategic knowledge explicitly.

One particularly important outcome that teachers expect to see in their students is that of seeking help (help seeking in this context is in relation to goal attainment and does not refer to help seeking in terms of health, social, personal or developmental needs). Experts regularly seek help (actually it is instrumental help seeking, Karabenick, 2004, rather than executive help seeking where others are used to reduce effort expenditure) because they recognise when they do not know something that is necessary in order to complete a task (remember that experts are goal-directed and self-regulated). Highly motivated students are more likely to seek help when they need it, just as they are more likely to use metacognitive strategies (Karabenick & Dembo, 2011; Karabenick, 2004). On of our goals in technology education is to help students see the intrinsic value in seeking help from peers and others in order that they accomplish their design goals. Yet Karabenick and Knapp (1991) showed that those who need help are often the least likely to seek it. Help seeking is an important self-regulatory strategy (Karabenick & Dembo, 2011) and is essential in professional design contexts and the technology classroom.

Conclusion
If students in technology education are not to become context bound and capable only of executing a restricted range of psychomotor and cognitive procedural skills, they must expand their range of cognitive and metacognitive capabilities in order to become self-regulated learners. They must learn by designing in multiple contexts and develop conditional and strategic knowledge as well as declarative and procedural knowledge. Becoming self-regulated requires students to recognise what they do and do not know in each learning context. They must therefore stay in touch with their knowledge. Where they recognise and acknowledge that they need to learn something new in order to resolve design problems they need to seek help from others be it a teacher or peers. Students need to devote more time and effort to defining problems in more abstract terms in order that underlying problems are resolved and learning can be transferred to new contexts. They must develop their recognitional and sense-making skills in order that they can then bring the most appropriate declarative, procedural, conditional and strategic knowledge to bear.
They must then be able to actively define and redefine the problem they are solving as they answer the design problems, manufacture and then evaluate their efforts against criteria that are defensible against the design context and problems they are working on. This demands much greater cognitive and metacognitive engagement in design tasks and the capacity to argue and defend ideas at conceptual and concrete levels. Manufacturing an attractive piece of work is not good enough a form of evidence for being a flexible and adaptable thinker and actor. We want learners to develop adaptive expertise over time (Hatano & Inagaki, 1986) so that they can apply their knowledge in many contexts and not just the first one they learned them in. This demands a degree of coordination in order to ensure a consistent focus on developing self-regulatory behaviours as well as the appropriate forms of knowledge. Setting goals and explaining them to others, monitoring their own work and judging it against standards (and teacher/expert examples) are important components. Motivation through self-reinforcement of the success of these processes will enhance future performance in and out of school contexts. This signifies a shift from external regulation by teachers towards self-regulation by students. When combined with adaptive mastery of declarative, procedural, conditional, and strategic knowledge forms, students will be better able to transfer and use their knowledge adaptively and flexibly in new and challenging contexts.

References


Developing a framework for Training Design and Technology Teachers

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This paper reports on the development of a new framework for an undergraduate design and technology teacher training programme at a university in England.

A well-established programme had existed at the university for over ten years, with material subject content centring on electronics and resistant materials. In 2007 textiles was added as a core material and in 2009 the option of food technology was added with electronics becoming optional for students. These amendments were a positive response to local schools wanting design and technology teachers with a wider base of material subject knowledge. By January 2009 a new team was delivering the programme with a new programme leader. This team brought a different philosophy of design and technology to the programme than previously existed and thought the existing structure was disjointed and incoherent to students.

As a result the action research undertaken by one of the authors had a focus of:

- improving the coherence and flexibility of the programme
- providing Design and Technology teachers with skills and expertise which reflected the needs of local and regional schools
- responding to external agendas (Ofsted, 2011) and (Design and Technology Association, 2011).

The outcome of the research was a framework with five elements that reflects the team’s philosophy of design and technology with a particular emphasis on the integration of the subject content of designing, making and technology, and related pedagogical knowledge.

Introduction

Those who want to train to become a secondary school teacher in the UK can do so through a number of different routes, the most popular route is for those who have completed their first degree (e.g. Post Gradate Certificate of Education – PGCE), however, a small percentage (16%) of trainee design & technology (D&T) teachers in England study on an undergraduate degree programme. Undergraduate D&T programmes commonly follow a '2+1' model, the first two years focussing on D&T subject knowledge and the final year, known as the ‘professional year’, runs concurrently with the one year PGCE route (Figure 1). This paper is about one of these undergraduate programmes at a university in England, reporting on how the programme has evolved since 2004 up to a major revalidation in 2011 resulting in the development of a new framework.
Undergraduate route into D&T teaching

- B. Sc. (Hons) or BA (Hons)
- Year 1 & 2 focussing on specialist subject knowledge

The final year of the undergraduate route and the PGCE year are common and called the professional year

Postgraduate route into D&T teaching

- Non teacher training undergraduate degree
- Postgraduate Certificate in Education (PGCE)

Qualified Teacher Status (QTS)

Figure 1 Routes into secondary teaching

The paper will explain the previous framework, the lecturers' philosophy of teacher training and D&T education and the research undertaken which led to a new curriculum framework.

Previous structure

Undergraduate and post graduate D&T teacher training programmes are well established at the university and have existed for over ten years. At the end of the undergraduate degree if successful, students are awarded an honours degree design and technology education with qualified teacher status to teach D&T in secondary schools (11-16 year old pupils).

Prior to 2007 students were only taught about resistant materials (i.e. materials which resist external forces such as wood, metal and plastic) and systems & control; these subjects were taught in the modules: exploring materials (year one), control systems, energy and machines (year one), robotic design and advanced manufacturing (year 2). In 2007 textiles was added as a core material and the option of food technology was added in 2009 with electronics also becoming optional for the first time. These amendments were in response to local schools wanting design and technology teachers with a wider base of material subject knowledge as well as changes in the national curriculum (Qualifications and Curriculum Authority, 2007a). The textiles subject knowledge was added to exploring materials and advanced manufacturing for teaching and assessing. Food technology content was taught in three new modules: health and nutrition (year one), food design technology (year one) and consumer studies (year two) (Figure ). Students graduating from this course would be expected to be able to teach two material areas to pupils in key stage 3 (11-14 year olds) and one material area to pupils in key stage 4 of secondary schools (14-16 year olds).

Included within all of the modules in year 1 (both semesters) and year 2 (semester 1
only) were three integrated projects. Students used skills, knowledge and understanding from all of the modules to design and make three discrete projects. Design briefs for these projects included:

1. Working as a group, design a range products that enhance users experience of a local contemporary art gallery.
2. Design a range of food products or recipe ideas to make use of local seasonal produce as part of a local campaign.
3. Design and make a robotic control product.

These projects went some way in supporting students to recognize that design and technology was a subject that integrated the discrete material areas and design skills that were currently taught in separate modules.

By January 2009 a new team was delivering the programme with a new programme leader. This team brought a different philosophy of design and technology to the programme than previously existed and thought the existing structure was disjointed and incoherent to students.

The timing for the revalidation was right for a new team although this was not a reason in itself for the revalidation it was the main motivation for the team. The revalidation was
taking place primarily for internal reasons. The programme was due for revalidation as part of the university’s quality assurance procedures, which included the removal of small modules (i.e. 10 credits or less) and the number of options within a programme. Half of the modules were identified as small modules and there were four optional modules (Figure 2). External influences on the revalidation were the new government reviewing teacher training and the national curriculum; tuition fees for university students were also likely to be increased for September 2012 which was a driver for increasing rates of graduate employment.

**Philosophy of the programme team**

Some parts of the existing programme did fit with the new team’s philosophy of teacher training such as the integrated project. However, the almost complete separation of pedagogical knowledge (educational perspectives modules) and the materials subject knowledge taught in discrete modules did not. The team’s philosophy of design and technology education has two parts.

1. Congruent teaching
2. Students constructing their own knowledge and determine their own priorities for learning

The first part is congruent teaching (Swennen, Lunenberd, & Korthagen, 2008) which has three elements to it: (1) modelling good teaching (2) explain the choices they make while teaching (meta-commentary), and (3) link those choices to relevant theory’ (pp. 531). The department has evidence of their practice of this in other research (Hardy, Tinney, & Davies, 2012) and (Davies & Hardy, 2011) through the use of web 2.0 technologies in their practice.

Our philosophy of design and technology in schools is developed from, amongst other factors, our own teacher training, our practice as D&T teachers and our continuous debates about design and technology. We see design and technology as a subject which cannot be defined purely by its knowledge as detailed in the national curriculum (Qualifications and Curriculum Authority, 2007b) but as a subject where those involved are constructing their own subject knowledge as needed to respond to different learning situations. However there is a need to have a framework to understand the main concepts around material and processes; this is our platform for constructing learning. For the department D&T capability evolves for individual learners based on their experiences within learning contexts. Developing from existing knowledge of materials and processes, the learner draws on this to learn their own relevant knowledge in response to a design and/or making situation. (Note: here learners are both the trainee teachers on the undergraduate programme and pupils in D&T lessons in schools).

**Method**

The methods used in this research included a review of current literature relating to D&T teacher training, interviews with three local schools and D&T academics and team discussions based on the Delphi technique to agree on course aims and module outcomes.
The literature review provided the overall rationale for the new programme: it would aim to produce D&T teachers who have the necessary subject and professional skills to:

1. meet the Qualified Teacher Standards (QTS) requirements (Training and Development Agency (TDA), 2008),
2. meet the Design and Technology Association (D&TA) Minimum Competences requirements (Design and Technology Association, 2010) and
3. address the D&TA manifesto for Design and Technology (Design and Technology Association, 2011).

Firstly, meeting the QTS requirements is a compulsory component of successful completion of teacher training courses in England, but not necessarily a requirement to teach in England (Department of Education, 2012). Secondly, the Minimum Competencies provide subject knowledge guidelines for core skills in designing, and for designing and making skills for each of the material areas identified as electronics and communication technologies, resistant materials technology, food technology and textiles materials technology (Design and Technology Association, 2010). Most teacher education establishments do use these competencies as a framework for subject knowledge (Banks, 2009) and the programme had been doing this for a number of years, which we wanted to continue at this stage. The expectation from the competencies is that students will be trained to teach only two materials to key stage 3 and one to key stage 4 and beyond. Data from interviews with local schools indicated that this was no longer sufficient and it was decided to enable our trainees to be able to teach all four material areas in an integrated way to key stage 3 and at least one to key stage 4.

Finally, the manifesto (Design and Technology Association, 2011) was produced as a response to the national curriculum review in England which, amongst other issues, questioned the inclusion of D&T as a compulsory subject in secondary schools (Great Britain. Department for Education, 2011). The manifesto endorses a break with two well-established traditions in D&T:

1. move away from rotational courses in key stage 3 where pupils move from one material area to another, providing little progression and integration and
2. provide a mix of opportunities for pupils which were not always focussed around designing and making activities.

The mix of opportunities were:

- Designing without making
- Making without designing
- Designing and Making
- Exploring Design and Technology in Society (Barles, 2011; Design and Technology Association, 2011)

This resonated with our philosophy where materials were integrated and not all D&T activity had to follow every aspect of the design process, start with a design brief/situation or end with a fully functioned product and evaluation. The current programme was provided plenty of opportunity for students to show they could ‘design and make’ and ‘make without designing’ but the other two opportunities were rare and the structure of
the programme and assignments did not facilitate their inclusion in a meaningful way. The department had also undertaken a small-scale research project which demonstrated how teachers from the different routes had different strengths which complemented each other (Atkinson, Knox, & Hardy, 2011). The concluding part of the paper suggested that those on the undergraduate route need to ‘develop ways in which to improve skills of innovative and designerly flair’ (p.33). The revalidation provided an opportunity to address this.

**New framework and structure**

The first outcome of the discussions and literature search were new aims for the programme:
- To enable students to become an exciting and effective secondary school teacher by providing them with appropriate professional skills, knowledge and values,
- To provide students with the knowledge and skills of Design and Technology to enable them to apply the subject innovatively, dynamically and responsibly within the 11-16 phase and to contribute to the 16-19 curriculum and
- To have a critical understanding of Design and Technology, its place in the secondary school curriculum and a wider social context.

The second outcome was a framework with five elements that reflected the team’s philosophy of design and technology with a particular emphasis on the integration of the subject content of designing, making and technology, and related pedagogical knowledge. The concept of congruent teaching was taken one stage further than the work by (Swennen, Lunenberd, & Korthagen, 2008) to include the curriculum structure and content into our definition of congruent teaching; defined as a congruent curriculum.
The visual for the programme (figure 3) shows the four elements which make up the modules as horizontally aligned rather than vertically stacked representing the belief that no one part is more significant than the other. The elements of Mainly Designing and Mainly Making reflect the team’s interpretation of the manifesto activities of designing without making and making without designing. Designing may involve making in some form, to model ideas or test components of a concept. In the same way, design decisions need to be made when making product, for example during the realisation of final solutions as unforeseen manufacturing problems occur. The overlap of the two in the framework highlights their relationship. The element of Design and Technology in Education and Society is where the programme will allow students to debate and develop their own philosophy of the school subject D&T, their understanding of technology and its impact. Values in D&T have long been debated and it is in this element that there is space to facilitate this debate with the stakeholder group of trainee teachers. The fourth element, Designing and Making, is similar to the integrated project from the old programme but the assignments expect the students to reflect on how they have chosen to develop their subject knowledge using the minimum competencies. The e-portfolio is the tool students will use to support their subject knowledge construction and this is why it runs through the centre of the framework. For this programme an e-portfolio is a digital collection of artifacts such as documents, photos, videos and reflections, articulating an individual student’s learning during the four modules.

Figure 3 New framework for programme.
This framework was translated into a modular structure for delivery (Figure 4). The new modules enable all students to develop their knowledge in four material areas in year 1, as opposed to three previously. All students will now study all materials areas, demonstrating their equal value and encouraging a cross over in the use of materials. The revalidation allows a greater flexibility of choice and combinations of materials when designing and making, reflecting the possibilities in industry and schools.

### Figure 4 Module structure after September 2011.

The new structure provides:

- opportunities for students to identify and address areas that are less strong, aided by a personal profiling system and policy for negotiated learning through using the tool of the e-portfolio;
- opportunities for students to extend their knowledge and skills in preferred areas, to an advanced level;
- a translation of the subject methods and content into the school context (curriculum congruence).

This new programme is seeking to challenge our students and D&T teachers with a curriculum model through which D&T can be delivered innovatively with a modernised curriculum (Ofsted, 2011).

### Conclusion

The team has taken a pragmatic approach in creating the new programme concerning its philosophy of teacher training and D&T. We are using two pieces of literature which are useful in elucidating our philosophy (i.e. minimum competencies and manifesto) whilst acknowledging there are limitations and contradictions within these documents. The minimum competencies tend, in our experience, to be used as a checklist for
assessment rather than as a tool to support students on the programme in constructing their own knowledge. The separation of the competencies into the five sections listed above does not fit comfortably with integrating the materials and there is agreement with (Martin, 2008) that the competencies may no longer be a useful tool for D&T teacher training. However with limited time (the first year of the new programme was taught in 2011/12) they are useful as a starting point for students to use. In the first year we scaffolded the students learning in using the competencies and e-portfolio to construct their subject knowledge. Recent research by the team exemplifies how we have developed strategies using e-portfolios to put this into practice (Hardy, Tinney, & Davies, 2012).

The manifesto from the Design and Technology Association and other publications used in its campaign for the subject are not overt in their focus on electronics and communication technologies and resistant materials, but have made little reference to food or textiles. STEM (Science, Technology, Engineering and Mathematics) is a recurring theme in the campaign highlighting the contribution D&T can make to STEM subjects and careers. Whilst this is useful in the promotion of the subject, emphasising a value D&T has to the economy, we believe this undermines other equally important values of D&T.

Further research
As the programme is established opportunities for further research will arise which could support the development of the programme. This may include a focus on the different elements of the programme, their content and student outcomes.

Other research may include:

- How partnership with local schools may impact on the development of the programme;
- The value of minimum competencies in the context of a modern curriculum and
- A longitudinal study on the impact of a congruent curriculum on graduates’ teaching.

References


Controls behind the scenes:
On Position, Ideology, and Expectation

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Thinking about learning in education inescapably draws us to consider teaching, the two, or so we assume, being so closely intertwined. And yet, the crucial role of the teacher-student relationship notwithstanding, two further aspects associated with learning – frequently under-examined by both student and teacher – are in need of more detailed analysis. The first of these is the critical issue of self-learning, i.e. the possibility, indeed the necessity, of learning in the absence of formal teaching practices, such that self-learning becomes an intellectual extension of extant educational delivery. The second, of perhaps more significance, deals with the issues of existing knowledge and extant beliefs, and thus with the preferences, prejudices and assumptions that lie within the minds of the students and which, consciously or sub-consciously, affect, potentially enhance, and determine, control and direct both their learning experiences and their acceptance and interpretation of information.

Given the intense and inescapable interconnection between learning, self-learning, and pre-existing beliefs, the paper explores three key issues relating to learner and teacher, viz., the concept of position, the notion of ideology, and the role and effect of expectations in the receipt, development, and transmission of knowledge. Drawing on a range of recent discussions within the educational literature the paper seeks to explicate the centrality of expectations, beliefs and assumptions in how students understand, critically interact with, and accept or reject the information, ideas and views presented to them.

Introduction

Thinking about learning in education inescapably draws us to consider teaching, the two, we assume, being so closely intertwined. Information provided accords both with information received and, we trust, information understood, and the strong symbiosis between teaching and learning thus constitutes the key ‘spine’ within education. And yet, the crucial role of the teacher-student relationship notwithstanding, two further aspects associated with learning – frequently under-examined by both student and teacher – are in need of more detailed analysis. The first of these is the critical issue of self-learning, i.e. the possibility, indeed the necessity, of learning in the absence of formal teaching practices, such that self-learning becomes an intellectual extension of extant educational delivery. The second, of perhaps more significance, deals with the issues of existing knowledge and extant beliefs, and thus with the preferences, prejudices and assumptions that lie within the minds of the students – and, indeed, their teachers – and which, consciously or unconsciously, affect, potentially enhance, and inevitably determine, control and direct both their learning experiences and their acceptance and interpretation of information.

Given the intense and seemingly inevitable interconnection between learning, self-learning, and pre-existing beliefs, this paper briefly explores three key issues relating to both learner and teacher, viz., the concept of position, and thus the centrality of ideology within the educational framework; the role and effects of expectations in the receipt,
development, and transmission of knowledge; and the significance of transformative learning as the key instigator of critical engagement and self-reflection, thus offering perhaps, indeed, obliging a challenge to established beliefs and assumptions.

On Position
Let us start, then, with ‘position’, a well-established concept referring to an individual’s and/or group’s particular beliefs and views, and how these condition and affect how we engage with, understand, and perhaps make propositions concerning a range of specific intellectual, emotional, and/or practice-based areas of our daily lives. Thus, how we respond to, analyze, and interpret certain information; accept, criticize, or reject certain views; or put forward our own proposals for the world to consider, is fundamental to history, theory, education, politics and so on. It is similarly the focal point of design, an individual’s or a collective position affecting, enhancing and often controlling design intentions, design reasoning, design preferences and thus design choices.

The concept of position, then, means, first, that when we engage in such analysis, interpretation, evaluation, criticism, and acceptance or rejection, we are inescapably engaged in making judgments; and second, and more importantly, that such judgments and such decisions are necessarily mediated. Hence, whatever we are examining, appraising, or considering – and it might be a physical object in the world, like a building or an art work, or an abstract construction like an idea or a theory – it is inevitably ‘seen’ through the lens of some set of beliefs, some views held by the individual. Such opinions almost certainly represent preferences, prejudices or biases held by that individual, which, significantly, might be known or unknown to the potential decision-maker. Whatever they are, however, they inevitably determine, establish and ‘colour’ the individual’s judgments, and thus both affect and effect the decisions that are made.

Positions are, of course, neither intrinsically individualistic nor irredeemably self-determined. In relation to particular disciplinary areas they are inevitably, to some degree, communal and agreed upon within specific groups, while being antithetical to other groups holding quite dissimilar albeit equally strongly-held views. In relation to the individual they are inevitably given to each ‘receiver’: neutrally, as information merely to be considered; persuasively, as views that we wish the recipient to accept; or via a process of coercion or imposition, a process that may, again, be potentially known or unknown. A detailed discussion of how such views come about – and all three possibilities may be applicable to each one of us in respect of certain issues – must lie outside the scope of this paper, but, as Cranton, citing Mezirow, notes, “Adult learners have assumptions, beliefs, and values that determine the way they interpret the world and their experiences [my emphasis]” [1994: 730].

Such ‘foci’, then, affect not only the individual but, potentially, disciplinary areas and agreements or disparities within disciplinary areas, thus affecting choices, directions, and specific – if sometimes quite oppositional – ideologies. As Landau suggests in his paper ‘Notes on the concept of an architectural position’, his starting point is with:

…the variety of approaches that have been responsible for the architecture, with the architects’ point-of-view, with their commitments, their beliefs, but also with the exchanges that have lead
up to those beliefs and which, in some way, have played a part in the evolution of the architectural culture. [1982: 111]

In relation to all disciplinary areas, although in this instance in relation to education, and thus to teaching and learning, a number of questions might be put to both student and teacher. First, while it might be asserted that everyone has the right to hold an opinion, it might also be suggested that, irrespective of this opinion and its often-unconsidered acceptance, everyone should be encouraged to ask themselves why they hold this view? What is the basis of the belief structure that informs them? What tells them that their opinion is right? Second, they should ask themselves where and from whom they got these beliefs? Why they believe them? And have they subjected such beliefs to critical scrutiny, or have they just accepted them, just taken them for granted? And third, it might be recommended not only that they ask themselves these questions, but that they ask their colleagues and associates, fellow students and teachers, why and on what basis they hold the views that they do; and have they subjected their beliefs to critical scrutiny?

This suggests, from a teaching perspective, that we all should both interrogate our own positions, and encourage our students to consider and understand the concept and effect of ‘position’; to analyze both the views they hold and the views they are presented with; and to question and critically engage with those sets of beliefs and preferences that they accept, and/or are encouraged or forced to accept, again knowingly or otherwise.

Education often deals with the provision of useful information and with the development of discipline-specific skill sets, and while the enhancement of thinking and reasoning skills is not necessarily ignored, the concept of position, with all its attendant influences and effects, often remains invisible to staff and students alike, and/or is uncritically regarded as being the undeniably ‘right’ position to assume. Hence, we should also consider, among other questions, first, can we avoid having a position? Is this even possible? And don’t we all inevitably have a position on some issues? Second, are we aware that we hold such positions and views? And do we understand that they inescapably influence our choices, our decisions, and our actions? And third, and perhaps most importantly, can we articulate our position(s)? Can we say what they are? And can we explain them clearly and precisely, both in terms of what we believe and why?

Given that we inevitably ‘think through’ our beliefs and opinions, our preferences, prejudices and biases, then it is important, from both an individual and a disciplinary perspective, to understand the nature, the sources, and the potential ‘collectivity’ of such positions. As Landau observes, his analysis:

…begins with a need to find a way of approaching and characterising, first, particular individual sets of architectural beliefs, then secondly, to be able to shift from the sets of individual beliefs to the sources of those beliefs, which may be exposed in the writings, readings, conversations, interactions – all contributing to the discourses of the community of interest and out of which the architect’s beliefs come to be formulated. [1982: 111]

On Transformative Learning

Given the ever-present effect of position on our receipt, interpretation, and acceptance or rejection of available ‘information’, it is useful to return not just to Cranton’s previous assertion that “…learners have assumptions, beliefs, and values that determine the way
they interpret the world and their experiences”, but to her follow-up statement that
these assumptions may be challenged by people, events, changes in context, crises, or new
experiences. The individual may then be lead to an examination of his or her assumptions,
including their sources and the consequences of holding those assumptions. [1994: 730]
The term ‘may’ is, of course, of great significance here: how do we get both learners and
teachers to understand the necessity of subjecting their beliefs and assumptions to critical
scrutiny? And it is this notion that takes us beyond the conventional phrase ‘teaching and
learning’ and into the realms of self-learning and, more importantly, transformative
learning.

Now, how an individual actively engages with and utilizes transformative learning is a
difficult – and an individualistic – issue. But what constitutes transformative learning in
general; what its key components or methodologies are; and what it may ‘do’ for us in
terms of educational and intellectual and/or personal development is easier to address.

Directed essentially at adult learners – though there is no reason why it might not
usefully be applied and explained to later-year school students – Mezirow’s concept of
transformative learning is based on “…how learners construe, validate and reformulate the
meaning of their experiences” [Cranton 1994: 730; c.f. Mezirow 1991]. Once again it is the
‘small term’ – in this case, ‘how’ – that is of significance here. Articulate, and often
persuasive, statements by learners about how they construe and validate their experiences
are not the same as statements indicative of how they come to analyze and understand on
what basis they interpret and accept such experiences, and why. Hence also the notion that
‘reformulation’ is not just about how we come to change our minds, but about our
understanding of why and on what basis we challenge our extant beliefs and assumptions
such that intellectually significant changes come about. As Cranton observes,
transformative learning theory “leads us to view learning as a process of becoming aware
of one’s assumptions and revising these assumptions based on critical self-reflection”
[1994: 730].

It is, of course, how one employs and/or applies critical self-reflection that is
important here. For example, while adopting the intention of validating and reformulating
our beliefs might be construed as being desirable and potentially useful, such intentions do
not necessarily guarantee substantial changes in relation to a more thorough and
intellectually rigorous analysis of our assumptions and belief structures. Guarantees
notwithstanding, then, critical self-reflection and the knowledge of how to do this is of major
importance in terms of teaching and learning strategies, not least in relation to design and
technology education.

**Influencing teaching and learning**

While we cannot address here the enormity of what it means to learn, it is interesting to
note Sherman’s view that many variables are involved in influencing learning, some of which
he suggests might be stable – such as intelligence – and others controllable – such as
institutional methods and learner knowledge [1985: 86]. Of more significance is the view
that control may be effected both by the institution (e.g. content organization) and by the
learners themselves (e.g. the prior knowledge of the individual learner, the extant academic
skills, and so on). Yet while introducing both Perry’s [1970] proposal of nine
developmental stages associated with student learning, and Briggs’ [1978] identification of five levels of intellectual sophistication, Sherman notes that “although clearly useful in understanding intellectual progress, such structured schemes provide little information about the environmental and personal actions that foster development” [1985: 86].

This statement is of considerable importance since it relates not to ongoing knowledge acquisition, but to how such potential information is understood, and thus how it is accepted or rejected. And this, in turn, leads us to a collection of important and interrelated issues.

First, it might be noted that, as academics and teachers, it is imperative that we continually examine our own belief structures and assumptions; and do so with a rigor and a determination that goes beyond mere self-reinforcement. Beyond the provision of information and/or the explication and teaching of certain skill sets, it is important that we are aware that what and how we communicate to our students is intrinsically tied to positions, beliefs, ideologies and often-unrecognized assumptions. As hinted at earlier, we, as designers or design teachers, have views on design and technology: on how things should be done and why; on what should be accepted as cutting edge ideas or rejected as inappropriate for the time; on what design — and designers — should do, and why, and for whom; and thus on a range of intentions, preferences and, it need hardly be said, prejudices.

Second, then, it might be suggested both that we need to make clear to our students just what our own positions are, and thus how our interpretation and assessment of their work is, to more or less degree, coloured by our beliefs and preferences; and that we should be seeking to explain to them how to analyze and recognize what they take for granted, and how to critically interrogate why their ‘choices’ and ‘likes’ are as they are, and where they got them from. From a student perspective what comes out of this, of course, is essentially unpredictable. Is it the conventional teaching and learning? Or does it translate into self-learning and, potentially, transformative learning?

If Sherman is correct in his assertions that “learning is an individual and dynamic process controlled by the learner [my emphasis]” [1985: 94] and that “[a]n essential element appears to be the personal, conscious, and purposeful selection of learning skills for each assignment task” [1985: 88] then we must still ask if this constitutes self-learning in a sense that goes beyond merely the receipt and selection of information; and if such choices are not already predetermined by established beliefs and preferences. Thus we might point out that while educational choices are essentially personal, they are not necessarily all conscious; that they may be purposeful, but not necessarily in ways that alert the student to why they are making such decisions, when others could be made; and, perhaps most importantly, that many learners don’t want to self-learn. As Brookfield suggests, “many learners within formal courses, classes, and programs have stubbornly resisted the efforts of educators to transfer control over learning to them [Brookfield 1986, in Cranton 1994: 729]. Some students thus just want to be ‘told’, or just want to accept what they already know and believe. Thus, as Cranton quite rightly observes, “becoming self-directed involves a change in basic assumptions about themselves as learners, the role of the teacher, even the goal of education” [1994: 729]. Under such conditions, she asserts, self-directed learning translates into transformative learning.
Yet this has two fundamental requirements: first, that basic assumptions and beliefs must be challenged, and, second, that such challenges must be rigorously (self-)imposed and examined such that change can occur. Too often, it might be suggested, critical reflection is perceived to take place, but basic assumptions and beliefs remain unchanged. “Transformative learning is not complete,” says Cranton, “without the individual acting on the revised assumptions” [1994: 740]. Such learning; such transformations in one’s beliefs and assumptions; and thus the increasing sophistication of one’s thought processes, is not a one-off phenomenon but part of an ongoing and evolving educational development. In this sense it is akin to lifelong learning, the desire, as Naudé suggests, “…to uncover the treasure of underdeveloped capacities that lie ‘within each of us’ “ [2011: 77-78]. Yet we must be clear that this is not just receiving more information, nor simply receiving new and different information and/or knowledge, but rather assessing what this new knowledge is, why we accept it, where it comes from, and what it causes us to believe and/or do.

Conclusion: Ideology, Argumentation, and Contestation

Given the inevitable, if often unconscious and/or unrecognized notion of position and assumption on the part of both teacher and student; and given also the desirable and potentially education-changing role of transformative learning via deliberate and self-applied critical reflection; the paper concludes by briefly identifying three key issues which might add substantially to our understanding of critical learning development: ideology; argumentation; and contestation.

The first of these, ideology, is, of course, both a well-established and a very general term. Dating back to around 1801, the French philosopher Destutt de Tracy used it “to denote the ‘science of ideas’ which would reveal to men to sources of their biases and prejudices” [Bell 1999: 414]. While this interpretation rapidly fell out of use, it was revived in the late 1920s by Marx and Mannheim, and has now come to be most usually associated with the sociology of knowledge. Often linked to the terms ‘politics’ and ‘power’, Bell asserts that it may be employed “to argue that all ideas are socially determined” and thus that “ideologies may be seen as justifications which mask some special set of interests [my emphasis]” or as “belief systems which can be used to mobilize people for actions” [1999: 414]. Self-evidently, then, it might be suggested that teaching practices are in part ideologically driven, both from the perspective of ‘particular’ ideologies – “the self-interests of specific groups” – or ‘total’ ideologies – what Bell describes as Weltanschauungen or “complete commitments to a way of life” [1999: 414]. Beliefs, views, and positions cause us to see the world in certain ways, and thus affect what we teach, and how, and from what perspective.

While this might be expanded greatly for further consideration, just three questions might be advanced here. First, is it possible – on the part of both student and teacher – to have what we might call a ‘neutral’ education? Is it really possible to provide ‘information’ without presuming ‘interpretation’ and ‘selection’? Second, if ‘my’ position is regarded as being inherently ‘right’, then to what extent do – or should – we take note of Blackburn’s warning that “[d]erogatorily, another person’s ideology may be thought of as spectacles that distort and disguise the real status quo…” [1994: 185]. And third, two suggestions by Amory might be offered as incentives to re-think our own assumptions: first, his view that
“there are hidden ideological contradictions in educational technology as a field of practice and also of theory” [2010: 69]; and, second, that “belief systems are... an integral part of the development and use of technology by all components of different societies. Globalization and the persistence of dominant hegemonies are driven, in part, by ideological belief systems” [2007: 657].

The second key issue worth further analysis is that of argumentation, and its significance for developmental learning. As Jonassen & Kim note, “…meaningful learning requires deep engagement with ideas. Deep engagement is supported by the critical thinking skill of argumentation. Learning to argue represents an important way of thinking that facilitates conceptual change…” [2010: 439]. Perhaps more important is Kuhn’s assertion that

...thinking as argument is implicated in all of the beliefs people hold, the judgments they make, and the conclusions they come to; it arises every time a significant decision must be made. Hence, argumentative thinking lies at the heart of what we should be concerned about in examining how, and how well, people think. [1992: 156-7]

Hence, we should take particular note of Siegel’s view that

[argumentation theory is also concerned with the analysis of the power and convicting force of reasons. When do reasons for a claim warrant acceptance of that claim? By what criteria are reasons evaluated? How are these criteria themselves justified? [1995: 159]

Now, if this paper, however briefly, is about learning, and teaching, and position, and thus about self- and transformative learning, then we must conclude not with a simple statement of what should be done, but with a more complex suggestion about the significance of future differences causing problems for education. To do so I wish to cite Barnett’s notion of what he sees as our current learning epoch, “a learning-amid-contestation view” [2011: 5]. Under this view, he suggests, “learning has its place in a world in which, the more one learns, the more one is aware of counter positions and perspectives. Here is a conundrum for learning here becomes a kind of un-learning” [2011: 5]. Students must therefore continually and critically interact with both their own and the views of others since, he suggests, we live in an educational world “in which every position and every perspective is subject to contestation” [2011: 5].

Hence, a final question: “In a world of contestation, who is to decide which learning is of value?” [Barnett 2011: 5].

References


Design problems, satisficing solutions, and the designer as formalizing agent: Revisiting wicked problems

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In considering the terms ‘design problems’ and ‘design solutions’ at least five intertwined sets of issues are immediately invoked: (i) the ‘over-accepted’ assumption that design is problem-solving; (ii) the proposition that, in significant ways, designing far exceeds problem-solving; (iii) the view that design problems are inevitably ‘wicked’ problems for which single or ‘set’ solutions are not to be expected; thus (iv) the realization that design outcomes are inescapably ‘satisficing’ solutions; and (v) the critical contention that, in important respects, it is the designer who sets the problem rather than simply ‘receiving’ it.

Drawing on a variety of sources on wicked problems and on the nature of design problems, as well as on the author’s previous work on the centrality of designer-determined problems as well as specific solutions, the paper re-visits Rittel and Webber’s assertions about wicked problems, and explores the issues of problem-finding and problem-setting; of the co-extensive nature of problem and solution; of the notion of foreknowledge in the design process, and thus the inescapable ‘unknown yet known’ nature of future design solutions; of the absence of neutrality in the designer; and thus of how designer-driven solution criteria are central not only to problem-solving, but to the role of the designer as formalizing agent in terms of designer-driven problem establishment. The paper concludes by demonstrating that design skills, both learnt and taught, are inevitably augmented – or constrained – by notions of position, assumption, desire and expectation.

Introduction: Thinking Through Design

This paper is about design problems, and therefore about design solutions. The two, it is usually considered, go hand-in-hand. The design problem, we imagine, tells us what issues we need to address and thus ‘solve’, although we might add here that it identifies why such issues are problematic, and thus why, and potentially how, we might address them. The design solution, it is often asserted, follows from the problem; demonstrates that we have addressed such requirements in a manner which ‘removes’ or ‘ameliorates’ their problematic nature; and does so in a way that is acceptable to the client. The last statement is introduced on the basis of the assumption that design problems are presented to the designer by some external agency for successful solution. Now, there is nothing particularly controversial about these propositions – other than that they are assumptions.

The idea of what constitutes a design problem; the inference that the design problem ‘contains’ the requirements for the solution; the expectation that the solution evolves from the problem-as-given; the belief that the designer ‘neutrally’ applies to the problem professional skills and expertise; and the tacit assumptions that the problem and the solution are somehow ‘separate’ in terms of the ongoing design/development process, and that the designer is not, in significant ways, the problem-setter, are all accepted but highly questionable presumptions. And while a number of these issues have been dealt with in
previous papers (c.f. Harfield 2007a; 2007b; 2008), it is worth outlining here five intertwined sets of issues that are evoked by this assumed design/problem/solution nexus.

The first two comprise the ‘over-accepted’ premise that design is problem-solving; and its parallel or perhaps counter-proposition that, in significant ways, designing far exceeds problem-solving. Design ‘outcomes’ might well be equated with ‘solutions’, but the notion of the so-called ‘problem’, how it is articulated, what it requires, when and how such requirements are determined, and by whom, are both important and contentious issues.

The second pair of concerns is well-established within the design disciplines, yet not necessarily explored sufficiently. These comprise the view that design problems are inevitably ‘wicked’ problems for which single or unequivocal solutions are not to be expected, and the attendant realization that design outcomes are inevitably ‘satisficing’ solutions. Yet while both may be accepted, the question of what might constitute ‘wickedness’ in design terms; how and why such wickedness is significant; and, perhaps most critically, for whom is such satisfaction generated, and on what basis, are issues in need of more careful analysis.

Whether designers, or design students, would be interested in conducting such analysis is a moot point, but design educators should be, on the basis of the critical contention that, in important respects, it is the designer who sets the problem, rather than simply receiving it. Important, externally-generated problem requirements notwithstanding, design outcomes are essentially designer-led, not merely in terms of professional skill applications, but in terms of essential – and inevitable – designer choices, desires and expectations, as well as designer preferences, prejudices and beliefs. And it is such ‘views’ that essentially determine the nature of both the solution and the problem.

**Revisiting Wicked Problems I**

Before addressing the issue of the self-construction of design problems it is important first to (re)examine the notion of ‘wicked’ problems. To do so, let us return to Rittel and Webber’s classic 1973 paper ‘Dilemmas in a General Theory of Planning’.

While the idea of wicked problems has been absorbed into the general understanding of design (c.f. e.g. McDermott 1982; Buchanan 1992; etc), Rittel and Webber’s proposals are clearly directed at planning issues, and specifically at social policy problems. They are thus significant from a societal and cultural perspective, rather than a particular disciplinary one, and, political commitments aside, are far less ‘individualistic’ and personally-based than designers offering ‘their’ solutions to what, it will be argued, are ‘their’ problem specifications. Rittel and Webber’s early statement is thus particularly useful in establishing – from a socio-cultural perspective – what is *not* unequivocally present in terms of problem setting, problem solving, and the ostensive criteria used to evaluate potential solutions.

“Policy problems cannot be definitely described,” they suggest,

> Moreover, in a pluralistic society there is nothing like the undisputable public good; there is no objective definition of equity; policies that respond to social problems cannot be meaningfully correct or false; and it makes no sense to talk about “optimal solutions” to social problems unless severe qualifications are imposed first. Even worse, there are no “solutions” in the sense of definitive and objective answers” [1973: 155].
Now, while the above may be useful in terms of understanding the complexities associated with social problems and policies, the key question is what, if anything, can the above statement tell us about the potential ‘wickedness’ of design problems? From such a short statement, five ‘partial’ quotes might be selected that are potentially applicable to how design activities should be construed:

(i) that design problems “cannot be definitively described”;
(ii) that there are no “undisputable” outcomes or answers that are accepted by, or may be of benefit to, everyone;
(iii) that solutions “cannot be meaningfully correct or false”, i.e. it is inescapably an individual matter of opinion and decision;
(iv) “it makes no sense to talk about “optimal solutions”…unless severe qualifications are imposed first”; and
(v) “there are no “solutions” in the sense of definitive and objective answers”.

Rittel and Webber, of course, expand the above to produce ten ‘delineators’ of wicked problems. And while these cannot be examined in detail here – indeed, not all are necessarily relevant to design considerations – several comments are of particular import in that they go beyond our ‘normal’ understanding of wicked problems. Thus, while assertion 1, “[there is no definitive formulation of a wicked problem”, is readily accepted, it is the immediate explication of this that is of such significance for the ways in which design problems are understood and the ways in which design problems and design solutions are co-extensive [Harfield 2007a: 166ff]. Hence, consider Rittel and Webber’s suggestion that “the information needed to understand the problem depends upon one’s idea for solving it [my emphasis]” [1973: 161].

This is of particular importance for design: considering the potential solution-type as a means not just of interpreting but of determining the problem is more significant and more commonplace than might be understood, especially given that many of the ‘imposed’ beliefs and preferences are unconscious and/or unconsciously applied. Hence, the particular ‘position’ that the individual designer/problem-solver ‘takes’ in relation to the problem is what ‘prefigures’ the information that the designer is both looking for and finding. The questions that ‘come out of’ the problem are determined by how the designer chooses both to understand and, in significant ways, to construct the problem. The (design) problem is thus not just ‘there’ and – beyond the simply pragmatic and functional requirements – filled with a universal set of questions and information that is the same for everyone. Rather, it is like a sentence describing some set of responses to a situation, and which is thus different for everyone: different in minor ways of similar but varied descriptions, and different in major ways of completely different responses. Solutions are thus co-extensive with problems in the sense that how one understands and addresses the problem is frequently based on, and thus to a significant extent controlled by, the nature of the solution, or, more appropriately, the ‘solution-type’ that the designer wishes to ‘impose upon’ the practical issues of the design brief.

Of course, one cannot take all of Rittel and Webber’s claims seriously in terms of design. The follow-up sentence to their initial suggestion is that “in order to describe a wicked problem in sufficient detail, one has to develop an exhaustive inventory for all the conceivable solutions ahead of time [1973: 161]. This is, of course, impossible – what
Ritchey calls a “seemingly incredible criterion” [2008: 2] – and from a design perspective an impossibility for at least three reasons:

(i) the number of potential design solutions / permutations is infinite, and it cannot be the case that all can be considered, or even conceived of, prior to ‘beginning’ the path to the solution;

(ii) the choice of one or more potential solutions, and the selection of the many different ways that might be utilized to approach the process is highly determined by the extant knowledge, beliefs, preferences, and ideological position(s) of the designer; and

(iii) as the process proceeds, then more and different potential solution possibilities come to the designer’s mind. These – which may involve major shifts of viewpoint or small-scale modifications and/or improvements to the proto-solution under consideration – provide ‘extra’ solution possibilities which were not present, and could not be present, at the outset of the problem-solving process.

The above criticisms notwithstanding, Rittel and Webber clearly understood the issue of co-extensivity: “The process of formulating the problem and of conceiving a solution …are identical [my emphasis], since every specification of the problem is a specification of the direction in which a treatment is considered” [1973: 161].

This is intrinsic to design since the problem that the designer tackles is not the initial set of pragmatic requirements identified as the problem-as GIVEN, but is the problem that the designer formulates, i.e. constructs. In the same way, deciding what you are trying to solve, and the means of attempting a solution, is the means of establishing just what the problem is. Problem and solution are thus intrinsically co-extensive. As Rittel and Webber note, “…one cannot first understand, then solve [my emphasis]” [1973: 162].

This continues under their second criterion, “[w]icked problems have no stopping rule”, when they assert that “the process of solving the problem is identical with the process of understanding its nature…” [1973: 162]. This is interesting from a design perspective in regard to what might be termed the ‘external’ dimensions of design problems. Design tasks are not ‘closed’ and do not have definitive solutions. Hence, the very nature of them is that ‘we’ – the potential problem solvers – must develop an understanding of them as we proceed through the process. Thus, we form our understanding as we impose ourselves on the problems. And the ‘external’ problems become quasi-internal problems: we determine what the problem – and thus what the solution – is to be, or what sort of ‘views’ or ‘criteria’ or ‘preferences’ will inform it.

Such imposition – on both problem and solution – is not, of course, ‘fixed’; it varies, evolves, mutates as the designer proceeds with the solution-directed process. The designer is thus the formalizing agent, albeit with the formalization going beyond the application of professional skills, experience and knowledge, and being subject to the influence of desires, wants and ideological ‘frames’.

Revisiting Wicked problems II

Of the remaining eight indicators proposed by Rittel and Webber, three are deserving of brief comment here.

First, and in relation to assertion 3, “[s]olutions to wicked problems are not true-or-
false, but good-or-bad” [1973: 162], it is worth noting that, in design terms, the criterion ‘good-or-bad’ is itself potentially unrealistic. Given the range of possible outcomes, all of which might meet, to varying degrees and for varying reasons, the requirements of the ‘problem’ from both a pragmatic and a ‘designer-desired’ perspective, ‘better-or-worse’ might be a more appropriate descriptor, although phrases like ‘better in regard to y…’ or ‘closer to what I (as client or designer) want…’ might be more indicative of how decisions are made. It might also be noted that other solutions, by different designers, may be regarded as ‘better’ not in relation to ‘up-front’ client requirements, but on the basis of designerly persuasion, which is often symptomatic not of ‘betterness’ per se, but of which solution is selected and accepted.

Second, and in relation to assertion 7, “[e]very wicked problem is essentially unique” [1973: 164], it is interesting to note Rittel and Webber’s concern for important as opposed to trivial uniqueness. While they concede that all solutions, no matter how similar, exhibit minor differences, they wish to make clear that their phrase “essentially unique [my emphasis]” implies “…an additional distinguishing property that is of overriding importance” [1973: 164]. From a design perspective this is significant not because all design solutions inevitably exhibit differences, and thus, to some degree, ‘uniqueness’; not because ‘minor’ differences are often construed as being indicative of an important aspect of design, namely the creation of novelty or ‘newness’; but because it is an interesting perspective to ask of designers – and design students –

(i) what is the distinguishing property of their design that is of overriding importance;
(ii) on what basis;
(iii) how is it to be explicated and supported; and
(iv) what does it ‘do’ in terms of ‘social benefit?

While, from a design perspective, the last issue is not essential, it is important. It is important not because it trivializes novelty and difference in relation to design processes and design outcomes, but because it foregrounds a key question: what is the purpose and intention of design beyond newness, difference, formal attraction, aesthetic sensibility, and so on?

Third, and finally, assertion 8, that “[e]very wicked problem can be considered to be a symptom of another problem”, might usefully be examined in terms of design. Rittel and Webber’s contention is not only that “[p]roblems can be described as discrepancies between the state of affairs as it is and the state as it ought to be” but also that the removal of such discrepancy “…poses another problem of which the original problem is a “symptom” “ [1973: 165]. Two design perspectives might be cited here. First, while many design issues might be couched in terms of the difference between ‘what is’ and ‘what should be’, this ‘journey’, particularly when dealing with clients, is usually not a discrepancy of any sort, but a set of needs, wants, desires, etc. In the same way, while the designer will undoubtedly consider ‘what can be explored that will lead to an acceptable outcome?’, the inherent context of such proposals will also be a set of wants, desires and expectations that certainly address the problem-as-given, but that takes a particular range of solution possibilities that ‘absorbs’ the client requirements and demonstrates the achievement of them via the medium of a specific design position or ideology.
Second, then, it might be said that all design solutions are to some degree symptomatic of other design problems or design issues inherent within the designer and – successfully or otherwise – overlain on the client’s generic requirements. Design at any time operates within a variety of contexts and is affected by a variety of conceptual and positional determinants that influence, to varying extents, how the designer seeks to proceed, and thus how the assumptive design problem is to be addressed.

The designer as formalizing agent

Now, if it is accepted that the designer is not merely the problem ‘receiver’, nor the problem-solver in its supposedly ‘neutral’, objective, apply-one’s-professional-skill-set-to-the given-situation sense, then we must briefly outline three questions relating to the designer’s interpretation of, augmentation of, and determination of both the problem-as-design-goal (Harfield 2007a: 169ff) and the ‘personalized solution’.

First, then, it might be suggested that it is important for designers to consider – and to recognise – the issue of ‘problematization’ (Harfield 2007a), i.e. not only how and in what ways each designer determines the nature of the ‘augmented’ problem, but how such ‘designerly’ problem setting also informs and constrains both the nature of the acceptable solution and the criteria for such acceptability. ‘Acceptability’ relates, of course, not only to a detailed understanding of the client’s stated wishes and requirements but also to:

(i) the analysis of, addition to, and potential reconsideration and reconfiguration of such issues by the designer and in conjunction with the client;
(ii) the determination – or perhaps the simple assumption – by the designer of what, from her/his perspective, will constitute both the nature of the augmented problem-setting and the solution-type that they ‘take’ to be the outcome; and
(iii) the reconciliation between designer’s output and client’s requirements, and thus client acceptance of the proposed outcome based on persuading or ‘selling’ to the client the design quality of that outcome. Such persuasion is not, however, to be considered an ‘advertising’ ploy. While both the enhanced problem and the specific outcome is, from a designer’s position, highly personalised, ‘selling’ that outcome is based on qualitative design criteria. ‘You’ employed me as a designer because ‘I know what I am talking about’ and I can produce excellent design outcomes that both (a) meet your requirements to a high level, and (b) do so in a way that enhances your requirements via design significance.

The second question – again to be recognised and considered by each designer – is whether the personal projection of ‘self’ onto ‘problem’ is intellectual, reasoned and ideological, or whether it is simply intuitive? Hence, is it known or unknown? While there is no universal answer to this it might be suggested that many assumptions that we, as designers, hold, and act according to, are unknown or, at least, generally unconscious. Thus, the contemporary nature of the discipline, the current debates, the designerly requirements, positions and expectations – and our adherence and commitment to these, knowingly or otherwise – suggest that design is generally not neutral in respective of the brief, nor in relation to the prospective solution, and cannot be so!

Third, then, it is important to ask what is the role of education in revealing ideology, belief systems and theory commitments in design? If my assertion that position precedes
solution is accepted, then it is an essential part of the educational process to make students and designers aware of the influences and inputs that 'control' their design thinking, but also to encourage the educator to be aware of their own positions and thus how they influence students via such views (Harfield 2007b: 1).

Self-evidently, then, designers are the formalizing agents in the design process. They interpret the requirements and add to them; make the decisions; determine the solution possibilities and the final outcome; and hopefully persuade the client. But while ‘our’ understandings of design, and the positions that we ‘hold’, may be extremely positive and directed:

...It is important that the potentially negative and restricting effects of any such predetermined assumptions, views and commitments...must be explored and revealed. While theoretical, formal and aesthetic ‘blinders’ might usefully sharpen focus, and certainly aid and inform solution development, they simultaneously limit scope and reinforce preconceived expectations (Harfield 2008: 184).

Conclusion

Let me conclude this paper with four observations that may cause us to re-think our assumptions about design.

First, designers (and theorists) influence contemporary practice and what should be the case, now. At the same time contemporary practice and internally-persuasive contemporary positions and theories influence designers. What, then, is the role of position in design practice; to what extent are we conscious of the positions, beliefs and assumptions that we subscribe to; and what do such 'constructive perspectives' cause us to do, or not do, think, or not think, in relation to what design is?

Second, while we might readily accept – and wish to accept – the designer as the central formalizing agent within design practice, let me offer a radical shift in viewpoint:

While architecture has always been associated with the quest for ideas, with issues of novelty and difference, and with the role of the formalizing agent within the design process, it is only recently that – for some – attention has been shifted to the deliberate distancing of the designer from the formalizing process, and to the ways by which this might be accomplished. While the desire for novelty and difference not only remains but has perhaps increased as a central focus of design, use of an ever-expanding range of digital and aleatory techniques is concerned not just with the means of eliciting different design possibilities, but also with the deliberate removal of personal, frequently conventional, essentially memorized, and often highly intentioned views from the design process itself. [Harfield 2011]

What role the designer, then, if we are to sublimate design control?

Third, an ideological question: to what extent is design assumed or intended to produce objects or outcomes that confer social benefit; and does it? And to what extent is it conditioned by formal and aesthetic preferences; by the incentive, indeed the requirement, for the ongoing production of novelty; and by its intra-disciplinary presumptions and constraints?

Finally, let me close with a recollection by Skaburskis, who, he tells us, attended a lecture at Berkeley on 12 October 1969, where Rittel outlined ten attributes of wicked problems – albeit with some minor differences from those presented in the 1973 paper. Given, though, our assertions about the role of the designer not merely as the problem
‘receiver’ and/or the problem-solver, but as the agent who effectively determines the nature of the problem to be addressed – the problem-as-design goal – and establishes the very formalization and solution-type that will achieve this goal, what is of more interest is a different comment by Rittel. As Professor of the Science of Design Rittel ran an undergraduate architecture course and offered the following highly contentious – although, it might be suggested, also highly connected – piece of advice. “Rittel told architects,” writes Skaburskis, “that for a good designer “form follows fiction [my emphasis]… to be a good designer, you must be a good story teller”” [2008: 279 / internal quote by Rittel].

References
There are strong connections between assessment and learning. Assessment can have many purposes. One purpose is when the teacher acquires information in order to adjust their teaching to better meet the pupils’ needs for future progress on their learning journey. This paper provides findings from a qualitative study that explore and describe the process of assessment in Technology education in the Swedish compulsory school. How do teachers follow up their pupils’ progress? What equipment/assessment tools do they use, in order to ‘locate’ their pupils and move them forward on their learning journey? The results are based on classroom observations and the teachers’ written assessment documentation.

**Key words:** technology education, formative assessment, follow-up, Global Positioning System (GPS)-performance in education

**Introduction**
This paper aims to describe findings from a study regarding teachers’ work with assessment with the purpose of moving their pupils forward on their learning progress in the mandatory school subject technology. Thus, emphasizing assessment as the link between teaching and learning.

**Navigare Necesse Est**
The importance of navigating at sea is familiar to me, after years of sailing with our family boat. Teaching could, to my experience, in many respects be seen as a similar activity to teaching and learning, which put demands on all the participants. Despite thorough planning; you still need to make frequent checkups since you neither know exactly what will happen during the journey in advance nor which way to take to the wanted destination. Sailors use different equipment to navigate e.g. stars, nautical charts and their former experience from sailing and from the surroundings. Lately it is also possible to use a Global Positioning System device, a GPS-device. In order to navigate with the GPS, to alter the gap between your current and your wanted position, you need four things: (1.) a GPS-device, (2.) accurate software, (3.) information from three different satellites, and last but not least (4.) knowledge to interpret and translate the information into the current settings. Depending on the performance of your GPS-device and your own prior experience, you can get various accurate position precision. Neither teaching nor sailing is an easy laid back activity. This, I find, is part of the fascination with the journey, both as a sailor and teacher.

**Where are we and Where are we Going?**
The teacher has to start from where their pupils are currently situated and take their teaching from there (Kimbell, 2007). Teachers often assume that they are able to
determine if their pupils are ‘on track’ or not. This assumption is often based on what the teachers themselves think that they have taught their pupils or not, or that pupils are moving forward in the same pace as the teaching (Kimbell, 2007; Wiliam, 2011). This is somewhat problematic. Firstly everything taught is not necessarily learnt by the pupil. Secondly pupils learn stuff in other surroundings as well. The teacher’s interpretation of gathered information can also be influenced and biased by the teacher’s prior experience and view about the pupils as individuals and as a group. Both the teacher’s and the learner’s expectations regarding her/his possibilities to achieve the goals set up may also affect the results (Rosentahl & Jacobson, 1992; Kimbell, 2007, Hattie, 2009). Teachers need to be aware of the difficulties of assessment in order to deal with it properly and consciously (Kimbell, 2007). Moreland et al (2008) cues the importance of the teachers knowing where they are going; it helps the pupils learn. When the teachers involve their pupils and clarify the criteria for success it has a countervailing effect where all pupils’ benefit but the low-achievers benefit the most (Jönsson, 2010). According to Hattie (2009) and Jönsson (2010) it is successful for teachers to share worked examples of prior pupil work of different quality.

It is important to be aware of the variety of knowledge to build upon and how the learning takes place for the individual and the group as a whole. The teacher’s ability to adjust their teaching based on the pupils’ different starting points and to bridge the gap between the current and the wanted destinations is the characteristics of assessment for learning (Black & Wiliam, 1998). This requires thorough planning including questions to ask along the way and adjust what is happening in the classroom from the evidence gathered to meet the pupils’ needs (Kimbell, 2007; Wiliam, 2011). Considerable research shows that this planning benefits from being done together with others (Leahy et al, 2005; Moreland et al, 2008; Black, 2008; Pettersson, 2009; Wiliam, 2011). Teachers who lack others to discuss with and only have their own experience to rely on are at risk of getting non-aligned with the current view of learning and steering documents (Pettersson, 2009).

Documenting and Follow-up in Sweden

Within the Swedish context the sidelined technology subject has been mandatory since the beginning of the 1980s and is still lacking thorough roots and tradition (Hartell, 2010). Sweden has a strong tradition of classroom assessment, and relies on the belief in teachers’ ability to independently assess pupil’s knowledge and decide on what grade to be given (Klapp Lekholm, 2009). The state of knowledge among the Swedish youngsters in technology is not easily interpreted and described (Hartell, 2011). Some national tests are provided as support material by The Swedish National Agency for Education (NAE) but none in technology. The importance of discussions among teachers regarding learning and assessment has been highlighted (Pettersson, 2009; Klasander, 2010).

In 2008 the Swedish teachers were provided with a navigational tool, the Individual Development Plan with written assessment (in short IDP). The intention of this public document is to support the future learning of the individual pupil, i.e. to be formative. It shall not include any harmful information. It falls, according to Hirsch (2011), into the long cycle of formative assessment. In short the intention of the document is similar to a GPS-device (Hartell, 2010). The design of the document is decided upon at every school.
and shall include written assessment in every school subject given and is not to be used to compare between schools or individuals. Similar documents are found internationally but with the difference that the Swedish IDP phenomenon is mandatory for all pupils and not just for those in special needs (Hirsh, 2011). The NAE report (2010) showed that the introduction and in-service training offered to teachers regarding the IDP-document were not sufficient.

**Purposes of Assessment**

Teachers work with assessment all the time; by asking questions, looking for glimpse of understanding and so on (Kimbell, 2007). However, the aims and purposes of the assessments obviously differ (Newton, 2007; Pettersson, 2009). By being clear on what to be assessed and what the results shall be used for, as well as foreseeing the consequences of the assessment, the validity increases (Nyström, 2004). If the purpose of the assessment does not include the pupil's future progress, one must question the usefulness of it (Nyström, 2004). By feeding back to the analogy between sailing and teaching; I would like to point out that there also are considerable differences. When sailing you can change the pre-planned route and destination to something more suitable. When teaching you can change targets and align along the prevailing conditions that exist but the Swedish National curricula stipulate two tuning positions that the pupil is entitled to exceed during their nine years of compulsory school. To “navigate” pupils towards the goals of the curriculum and, making sure to keep every pupil 'onboard', is a challenge worthy of a professional around-the-world-sailor.

**Assessment for Learning**

Not all teachers who teach technology grade their pupils but they all work with assessment somehow. Teachers who fail to assess what the pupils cannot conclude if they are contributing or impeding their pupils’ process. Refusing to assess is really a concession to those who argue that no learning takes place (Lindström, 2006). Lots of information concerning pupils’ performance and skills is gathered, but seldom used (Wiliam, 2009). However well the intention of the gathering and the interpretations of the information are conducted; it is only formative when the information is used by the teacher, pupil or peers to modify and adapt the surrounding conditions for the learner to better suit the learner's needs (Wiliam, 2009).

There is an unbreakable connection between successful teaching and formative assessment and learning, where assessment can be seen as the bridge connecting the teaching and the learning (Wiliam, 2011). International research is conclusive about the effectiveness of formative assessment but also the misuse and difficulties of the concept are identified (e.g. Hattie, 2009; Black & Wiliam, 1998; Bennett, 2011; Wiliam, 2011). Wiliam (2009) stresses the necessity to divide formative assessment into three different cycles of time; long, medium and short. The effect of the formative function decreases with time elapsing between collection and use. The most effective formative assessment is that which occurs minute by minute every day in the classroom and is, according to Wiliam the one that should be seen as formative in its true sense. The long cycle (e.g. IDP-documents) is not to be diminished as it may have an effect on a more comprehensive and
strategic long-term basis.

**Formative Assessment in Technology Education**

In the next section a brief overview of previous research concerning formative assessment with the focus on technology education is presented. The review has been made through Swedish and English literature and selected to fit the theme of this part of the study and not to be a complete review.

Discussions and the use of pupil’s questions in technology are cued by Black (2008) and Moreland et al (2008). They highlight the permissive classroom climate as well. The possibility for the pupils to ask questions, the possibility of working with the feedback and the notion of learning from one’s experience including mistake are stressed. Black emphasizes the wait time both before and after pupils reply as crucial for pupils’ learning. By increasing the amount of wait time from the average 0.9 seconds to 3 seconds the possibility for learning increases extensively according to Black. Moreland (2008) says it is beneficial that the teachers themselves understand technology since it helps the learning of the pupil. Kimbell (2007) stresses the importance of planning questions in advance. Blomdahl (2007) argues that a lot of time and effort are spent dealing with other matters e.g. finding equipment, time and group size instead of planning the tutoring in the technology subject. Their practice mainly focuses on managerial in the classroom and the teaching and learning come in second place. Blomdahl (2007) cues the lack of habit, among the Swedish teachers, to describe their teaching practice. Collegial discussion regarding teaching is rare among technology teachers according to Bjurulf (2008) and Klasander (2010). Bjurulf and Klasander show that the teaching of technology is influenced by the teachers’ prior experience and they are not covering the whole of the syllabus e.g. technological systems. Discussion regarding grading between pupils and teacher occurred occasionally in the end of the theme (Bjurulf, 2008). Bjurulf says the teachers’ assessment does not reflect the teaching practice in technology e.g. the teachers seem to value theoretical skills higher than practical skills despite most of the teaching time is spent practically. Bjurulf (2008) cues the notion of a hidden agenda; where the enacted syllabuses recognize criteria connected with personality, i.e. working alone, not asking questions and being thorough, as criteria for success. This was known among the high achievers.

**Results**

This paper provides results of a qualitative study that explores the process of assessment for learning in technology education with the focus on teachers. This results presented are based from two teacher-focused sub-studies (1.) regarding the documenting of pupil’s attainment and (2.) teachers’ assessments practice within the classroom. The results build upon authentic samples of assessment documents in technology (IDP with written assessment in technology) and from classroom observations and teacher interviews. The sub-studies are presented in short separately with some clarification specific to the sub-study and then discussed together.
Sub-study 1. IDP-documents in Technology Education

This sub-study have investigated the possibility to navigate the pupils in technology education using the IDP-documents. The results rely on samples of 351 authentic IDP-documents from school year 1-6, from five different municipalities. According to the regulations every school can decide on the design of the template (some schools within a municipality can use the same). This sample includes 14 differently designed IDP–templates. Some IDP-templates included a box to tick for the goal achievement of the pupil in a particular subject where others included pre-formulated goals and/or space for the teacher to write additional comments.

Every individual pupil is entitled to a written assessment in every subject given. When looking for information about pupil knowledge in technology; the information is limited. Most (9 out of 14) of the IDP-templates totally lacked written assessment in technology. Thus the hypothesis presented at TERC 2010 (Hartell, 2010) was confirmed. Technology was not the only missing mandatory subject in this sample but the least frequent. One municipality even lacked technology in all their six templates. None of the IDPs, which included technology, contained individual information about the individual pupil regarding where to go next. Thus this study shows that IDPs are not useful in navigating pupils in technology education.

Sub-study 2 Short Cycle Assessment

Wiliam (2009) emphasizes the short cycle of formative assessment in the classroom. Lindberg (2005) cues the lack of knowledge about teacher’s classroom assessment within the Swedish context. This sub-study investigates and describes the short cycle of formative assessment in primary technology education. There are many things going on in a classroom. The five key strategies for formative assessment (Black and Wiliam, 1998) were used as spectacles in an observational scheme (which was inspired by Kimbell & Stables, 2008). By using observations, photography and sound-recording (which has been transcribed with high accuracy) and complementary teacher-interviews, traces of the five key strategies for formative assessment have been captured and described in order to describe these teachers’ work with assessment. The purpose was to describe two teachers’ work with assessment together with their pupils during a technology theme in school year 4 and 5 (10-11 year olds).

The results show traces of the five key strategies and these teachers’ un-doubtable intention of moving their pupils forward on their learning journey. They show, through e.g. glimpse, intonation, voice etc., their high expectations of their pupils’ ability to learn. They assess for them, not to them. Unfortunately previous results (e.g. Black et al, 2008) show that they are not likely to be as successful as their intention. They keep track of their pupils solely on regards of what happens during the classroom activities and keep the information within themselves. The results also show the lack of teacher training and teaching material. These teachers sorted it out by bringing equipment and stuff from their own home and from other subjects. Lot of time and energy are spent on this and they are not just teachers in the technology subject. They ask for organized collegial discussions regarding assessment in general and in technology in particular which neither of them is given the opportunity. This lack of equipment and collegial discussions are consistent with
previous findings (Blomdahl, 2007; Bjurulf, 2008).

The conclusive results show that these teachers are left to their own prior experience in planning, assessing and teaching for their pupils in technology education. Neither the validity nor reliability of these teachers’ enactment in the classroom is investigated here. Still it can be questioned through previous results (e.g. Kimbell, 2007; Pettersson, 2009 & Wiliam, 2011) which show that planning teaching and assessment are done profitably together with others.

**Discussion**

The results presented here show that the teachers are alone in making sure their pupils reach the stipulated tuning points stipulated by the national curricula. They are left to their own experience in finding the starting points, planning, executing, managing and assessing in technology. It might be considered trivial to use the GPS-analogy but it is worth reminding of when navigating at sea with a GPS-device you need information from at least three different satellites in order to determine the position where you are at. The accuracy in the position increases when more satellites are involved. When using signals from only one source the risk of getting lost increases considerably, even though your previous experience can help to bridge the gap from where you are to where you want to go. The importance of teachers working with assessment both consciously and carefully, e.g. looking for glimpse of understanding in the eye and the importance of awareness concerning the interpretation building upon one’s own experience, is identified. There are many ways of finding out where the pupils currently are on their learning journey. IDP-documents are however not an option, in technology at least. It is not just the information that is needed. The evidence needs to be put into action. As a sailor I keep a record in my log to position us and as a teacher I need some similar notations to keep track on the pupils during the journey. The gathering of information does not by itself move the pupil forward; it is how it is used that matters. By being clear on where we are going the likelihood of getting there increases for all participants. The results presented here show the evident lack of available equipment to the teachers in making sure their pupils reach the stipulated targets. The importance of discussions regarding technology and assessment is identified previously and the results presented here emphasize the lack of it. Feedback is the description on what next step to take to alter the gap between the current and the wanted destination. The GPS-performance of the teachers I would say is the ability and possibility to do so. And the results presented here show that some tuning is needed.

**Conclusion**

Sweden has a tradition of teacher’s assessment which I think shall be acknowledged and valued. However, the results show that the teachers are left alone and this awakes new questions concerning consequences. I stress the need for further investigations on regards how this affect the pupil’s results. What I find even more interesting, is to investigate how to support teachers in moving their pupils further on their learning journey, thus how to tune their “GPS-performance”. The GPS-navigator is part of a complex system and the results from this study show that the teachers are alone in managing all this. I argue that the risk of getting lost within the educational context increases when you are left alone.
The need for discussions with others and the need for organized discussion regarding assessment and technology are both asked for here and previously identified as beneficial. Still, here, it is confirmed as an area of improvement. Research shows that when teachers discuss with other professionals both the reliability and validity of the assessments increase. To my experience this is not always so easy to organize. That is why I find it intriguing to investigate further how different digital tools can be used to shrink time and space (c.f. e.g. Hartell, 2012; Kimbell & Williams, 2012) and what possibilities it opens up for.

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Use of Video-Clip examples to interview Japanese Special Education Teachers about their teaching strategies

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Current educational globalisation has revealed differences in teacher practices across cultures. Qualitative ways of doing research have helped to unpack cultural reasons for everyday practices. This paper explores the use of video-clip examples (VCs) to interview Japanese special education teachers working with children with autism spectrum disorders about their classroom practices. A previous study showed that a group of Japanese teachers talked about their practices in an abstract way so that what they were actually doing with these children was unclear to an Australian researcher. In this study, VCs selected from observation data of Japanese teachers' own teaching provided a concrete focus when individual teachers talked about classroom interactions Callingham and helped them articulate their culturally embedded practice. This method provided a useful way to interview these teachers about their classroom interactions from moment to moment and about their lesson study practices focusing on learning process. Talking about live interactions in VCs clarified their explanations of what they were doing. Their talk about the VCs was also consistent with the lesson study process of transforming knowledge from tacit to explicit form in their own teaching.

Introduction

More cross-cultural research to expose culturally different ways of teaching children with autism spectrum disorders (ASDs) has been urged in order to find new culturally specific possibilities that improve teacher practice for educating those children. Many researchers have reported different ways of teaching among cultures (e.g., Callingham, 2012; Dronkers, 2010; Stigler & Hiebert, 1999). For example, Stigler and Hiebert (1999) discovered dominant ways of teaching children at public schools among three different nations (i.e., Japan, Germany, and U.S.A.). Moreover, qualitative cross-cultural studies have been an emerging topic in education for children with ASDs (Daley, 2002). In particular, social aspects of those children's disability have required a better understanding of a cultural role in teaching them in their local contexts (Trembath, Balandin, & Rossi, 2005). That is, expectations about social competence and related communicative skills have been defined within the culture where the children are present (e.g., Matson et al., 2012). Evidence-based practices evaluated as effective for teaching children with ASDs in English-language cultural settings (e.g., Simpson & Myles, 2006), therefore, could not be assumed to be effective in other cultures or to be valued and welcomed by teachers and parents with those cultural backgrounds.

Furthermore, economic and practical reasons for teaching children with ASDs in a group setting have been emerging. On one hand, government budgets for diagnosis and intervention have been stretched by its increasing prevalence and by its therapeutic focus
on one-to-one supports (e.g., Matson & Kozlowski, 2011; Sun & Allison, 2010). On the other hand, a current movement toward inclusive education has raised an idealistic expectation that regular education classroom teachers can respond appropriately to the needs of children with ASDs in their mainstream classrooms. In primary schools, it has been reported that children with ASDs in regular classrooms have spent more time with paraprofessionals (e.g., teacher aides) than with their classroom teachers or with fully qualified special education teachers (Suter & Giangreco, 2009).

Little research has been conducted to establish how qualified special educators use their knowledge and skills to work with these children in their classrooms. Some studies have suggested that group teaching may help children with ASDs learn appropriate social and communication skills through peer interactions (e.g., Bohlander, Orlich, & Varley, 2012; Krasny, Williams, Provençal, & Ozonoff, 2003; White, Keonig, & Scahill, 2007). That is, some English-language research has shown that peers can be a social model (i.e., peer-modelling), teach or encourage peers with ASDs (i.e., peer-instruction, peer-mediation), and develop social relationships among peers in their everyday classroom environments. However, this type of training has not yet been classified as evidence-based practice (Simpson & Myles, 2008). It has been recognised that it is logistically difficult to obtain appropriate evidence from long-term observations of interventions among peers (Koenig, De Los Reyes, Cicchetti, Scahill, & Klin, 2009). Likewise, little has been known about what special educators do with children with ASDs in their classroom settings.

Reflective inquiry into everyday practice in a traditional Japanese approach to professional development, known as lesson study, has attracted international interest. American researchers, Lewis, Perry, and Friedkin (2009) viewed this teacher-driven practice as in-school action research and developed a model showing how it is used to improve lessons. Matoba, Shibata, and Sarkar Arani (2007) emphasised school-university partnerships in professional knowledge creation through Japanese lesson study. This in-school research driven by Japanese teachers has been recognised as an essential part of their professional roles (Ōta, 2005), and Stigler and Hiebert (1999) reported that one Japanese teacher said that he will not be a teacher if he does not conduct lesson study. Much of the work relating to lesson study is voluntary in nature (i.e., before and after the teaching day). Studies of Japanese lesson study and its application to regular education in other countries (e.g., U.S, Hong Kong, Iran) have been increasing (e.g., Lee, 2008; Lewis, 2006; Matoba & Sarkar Arani, 2005). Kikkawa and Bryer (2012a, 2012b) called for direct observation of how special educators use the lesson study practice for improving their everyday practice in Japan, because this practice appeared to be an essential and embedded process in order to improve Japanese special educators’ everyday teaching practice.

The participating teachers of this study used one particular lesson style, called “seikatsu-tangen-gakushu” or life-skill learning unit, which has been widely used by special educators of children with intellectual disabilities (ID) in special education settings in Japan (Japanese National Institute of Special Needs Education, NISE, 2006). The frequent co-occurrence of ASDs with ID (Matson & Nebel-Schwalm, 2007) has meant that many children with ASDs have ID and are often enrolled in special education classrooms designed for ID. In this approach to teaching practice, group activities have been repeated with modifications added over a period of one whole unit (i.e., a series of featured lessons), and with a focus
on everyday life skills (e.g., daily-life skills, independency, autonomy) and social matters (e.g., peer relationships, group effort, group belonging). According to the teacher guide for using this life-skill learning unit (NISE, 2006), this practice has required special educators to have the “lesson skills” to create a “good” lesson designed around the specific children (i.e., individual needs, group needs). To achieve this, these special educators were recommended to engage in a lesson study practice to transfer tacit knowledge (i.e., an abstract view of the ideal lesson) into shared information (i.e., a visualisation of classroom interactions and events) through group discussions with teacher colleagues (Ôta, 2006).

The notion of an individual bringing a cultural lens or perspective to bear on that individual’s ways of viewing and understanding a phenomenon in social space has been discussed in recent cross-cultural literature (e.g., Okawa, 2008; Rodríguez, Rodríguez, & Mojica, 2012; Suzuki, 2009). That is, it has been shown that personal histories of researchers (i.e., where and how they have grown up and been educated) define how they evaluate the teaching practices of others and how they make sense of what they heard or saw during interviews and observations. Suzuki (2009), for example, suggested that, to understand culturally different ways of teaching, researchers need to suspend their own cultural lens. Kikkawa and Bryer (2012a) extended Suzuki’s notion by demonstrating that negotiation with the participating teachers about interview questions and research procedures is critical to a careful examination of teaching practice from local teachers’ point of views.

Discussions among a group of three Japanese special educators working in a primary unit showed a culturally distinctive interactive and inductive way of teaching children with ASDs in their classrooms, which involved formative assessment of the children’s learning (Kikkawa, Bryer, & Beamish, 2012). These teachers’ talk indicated that they used interactive ways of teaching these children to improve social awareness and cooperation, independence, and engagement in activities. To achieve these goals, these teachers developed a careful lesson plan with anticipations of possible interactions during the lesson and assessed how their children responded to their learning experiences from moment to moment.

However, the indirect and abstract nature of their talk often did not make clear what they were actually doing with these children to Australian researchers (Kikkawa et al., 2012). Haugh (2003) claimed that traditional Japanese values such as the importance of preserving harmony (wa) and group orientation (shudan shugi) accounted for the highly contextualised nature of Japanese communication and preference for nonverbal, subjective, emotional, and spiritual communication. What was clear to the Japanese special educators within their group discussion and to the Japanese researcher transcribing this interview was not culturally available to Australian interpretation.

This report considers how another set of three Japanese special educators working in a primary unit undertook reflective interviews with the researcher (first author) about their instruction and interaction with children with ASDs during their group lessons. Video-clip examples (VCs, hereafter) were made from taping of a lesson from their life-skills learning unit over many weeks. There was at least one child with ASDs in their groups of four to six children in Years 1-2, 3-4, and 5-6 respectively. These teachers engaged in multiple activities for this study during the first term in the school year.
Setting, Sample and Procedure of Using Video-Clip Examples

Videorecording seemed to provide an option for clarifying the practice of Japanese special educators and overcoming expressive vagueness and indirectness about their teaching. The usefulness of applying video recordings to education research has been increasingly recognised as technology with lower cost and simplified access has become more available (e.g., Knoblauch & Schnettler, 2012). Video devices were used to record classroom lessons in a special need education unit (SNEU) at a Japanese elementary school attached to a national university (Note. One lesson lasted approximately 45 minutes). School approval was confirmed, and then ethical consent was obtained from each participating teacher and parent of the children enrolled in the SNEU.

Three classroom teachers (see Table 1) of this unit participated in a series of short individual interviews every week across a 9-week period of field research. Before each interview, the researcher created VCs from the same week’s featured group lesson. The selection of moments was based on how these teachers used group instructions for their children with ASDs during their group lessons. Every Japanese teacher was invited to describe what they were doing and articulate what they were thinking at the specific moment shown in the VCs.

### Table 1 The Participating Teachers

<table>
<thead>
<tr>
<th>Teacher code (class)</th>
<th>Pseudonym</th>
<th>Gender</th>
<th>Age group of children</th>
<th>Number of children</th>
<th>Total</th>
<th>ASDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>JT1 (SNEU1)</td>
<td>Ms Ando</td>
<td>F</td>
<td>6-8 years old (Year 1-2)</td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>JT2 (SNEU2)</td>
<td>Mr Banba</td>
<td>M</td>
<td>8-10 years old (Year 3-4)</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>JT3 (SNEU3)</td>
<td>Ms Chiba</td>
<td>F</td>
<td>10-12 years old (Year 5-6)</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

A three-step process was used to making VCs: (a) conduct a direct observation while using video devices; (b) ask teachers for quick feedback after the lesson to find “Key Moments” from their point of view; and (c) review the audiovisual data and create video-clips of Key Moments identified both by the teacher and researcher. The VCs were then prepared prior to the follow-up individual interviews at the end of the week or, occasionally, early in the next week.

The reflective interviews started with overall reflections about their teaching week, the children with ASDs across the week and during the lesson, modifications made in their lessons since the last observation, and any input to that lesson from other teachers or educators. Reflection on VCs was then conducted at the end of each reflective interview. Ms Ando had more VCs (n = 23) because she used free play, which had more abstract learning goals and instructions. In contrast, Mr Banba (n = 15) and Ms Chiba (n = 18) used cooking activities, which had clearer aims and, therefore, more specific instructions by these two teachers. This reflective interview session was recorded by using a MP3 player, and audio data were directly transferred into the researcher's personal computer and transcribed into a Microsoft Word file. The original texts were translated from English to Japanese through a layered process of cross-interpretation (Kikkawa, 2007).
Usefulness of Using Video-clip Examples
In this report, the Japanese teachers’ talk about the VCs was reviewed in order to evaluate the usefulness of using this method for interviewing the Japanese special educators. This method enabled these teachers to talk about daily practices that may be conducted automatically and unconsciously. This method was also matched to their preference for specific and clear questions based on concrete examples when being interviewed (Kikkawa et al., 2012). The concrete images from VCs of their actual practices appeared to help these teachers talk about their stories in their classroom and confirm what occurs in the Key Moments from the teachers’ point of view. It also helped overcome the complexity of social interactions during classroom lessons, which did not translate well in simple Japanese-English transcription. It was also found effective for the teachers to talk about their ongoing process of lesson development. During reviewing the VCs, the Japanese teachers appeared to reflect on the whole process of their approach to the lesson: They talked about their ongoing process of teaching children with ASDs before, during, and after the lesson shown in the video. Additionally, these teachers reported issues in teaching children with ASDs in a group. Thus, there seemed to be several advantages of using video-recording for self-reflections on group teaching. Table 2 summarises features of those children who appeared in teacher-facilitator conversations (i.e., dialogues) in this report.

Table 2: Children Who Featured in Teacher-Facilitator Dialogues

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Gender</th>
<th>ASD/other Diagnosis</th>
<th>Class</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aiko</td>
<td>F</td>
<td>ASD</td>
<td>SNEU1</td>
<td>1</td>
</tr>
<tr>
<td>Bunta</td>
<td>M</td>
<td>ASD</td>
<td>SNEU1</td>
<td>2</td>
</tr>
<tr>
<td>Chiaki</td>
<td>M</td>
<td>ASD</td>
<td>SNEU2</td>
<td>4</td>
</tr>
<tr>
<td>Daichi</td>
<td>M</td>
<td>ASD</td>
<td>SNEU2</td>
<td>4</td>
</tr>
<tr>
<td>Eiji</td>
<td>M</td>
<td>ASD</td>
<td>SNEU3</td>
<td>6</td>
</tr>
<tr>
<td>Fuji</td>
<td>M</td>
<td>ASD</td>
<td>SNEU3</td>
<td>6</td>
</tr>
<tr>
<td>Haru</td>
<td>F</td>
<td>-</td>
<td>SNEU1</td>
<td>1</td>
</tr>
<tr>
<td>Osamu</td>
<td>M</td>
<td>Down’s syndrome</td>
<td>SNEU3</td>
<td>5</td>
</tr>
</tbody>
</table>

Overcoming Abstraction in Japanese Expression
They used the broad term, *bamen*, or “scene”, to describe the moment of a lesson as part of a whole situation. They used this term to articulate what is happening at this moment in the lesson—all interactions, events, and interpretations of children’s inner engagement (i.e., thoughts). Dialogue 1 shows that Mr Banba talked about how he fostered “a sense of
group belonging” in the children of his class. He set up a lesson scene within which the children become aware of peers’ presence and are encouraged to interact, to help them during the lesson. More specifically, he employed a video letter from a chef (i.e., a SNEU head pretending to be a chef) to create a playful and exciting opening for the group lesson. His reflection indicates that one child with ASDs, Chiaki, became more active in taking initiative to lead the class after watching the video letter.

Lesson Preparation
The VCs helped the teachers articulate what they had prepared for the lesson and how they wanted to approach the children during the lesson. For example, Mr Banba explained why and how he developed a learning tool (i.e., cooking bowl) for one child with ASDs (Daichi), who found it hard to turn a bowl to transfer cake paste from his individual bowl to his group container. Dialogue 2 indicated that Mr Banba attempted several times to develop the cooking tool (i.e., putting handles on an individual bowl to prompt a better angle for the child to twist his wrist), which enabled Daichi to complete the task independently.

Similarly, Ms Chiba changed an arrangement of learning procedures (Dialogue 3): The children completed a certain amount of their tasks by themselves first before they were required to wait for their peers to finish the tasks. These children used to complete the activity step by step as a group. Therefore, they were required to wait for their peers at every step, and this procedure frustrated a child with ASDs (Eiji), who was able to complete these tasks quickly. It also had a negative impact on peer relationships between this child and another child (Osamu), who required more time to complete the same amount of work. The VCs helped Ms Chiba verbalise her intention of making this arrangement as she aimed to perform the activity as a whole group.

Lesson Delivery
Conversations about the event shown in the VCs also confirmed that the Japanese teachers made ongoing assessment of the children’s interactions and perspectives and of the teachers’ own actions. The conversations, although they appeared very casual, involved much professional judgements and thoughts. In particular, the teacher of younger children (Ms Ando) made ongoing assessment of children’s reactions to her interactions to gain better understandings of the children and also to develop further lesson planning. The following examples demonstrated why the teacher took the action as part of her instructions and how she viewed the moment through her own critical reflection.

In Dialogue 4, one VC showed classroom interactions between Ms Ando and the children of SNEU1: After Ms Ando entered the house, which the children made with jumbo blocks, she “accidentally” broke it down, which was her intention to create a collaborative bumen. After her action, the children complained to the teacher about what she had done. Ms Ando viewed the scene of the VC as a failure of her intention. She suggested that she should have made the bumen clearer to the children by being meaner to them so that these children would take actions collaboratively (e.g., protest) against her.

Moreover, Dialogue 5 indicated that a simple conversation between the teacher and the children, which seemed to be casual chat with no particular intention, involved teacher
intentionality. Showing the classroom interaction in a VC opened a dialogic space in which Ms Ando articulated her professional thoughts. In the VC, Ms Ando had a conversation with the children about the play in which they were engaging. She simply asked the children what they wanted to name this playing activity as part of her lesson planning process with the children. Similarly, Dialogue 6 showed that Ms Ando tried to understand the children’s perspective on what they want to do through interactions during playing together. In the VC, the children built a cubic house with jumbo blocks and played inside the house. She asked the children whose house it is, and one child with ASDs, Aiko, answered that it is for SNEU1. Ms Ando explained how she viewed the children’s responses. That is, she tried to extract the children’s story from their responses to understand a lesson from the children’s point of view. These dialogues illustrated the process of sharing the same image of the bamen with the children as part of developing a lesson.

Furthermore, Ms Ando’s reflection on classroom interactions within one VC showed how she made a professional judgement quickly on the critical moment during the lesson (Dialogue 7). In the VC, while the SNEU children played, one enemy, Sandman, visited to their lesson (Note. Sandman had visited their lessons several times before this lesson and behaved badly to the children). The children engaged in a group activity to defeat Sandman collaboratively as part of their routine and waited for him to run away. However, Sandman stayed in the room, cried, and revealed that he wanted to play with the children. As planned, Ms Ando asked the children what they wanted to do with Sandman when he said that he wanted to play with them. Some children said that they did not want to play with him, but one girl said that she would play with him. After Ms Ando praised the girl, the rest of children also agreed to forgive Sandman. Ms Ando’s reflection on this VC revealed how she planned this interaction ahead, why she planned it, what she did, and how she viewed the actual interacting moment (see also, Kikkawa & Bryer, 2012b). Her dialogue articulated that she planned the lesson with the hope that the lesson experience would become a model case of how to respond to a similar situation when the children encountered real-life trouble (i.e., forgiving a friend who was very mean to them but said “sorry”).

Likewise, the teachers assessed critical moments during the lesson to find for the best opportunity for creating a moment of making group effort (Mr Banba) and for using one child’s mistake as a group learning opportunity (Ms Chiba). For example, one VC of Ms Chiba showed that Osamu dropped his egg on the floor while other children were observing. Then, Ms Chiba asked the children what they should do now. Ms Chiba’s reflection on this VC indicated that she chose her action to encourage the child to solve the problem by himself as well as to facilitate other children to help the child (Dialogue 8).

**Post-lesson Evaluation**

Teachers’ reflections on VCs also revealed improvements made after the lesson. The teachers often made adjustments for their lessons (e.g., adding further individual support, rearranging learning environments) after the lessons were observed earlier in the week. Dialogue 9, for example, indicated a sequence of lesson experiences for the children and ongoing process of improving a lesson across the unit. Ms Chiba progressively added or
modified learning procedures, tools, and environments so that the children were able to feel self-satisfaction in each lesson.

**Advantages of Using Video-Recording for Group Teaching**

Use of this VC method had benefits for the teachers watching their own teaching. For example, Ms Ando noticed that she did not realise that one child with ASDs (Bunta) was wandering around other children playing together when she was delivering the lesson (*Dialogue 10*). She interpreted his wandering behaviour as him wanting to play with them but not knowing how to join his peers. Similarly, Ms Chiba found that one child with ASDs (Fuji) was not fully involved in the class, although he stayed “somehow” close to everyone during the lesson (*Dialogue 11*). These examples indicated the typical problem of group teaching in that one teacher does not see all that is happening in the classroom during the lesson. Yet, at the same time, the teachers spoke about the usefulness of watching videos of their own lessons for group teaching (viz., better understandings of children and improvements in their instructions).

**Discussion, Implications, and Conclusion**

This video-clip method of asking Japanese special educators to talk about examples of their practice was helpful in revealing culturally embedding practices. They talked freely about what happened in specific teaching moments and commented on their thoughts and professional judgements made before, during, and after a lesson. These reflections revealed the embedding of lesson study process in how they view their practice. That is, these teachers engaged in ongoing assessment of the featured lesson across the whole unit and in immediate assessment of children’s learning at specific moments within a lesson. Professional judgements were ongoing and dynamic during the lesson. Although classroom interactions did not appear to show much movement, the teachers carefully observed every moment and chose the best strategy for facilitating children’s learning (e.g., waiting patiently for children to show initiative and take actions that help friends). Their high engagement in creating a “good” lesson revealed the Japanese cultural emphasis on teachers’ role: Lesson is also special education teachers’ profession (Ôta, 2005).

Moreover, audiovisual examples of their own teaching provided these teachers with a concrete focus when they talked about classroom interactions and helped them articulate their practice. These examples helped the teachers and the facilitator to share the same “scene” or moment of the lesson, and they were able to refer to specific events or interactions. This cognitive sharing between the teachers and facilitator created a dialogic space to reveal culturally specific practices from the participating teachers’ point of view. Additionally, videorecording a lesson confirmed the dynamic nature of social interactions during classroom lessons (Ball & Forzani, 2007), revealed practical difficulties in missed opportunities when teaching children with ASDs in a group, and helped these teachers to plan and evaluate teaching children in a group.

The Japanese teachers were highly engaged in visualising their ideal lesson and using ongoing assessment of their own teaching when delivering a lesson. That is, they were translating theory into practice or translating ideal into reality. The apparently indirect and vague ways of expressing their practice were part of their process of creating a “good”
lesson: They looked at their own teaching critically and questioned what they could improve for the next lesson. Because there was no one definition of a good lesson, these teachers were required to inquire about their ideal practice for their own classes. This method of using video-recording examples from their own teaching helped the teachers express their personal thoughts or tacit knowledge in their own words; therefore, culturally specific ways of teaching children with ASDs became explicit to the facilitator.

References


Development and Application of STEAM program for Technology Teachers in Korean Elementary and Middle Schools

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Sang-Ho Woo
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Korea National University of Education, Cheongwon, Chungbuk

The Korean Ministry of Education, Science and Technology introduced the STEAM education policy starting 2011 for strengthening primary and secondary school education. Though a STEM education policy is in effect in the U.S., Korea is pushing for STEAM by merging Arts with STEM education. The aim of STEAM education is to enhance integrated thinking in primary and secondary education students on science and technology, humanities and art spheres by educating them in a combination of science, technology, engineering, arts and math. This study is intended to research and develop a STEAM program available to middle school classroom technology teachers. To that end, the authors developed the STEAM program for technology teachers under grants from the Korea Foundation for the Advancement of Science and Creativity (KOFAC) from January through May 2012. And, 32 people consisting of professors and teachers in the fields of technology, science, engineering, arts and math participated in this research to develop the program. The developed STEAM program consists of 12 themes in all and the whole program was composed of 5 areas of class summary, lesson plan, teaching and learning material, worksheet, and teacher’s material. The developed program was applied on a trial basis to technology class for the 1st grader of middle school to analyze its effects.

Introduction
STEAM education is fusion education that integrates and teaches the subjects and contents of science, technology, engineering, art and mathematics, and enhances students’ interests and level of understanding of science and technology and their creative problem solving skills (Kim, J 2012). Korea’s Ministry of Education, Science and Technology proposed a policy for expanding STEAM education in a 2012 operational report. One of the foundations for energising STEAM education is the development of diverse STEAM programs. The Korea Foundation for the Advancement of Science and Creativity is conducting diverse programs to develop and distribute various STEAM programs. Such projects include the operation of a STEAM leader school, STEAM teacher research society support, STEAM R&E support, operation of a STEAM training program for teachers, and development of diverse STEAM class models and programs. Among them, a STEAM program development project was conducted for 4 months starting from February of 2012 at the Korea National University of Education. Kim (2012) subdivided and categorized the linked (multi-academic integration) integration model, and named it STEAM education, which utilized the subject of technology as the base subject of the
integration, as T-STEAM. This study aims to develop a making activity oriented T-STEAM program that can be utilized in an actual technology class.

Research Method
For the development of a T-STEAM program, 32 professors and in-service teachers related to STEAM subjects conducted 7 conferences based on STEAM-related literatures. Steps of the program developments were based on the PDEE model (preparation, development, execution, evaluation) by Kim (2011a), and the composition of the STEAM program was based on 4 stages of situation proposals and 4 stages of creative designs. As for the type of integration, Multi-academic (X1), middle school (Y2) and activity-oriented cubics were selected from the STEAM cubic model and utilized as the standard of the program development that can cultivate creativity. Among developed programs, 3 of 6th grade elementary school programs and 3 of 1st year middle school programs were applied in actual technology classes. Then, the effects on the domains of sensible experience, creative design, content fusion and class satisfaction were analyzed by using the paired sample t-test with pre and post surveys that consisted of 20 of five-point Likert scales questions.

Results
There is a total of 6 T-STEAM programs developed for an elementary school, including 1 for the first, 1 for the second and 1 for the third time per each grade level. and a total of 12 T-STEAM programs for a middle school, including 1 for the first, 2 for the second and 1 for the third time per each grade level. Details are shown in Table 1. For all programs, the stream of times of the latest technology was reflected and topics that teach about cutting-edge technologies were selected.
<table>
<thead>
<tr>
<th>Grades</th>
<th>Unit</th>
<th>Hours</th>
<th>Topics</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th grade elementary</td>
<td>2. Living with plants</td>
<td>2</td>
<td>Green curtain by the classroom window</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Pleasant living environment</td>
<td>1</td>
<td>Inventing one and only cleaning tools</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Wooden goods in life</td>
<td>3</td>
<td>Putting arts on trees!</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Internet and information</td>
<td>3</td>
<td>Beautiful world seen through QR codes</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>3. Work and career</td>
<td>2</td>
<td>Making a future career pin button</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>6. Living with animals</td>
<td>1</td>
<td>Making a siphon timer for a bird cage</td>
<td>*</td>
</tr>
<tr>
<td>1st year middle school</td>
<td>III. Technology development and future society</td>
<td>1</td>
<td>Making a Styrofoam airplane</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Creating creative, traditional windows and doors</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>IV. Technology and invention</td>
<td>2</td>
<td>Designing my own paper cup</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Run! marble relay (Making a rolling ball)</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>IV. Information communication technology</td>
<td>1</td>
<td>Creative SNS application</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Communicating the Morse code with optical fibers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V. Manufacturing technology</td>
<td>2</td>
<td>Making a dry-ice rocket</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Making creative automata</td>
<td></td>
</tr>
<tr>
<td>3rd year middle school</td>
<td>III. Electro Mechanical System</td>
<td>1</td>
<td>Energy-saving LED signs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Making a line tracer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV. Construction technology</td>
<td>2</td>
<td>Making a creative crane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V. Life technology</td>
<td>3</td>
<td>DNA recombination with DNA models</td>
<td></td>
</tr>
</tbody>
</table>

* : Applied in a class

Each program was constructed with 5 domains of class introduction, class process plan,
teaching-learning material, activity sheet and teacher data. Diverse teaching and learning materials and activity sheets were suggested by reflecting STEAM elements that are related to learning subjects, so that teachers who utilize them in an actual class can selectively reconstruct and utilize necessary contents. Detailed components of each domain are shown in Table 2.

Table 2 T-STEAM program’s components by domain

<table>
<thead>
<tr>
<th>Domain</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>class introduction</td>
<td>Technology textbook content introduction, content summary, class flow diagram, class sequence</td>
</tr>
<tr>
<td>class process plan</td>
<td>Class process plan by sequence</td>
</tr>
<tr>
<td>teaching-learning material</td>
<td>Contents to be learned and taught, cutting-edge engineering, reference data</td>
</tr>
<tr>
<td>activity sheet</td>
<td>Activity instruction, activity stage, activity content</td>
</tr>
<tr>
<td>teacher data</td>
<td>Activity sheet example, production process, evaluation</td>
</tr>
</tbody>
</table>

Parts of 18 developed T-STEAM programs were applied in an actual class. Three of 6th grade elementary school programs were conducted 6 times from April 25th to May 9th. Three of 1st year middle school programs were applied in classes over the period of 2 weeks, from May 14th to 23rd. Surveys were conducted after applying them in a class, and the average value generally increased in the domains of sensible experience, content fusion, creative design and class satisfaction. In particular, the biggest changes were observed in the domain of creative design for both elementary and middle schools, followed by class satisfaction, sensible experience and content fusion. Also, problems of the program were confirmed and improved by collecting responses from STEAM class learners through open-ended questions.

Conclusion

Developed T-STEAM programs were able to achieve the goals of STEAM education and applicable in actual classes. Effects were analyzed by applying programs in actual classes, and significant results were generally observed in the domains of sensible experience, creative design and class satisfaction. For an elementary school, significant results were not obtained at the .05 significance level for the domain of content fusion. This can be interpreted as learners judging that diverse learning materials based on the linkage of learning materials among subjects increased the burden of learning. In case of a middle school, developed programs were applied in flexible, small-scale schools due to the issues of a short research period and fixed education curriculum operation. Since the research subjects were set to 10 persons and it is difficult to generalize the conclusion, there is a need to analyze the effects by applying them to other groups in a future. Also, the effects of the STEAM program were verified by conducting pre and post surveys on a collective
group, but future studies that analyze class effects between a class that utilizes the STEAM program and existing technology class through experimental treatments are necessary.

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Trends and challenges in technology and innovation in Kenya: an analysis of final year students’ projects

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Projects as a tool for teaching and training have been used in many places and circumstances with great success. It enhances the teamwork skills and cooperative learning strategies besides promoting problem solving abilities. This paper analyses a range of students’ projects with a view of outlining the major challenges and trends in technology and innovation. It analyses the scope and depth of the skills that have been incorporated in the projects by the students. Within the analyses, main technological advances and appropriations both observed and inferred within the statement of the problem and the objectives of the projects are outlined with a view of proposing the main trends in technology and innovation. The study analyses a list of 85 students’ projects done within the last five years in the department of technology education. The study recommends that the leads offered within the projects are indicators of the direction and technological demands of the areas that the projects are designed to operate. It is observed that although there is information technology and innovation explosion, the needs of the Kenyan society still anchor on the achieving of the basic needs of power, cheap power, security, basic manual handling machines, clean water, modern housing in addition to refining and processing of farm outputs.

Introduction

We cannot forget that teaching students is our foremost responsibility; and, as teachers, we must provide the best possible method by which students can learn. Today as in the past, projects provide students with a product to take home, something to show for their hard work, something that means more than a letter grade on a piece of paper (Howell, 2003 p.7). Projects based learning is one of the leading models in technology education, with projects aimed at developing higher levels of cognitive skills, creativity, teamwork abilities, self discipline and responsibility (Barak, 2004). It promotes the independence in knowledge creation; understanding and holistic thinking which are on demand at the workplace. There is need that workers should be able to deal with complex problems. Grabinger, (1996) reports that many public and private institutions believe that there is a growing need for employees who are able to think creatively and solve a wide range of problems. This has been created by the changes at the workplace (Middleton, 2003). Utilizing the project method of teaching in technology education is not a new development. Technology Education teachers have been using projects as a means of teaching technical skills, tool usage, and problem solving since the very beginning of the profession (Barak, 2004). The project method also provides an excellent means for increasing student learning and retention (Howell & Mordini, 2003). The project method is a teacher-facilitated collaborative approach in which students acquire and apply knowledge and skills to define and solve realistic problems using a process of extended inquiry. Projects are student-centred, following standards, parameters, and milestones clearly identified by the
instructor. Students have control over the planning, refining, presenting, and reflecting of the project. Through projects, students are engaged in innovation and creativity (Project Lead the Way, 2003).

The ability to provide creative solutions to complex problems is also seen to be increasingly important in many occupations (Yashin-shaw, 2003). Besides, use of projects promotes the acquisition of generic and employability skills whose importance for Technology Education (TED) programs cannot be overemphasized. On this issue, Kearns (2001) states:

Fostering generic skills requires active learning strategies in which learners take responsibility for their own learning so that they develop the attitudes, habits and skills of motivated lifelong learners and the acquisition of generic skills becomes a lifelong process. There are many examples of good practice…of the use of strategies such as action learning, situated learning and project-based learning (p.3).

In addition there are many benefits to encouraging teamwork in learning which is also called cooperative learning. This paper analyses student’s final year projects with a view of documenting the direction and issues that the technological problems being solved present. Through this paper, advantages of using projects as a means of teaching and enhancing creativity as well as problem solving skills are highlighted. The paper specifically highlights some of the advantages of cooperative learning that may be applicable to technology education.

Objectives
There is a wide consensus that one of the major goals of technology education is to develop learner’s creativity thinking abilities for problem solving and design (Barak, 2004). Problem solving skills are captured well in the list of main employability skills. There Fostering creative thinking is especially important in a rapidly changing society where generating innovative products and services is essential for the survival in many industries and business.

The ability to solve problems is an important attribute in most contemporary workplaces (Middleton, 2003). The kinds of problems vary with the work and workplace circumstances. Problem solving involves both divergent and convergent thinking. Divergent thinking is generative, moves in many directions, can make jumps, lives well with uncertainty, seeks richness, and need not be right at every step (Barak, 2004). Convergent thinking on the other hand is selective, sequential, moves forward along a prescribed path, and seeks the right answer. Creativity is associated mostly with the former. Creative problem solving is an integral part of technology education, in contrast to an instruction-following method of technology education, reproducing artifacts, and teacher-dominated work (Lavonen, Autio & Meisalo, 2004).

Justification of the study
This study was undertaken with a view to establishing a technology education training road map based on the present and inferred future challenges and issues in technology in Kenya. All teaching programs and learning programs should borrow the foundation from the past and focus on the needs in future. When planning a project for current technology-
related classes, the teacher must understand what is required of today's industry and technology. Howell (2001) wrote that students would be better served by building programs around project design. The project method of teaching should promote critical thinking; encourage divergent thinking and multiple solutions; engage students in real-world challenges; encourage student ownership, direction, and management of resources; and provide opportunities for teamwork and encourage collaboration (Project Lead the Way, 2003). Howell (2001) went on to say that the best way to teach team skills is through the project method. Working on a project is an excellent way for the students to learn what it takes to an effective member of a team.

Perspective
Schultz (1999) noted that the project method of teaching increases students' thinking and problem-solving abilities. Students working on projects also develop reflective thought processes and a sequence of order while working on a project. This reflective thought process requires students to determine the appropriate outcome. Each outcome, in turn, refers to its predecessors (Farra, 1998). John Dewey studied the reflective thought process and how it ties in with the project. He indicated that reflective thought helps students perceive the problem and its resolution. Dewey suggested that reflective thought provides students with a method to pattern an ability to improve their skill in thoughtful decision-making, and encourages others to sharpen the quality of their decisions and skills (Farra, 1998).

Creativity is the ability to produce work that is both novel and appropriate. The attributes of novelty are originality, unexpectedness and imaginative. The attributes of appropriateness are usefulness, adaptiveness and task constraints' reduction (Barak, 2004). Projects encourage creativity and give the student a sense of accomplishment, pride, and self-worth. Above all, an interested student is a motivated student; and a motivated student strives to do the best possible job. Projects do not promote a single answer, limit student participation, suppress collaboration, or discourage application of new contexts (Project Lead the Way, 2003).

Methods of data collection
No single source of information is trusted to provide a comprehensive perspective in any study program. Patton (2002) comments that using a combination of data sources and methods of collection operate as a validating aspect for cross checking the data. The use of combined data sources such as interviews, observations and document analyses increases the validity since the strength of one approach compensates for the weakness of another approach (Denzin & Lincoln, 2003; Patton, 2002). This is triangulation which makes the collected data stand strong against the queries of authenticity, reliability and credibility. For this paper, data was collected using observation and analysis of the real project and document analysis of the final year projects reports. A total of 85 projects were analysed. For each project, the title and the key objectives were evaluated in line with the general technological challenge being addressed.
Summary of Findings
The analysis of the projects revealed the following focal challenges that were being addressed: Provision of affordable electrical power, electrical power management systems with particular emphasis on conversion from DC to Ac and reverse, security devices such as anti-burglar doors systems, Design and structural analysis of buildings to be used for university and other educational institutions, automatic control devices such as rain water level management devices, automatic vehicles headlamps dipper, traffic control lights, reading assistance and facilitation devices, potato peeling machines, cleaning and sanitation machines, Security alarms, Computerised marks Retrieval system, Solar tracking systems, bar soap extruder and processing, and fire management control systems. All the projects had been worked on by teams of final year students from the Mechanical and Power Mechanics Technology (MPT), Electrical and Electronics (ELT), and Building and Construction Technology (BCT) areas of specialisation.

Lessons developed from the findings

1) Teamwork:
Majority of the analysed projects were carried out by teams of students working together in conjunction with a faculty member. This promoted the aspect of team work in achieving particular problems. By working in teams, the members were expected to share a common understanding of the problem at hand and this is a simulation of the society in general. Teamwork as a strategy for solving education and training problems helps to build higher-level cognitive skills as well as interpersonal skills. Examples of these interpersonal skills are getting to know and trust team members; communicating effectively and clearly; providing support and challenging fellow team members; and engaging in constructive conflict resolution. In addition, these social skills may help students to acquire a sense of social responsibility.

The teamwork strategy problem solving may be handy in promoting cohesiveness in multiracial societies. This is supported by findings by Pate cited in Divaharan and Atputhasamy (2002) that people of different ethnic backgrounds, working together on a task, problem or goal; develop positive feelings as well as mutual respect for each other. In the long run, this could serve to promote positive feelings and better understanding among the students from different ethnic groups. Researches in cooperative learning advance the claim that the experience of being in a cooperative group also gives rise to a feeling of having achieved success, which in turn enhances self esteem. Students thus look forward to coming to school and meeting their group. This positive feeling towards school is present among students involved in a cooperative group as compared to others who are not involved in a cooperative learning experience. Students learning cooperatively become active learners who want to contribute and discuss ideas with teachers. Finally it is claimed that students in a cooperative group engage in higher-order thinking because they need to reorganize their thoughts and explain concepts to the other team members (Divaharan & Atputhasamy, 2002). Cooperation is the key to successful discussions and group work. Cooperative learning should be infused in all subjects because of the role that it plays in all of life's experiences. Students will learn important life skills by working together and collaborating their ideas.

The following are eight characteristics of effective teams that were identified by Larson
and LaFasto (1989).

i. **The team must have a clear goal.** Team goals should call for a specific performance objective, expressed so concisely that everyone knows when the objective has been met.

ii. **The team must have a results-driven structure.** The team should be allowed to operate in a manner that produces results. It is often best to allow the team to develop the structure.

iii. **The team must have competent team members.** In the education setting this can be taken to mean that the problem given to the team should be one that the members can tackle given their level of knowledge.

iv. **The team must have unified commitment.** This doesn’t mean that team members must agree on everything. It means that all individuals must be directing their efforts towards the goal. If an individual’s effort is going purely towards personal goals, then the team will confront this and resolve the problem.

v. **The team must have a collaborative climate.** It is a climate of trust produced by honest, open, consistent and respectful behavior. With this climate teams perform well...without it, they fail.

vi. **The team must have high standards that are understood by all.** Team members must know what is expected of them individually and collectively.

vii. **The team must receive external support and encouragement.** Encouragement and praise works just as well in motivating teams as it does with individuals.

viii. **The team must have principled leadership.** Teams usually need someone to lead the effort. Team members must know that the team leader has the position because they have good leadership skills and are working for the good of the team.

As observed from the projects, these virtues were promoted through the work done by the technology education students.

**Cooperative learning**

Cooperative learning is instruction that involves students working in teams to accomplish a common goal, under conditions that include the following elements (Johnson, Johnson, and Smith, 1991): Effective cooperative learning should embrace the following attributes as outlined by Johnson et al (1991):

i. **Positive interdependence.** Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone suffers consequences.

ii. **Individual accountability.** All students in a group are held accountable for doing their share of the work and for mastery of all of the material to be learned.

iii. **Face-to-face promotive interaction.** Although some of the group work may be parcelled out and done individually, some must be done interactively, with group members providing one another with feedback, challenging one another's conclusions and reasoning, and perhaps most importantly, teaching and encouraging one another.
iv. **Appropriate use of collaborative skills.** Students are encouraged and helped to develop and practice trust-building, leadership, decision-making, communication, and conflict management skills.

v. **Group processing.** Team members set group goals, periodically assess what they are doing well as a team, and identify changes they will make to function more effectively in the future.

B) **Trends in technology**

From the analyzed projects, the following were the major areas of concerns that the project work was able to deal with from the training point of view:

i) **Generic skills development**

Generic skills are important because jobs today require flexibility, initiative and the ability to undertake many different tasks. They are not as narrowly prescribed and defined as in the past and generally they are more service oriented, making information and social skills increasingly important. Employers now focus on adaptation, cost reduction, increased productivity, and new markets, products and services. Employees need to demonstrate teamwork, problem-solving, and the capacity to deal with non-routine processes. They should also be able to make decisions, take responsibility and communicate effectively.

ii) **Applications of various courses learnt**

In order to accomplish the projects, the learners were expected to apply the design and analysis skills that they learnt in other courses of their program. For example, for complete mechanical projects, the learners were expected to apply knowledge in solid mechanics, kinematics and kinetics of machines, welding, soldering, brazing and fabrications technology, applied mathematics, thermodynamics, fluid mechanics and general communication skills.

iii) **General technology applications**

It is observed that although there is information technology and innovation explosion, the needs of the Kenyan society still anchor on the achieving of the basic needs of power cheap power, security, basic manual handling machines, clean water, modern housing in addition to refining and processing of farm outputs.

iv) **Innovations in technology**

It was noted that most of the projects were dealing with the challenges facing the rural populations of the country where the availability of electrical power is a challenge. This was viewed in relation to the tasks that must be done such as the processing of farm inputs, security of the people and their property, and creation of time saving situations for better life.

v) **Facilitation of reflection**

It was observed that after carrying out the project, the learners were able to reflect through the process of design, fabrication, testing and the working principles. This promoted deep learning that is more transformational. Hatton and Smith (1995) identified four essential issues concerning reflection: First is that there is a need for learning to frame and reframe complex or ambiguous problems, test out various interpretations, and then modify actions consequently. Second, thoughts should be extended and systematic by looking back upon actions sometime after they have taken place. Third, certain activities labeled as reflective, such as the use of journals or group discussions following practical experiences, are often
not directed towards the solution of specific problems. Fourth there should consciously account for the wider historic, cultural, and political values or beliefs in framing practical problems to arrive at a solution. This is often identified as critical reflection. All these aspects of reflection were found within the analysis of the projects.

vi) Peer and self-assessment
In addition to reflection, there was the aspect of self and peer assessment. This occurs where students want to know how well they are doing. Self- and peer-assessment enable those actively involved in the learning process to provide valuable feedback on student work and complement the comments made by university supervisors and evaluators. Engaging students in self- and peer-assessment helps them to appreciate quality work and to develop evaluative skills. It gives learners time to engage in a process of dialogue about what constitutes quality and to monitor their own progress. In line with this arguments Boud (1995) maintains: that if students mark their own work, either with respect to specified standards or their self-established criteria, they not only release staff for educationally worthwhile activities, but they are encouraged to reflect on their own work and the standards which can be applied to it. This happened to a greater extend in the projects analyzed.

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Evaluation of the Moi University’s Master’s Program in Technology Education

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This paper is based on an evaluation study that was funded by the international Vocational education and Training association. It was an evaluation report of the master’s program in Technology Education offered in Kenya. It is the only program for technology education teachers and educators in Kenya and in the region at the masters’ level. The department of Technology Education of Moi University in Kenya has produced Postgraduate Technology educationists, teachers and researchers for the Kenyan and regional market. The Master of Philosophy program has not been evaluated to assess its suitability and ability to meet the needs of the market since its inception in the year 2000. Thus, it was worthwhile to establish the status of the departmental achievements in relation to the stated objectives, needs of the society, future demands of the market and possible department’s response strategies to meet the future challenges. The findings of this research open a pathway for the revision of the program to make it more responsive to the needs of the global world of work. Besides, others who may be planning a program evaluation may borrow a leaf. This evaluation is premised on the fact that there is a need for training programs to be more responsive to the demands of the contemporary society and the workplace. It also proposes that a more generic approach to skill training should be adopted to facilitate transfer of learned competencies to similar situations.

BACKGROUND AND RATIONALE FOR THE STUDY

The twenty-first century demonstrates a radical shift from industrial societies to information or knowledge societies, where advances in Information and Communication Technologies (ICTs) are rapid and shape economic and social development. Globalization has changed the economic structures and the world of work. The teaching and training programs in Technical Vocational Education and Training (TVET) thus must work towards dealing with and actualizing these realities. Technical Vocational Education and Training has to consider the new demands and must provide appropriate and constantly updated training concepts.

Kenya is located in the Eastern part of Africa, bordering the Indian Ocean, between Somalia, Tanzania, Uganda, Ethiopia and Sudan. The current population of Kenya is about 40 million people. Various education commissions have been advanced in Kenya since independence in 1963. Examples are these commissions are the Ominde of 1964, the Gachathi of 1976, the Mackay of 1981, Kamunge of 1988 and the Koech of 1999. This has partly due to the emphasis the government and the people of Kenya have given to education and partly due to the way education has failed to respond to the various national needs from time to time (Eshiwani, 1990; Abagi and Olweya, 1999). Education is considered as a basic human right and a basic need in significant part of the world, Kenya included.

The report on the Presidential Working Party on the establishment of a second University, Mackay (1981) recommended that Moi University should be more technologically oriented than other universities. This recommendation was aimed at
increasing the numbers of scientists and engineers with the aim of accelerating the level of industrial development of the Kenyan economy. The technological basis for the university led to the establishment of the Department of Technology Education in 1989. It was aimed at training technical and technological teachers currently falling under Technical and Vocational Education and Training (TVET) in a broad spectrum of fields. According to most contemporary accounts, TVET is aligned directly to learning for work and includes training for specific job roles. In Kenya and at higher levels, TVET teacher training is offered within the Technology Education department of Moi University, the only program in Africa with TVET at the masters' level.

The Department of Technology Education in the School of Education at Moi University was started in September 1989. The first cohort of students was admitted in the 1989/90 academic year at the Moi University's main campus. The Technology Education program at the undergraduate level was started with the following objectives:

i) To prepare teachers who will be able to teach the 8:4:4 secondary and post secondary level technical group of subjects.

ii) To improve the quality of teaching of the technical subjects in the 8:4:4 system of education.

iii) To prepare teachers in technical education for training institutions where such level of competence may be needed.

The areas of specialization offered by the department are Power Mechanics Technology (Automotive Technology) (PMT), Electrical Technology (ELT), Construction Technology (BCT) and Metal Technology or Mechanical Technology (MET. The department of Technology Education offers a Master of Philosophy (M.Phil) degree in Technology Education by coursework and thesis. The program is designed to produce high level personnel to meet the needs of industry, government departments, research and training institutions. It offers enough flexibility for students to specialize in field related aspects of Technology Education. The main areas offered now are Mechanical Technology, Electrical and Electronics Technology and Building and Construction Technology.

The Technology Education program at the Master of philosophy level has the following objectives:

i) To provide teachers and trainers of technology with advanced training.

ii) To train researchers and evaluators for the field of Technology Education.

iii) To provide advanced training for personnel who will work as planners, administrators and policymakers in Technology education

Need for Evaluation

Stevenson (1994) has argued that course design in TVET is based on three principles. These are relevance, responsiveness and uniqueness. Firstly, TVET courses are considered to be relevant in the sense that they are based on current work-related requirements identified and agreed by employers. As the buyers of labour in labour market transactions, employers are one of the main stakeholders in TVET and have certainly increased their influence in marketised national TVET systems. For this reason, TVET courses set out with the primary aim of developing the skills, knowledge and attitudes that employers
deem to have value, and which they are prepared to purchase and reward through wages remuneration. In this regard, TVET programs impart 'market-driven knowledge' or 'valuable' knowledge.

Secondly, TVET is said to be responsive in the sense that it addresses the current skills and knowledge 'demands' of the market. The relevance and responsiveness of TVET courses give them utility. Stevenson's third principle of uniqueness is not as true today as it was a decade ago. In fact, TVET has spilled over into all the other sectors of post-compulsory education, with even universities offering some niche market TVET programs and more vocationally-oriented degree programs. It is also true to say that it is unique for another reason: no other sector of education systematically hands important determinations about curriculum and pedagogy to employers and corporate interests.

The teaching and programs in Technical Vocational Education and Training (TVET) thus must work towards dealing with and actualizing these realities. Technical Vocational Education and Training has to consider the new demands and must provide appropriate and constantly updated training concepts. The typical job roles of a TVET teacher include development of teaching/learning experiences, resources and assessment tasks for the TVET workshop, classroom, laboratory and workplace. Many teachers have actual work experience in the occupational and industry areas in which they teach. In turn they attempt to convey aspects of these first hand experiences to the learners in their programs. In fact, a TVET teacher's base qualification is usually in the area in which s/he teaches, rather than in education or teaching. TVET teachers are also involved in program planning, research, industry and employer liaison, marketing, professional development of others, and institute and system-wide research and development projects.

In most nations, education is increasingly viewed as a primary means for solving social problems (Worthen and Sanders, 1987). Also evaluation in education and training is not a new concept. It implies the determination of the worth and value of an education and training innovation. It is the assessment of the extent to which specific objectives have been attained. It is also the determination of the quality, effectiveness or value of the program, product, project, process, objective or curriculum. Evaluation is the process of making a judgment about the quality of student learning (Gabler and Schroeder, 2003). A precise definition of program evaluation was offered by Patton (2002:10) that program evaluation is the systematic collection of information about the activities, characteristics and outcomes of programs to make judgments about the programs improve program effectiveness and/or inform decisions about future programming.

Formal evaluation studies have played many roles in education and training including the following:
  i) To provide a basis for decision making and policy formulation
  ii) To assess student achievement
  iii) To evaluate curricular
  iv) To accredit schools
  v) To monitor expenditure of public funds
  vi) To improve educational materials and programs (Worthen & Sanders, 1987, p.5)

The third and sixth reasons inform the justification of this present study. The purpose of
evaluation as applied to formal programs are first to contribute to decisions about program modifications, second is to contribute to decisions about program continuation, expansion or certification. Third is to contribute to decisions about program modifications, obtain evidence to rally support for a program or to obtain evidence to rally opposition to a program and finally to contribute to the understanding of basic psychological, social and other processes.

Statement of the problem

One of the main pressures on the determination of content is the changing technology associated with a range of work processes. These technologies vary considerably, but most have a tendency towards renewal. Constant upgrading of technology throughout an industry, even if spasmodic, means that course content, techniques and processes must frequently change. In turn, related TVET programs also need to be adapted. In effect therefore, the curriculum development process in TVET must be able to accommodate constant renewal and upgrading (Achtenhagen & Grubb, 2001). This tendency towards renewal also drives the development of work-based provision of TVET programs. The department of Technology Education of Moi University in Kenya has produced Postgraduate Technology educationists, teachers and researchers for the Kenyan and regional market. The Master of Philosophy (M. Phil) program has been running for more than ten years and it has not been evaluated to assess its suitability and ability to meet the needs of the market. Thus, it was worthwhile to find out the status of the departmental achievements with respect to:

i) The achievement of the stated objectives at its inception.
ii) The needs of society regarding the postgraduate programs offered by the department
iii) The future demands of the market
iv) Possible department’s response strategies to meet the future challenges

It was of prime importance to evaluate the performance of the department in human resource development in order to establish a sound basis for future actions. This was a formative evaluation with a view to improving the program to meet the challenges of preparing teachers and researchers for the Twenty-first Century. The Master of Philosophy in the Department of Technology Education at Moi University was established in the year 2000. The department’s first set of graduates has now been in the field for more than six years. However, no study has so far been carried out to determine the effectiveness of the department’s Master of Philosophy programs. It was prudent that an evaluation be carried out to determine the context in which the graduates must work and the challenges the department must address itself to increase its efficiency.

Additionally this evaluation was important because technology is expected to lead the nation’s effort to industrialization. Technology has a great role to play in the accomplishment of the Kenya’s development strategy by the year 2030 unveiled this year. On TVET, the Vision 2030 states:

Vision 2030 proposes intensified application of science, technology and innovation to raise productivity and efficiency levels across the three pillars. It recognizes the critical role played by research and development (R&D) in accelerating economic development in all the newly
industrializing countries of the world. The Government will create the Science, technology and Innovation (STI) policy framework to support Vision 2030. More resources will be devoted to scientific research, technical capabilities of the workforce, and in raising the quality of teaching mathematics, science and technology in schools, polytechnics and universities (Republic of Kenya, 2007, pg. XI).

Objectives of the study
In order to achieve the evaluation goals, the following project objectives were used. Each objective is outlined alongside activities that were used for its achievement in order for it to be as precise and achievable as possible.

Objective No.1: To establish the position of the departmental achievements in comparison to the goals set at the inception of the department’s Master of philosophy program. This objective entailed the following activities: Activity 1.1: Obtain information related to the objectives of the program. Interview some of the departmental staff members who drafted the program. Activity 1.2: Get information related to the challenges at the workplace. Interview graduates and workplace supervisors on ideal programs that suit work requirements.

Objective No.2: To determine the strong points of the department’s postgraduates to guide future changes in the curriculum. This objective entailed the following activities: Activity 2.1: Determine the strengths of the department as stated by the program graduates. Activity 2.2: Determine the strengths of the department as stated by the program graduates’ employers and/or supervisors. Activity 2.3: Get suggestions of the possible areas that require improvement. Activity 2.4: Get the government’s technological requirements for the VISION 2030.

Objective No.3 To determine weaknesses of the department’s postgraduates to guide future changes in the curriculum. Activity 3.1: Determine the weaknesses of the department as stated by the program graduates. Activity 3.2: Determine the weaknesses of the department as stated by the program graduates’ employers and/or supervisors. Activity 3.3: Get suggestions of the possible ways of improving on the areas the department is weak in.

Study Area and respondents
The study covered the whole of Kenya but with emphasis on the areas where the Technology Education (TED) students were working. The subjects were former TED students in the field and their immediate supervisors. Employers/their representatives were also interviewed.

Sampling Techniques
The technique for sampling used was purposive stratified method. The stratification was based on two aspects. Namely:

a) The course of specialization such as Power Mechanics Technology (PMT), Building and Construction technology (BCT), Electrical and electronics technology (ELT) and Metals/ Mechanical technology (MET).

b) The level at which the graduate is teaching at:
   i) University
ii) National Polytechnic
iii) Institute of Science and Technology
iv) Technical Training Institute
v) Secondary School
vi) Any other

For each area of specialization, at least 5 respondents were contacted in order to participate in the study. The minimum numbers of the respondents were to be twelve, at least three from each of the four areas of specialization but the maximum was to be 20 alongside the key consideration and conditions stated above. The actual response and return rate was 75% and as the updates of the study continued, the percentages increased.

Research Instruments
For the purpose of the study two questionnaires were designed. These were for:
  i) The graduates of the department
  ii) The Heads of Departments, employers and supervisors

The graduates’ questionnaires consisted of questions on the departmental preparation and the level of courses taught. The employers and supervisors were required to comment on the graduates’ performance and preparedness. An interview schedule was designed to facilitate discussion with the respondents. The research instruments were delivered by use of several methods due to the diversity of the locations where the research respondents were found.

Data analysis and interpretation
From the analysis, it was clear that the intake for Master of Philosophy in Technology Education has been increasing, the greatest being in the recent years; 2005 (33.3%) and 2006 (26.7%). Most of the respondents, 60% were first employed as teachers.13.3% were first employed as lecturers. The rest took up other jobs. Different respondents specialized in different technical subjects with electricity registering more respondents (40%). This was followed by Power Mechanics Technology (26.7%). Metal Technology and Building and Construction shared the same percentage (13.3%). The findings showed that 66.7% of the total respondents interviewed teach in Technical Training Institutes, Institutes of Science and Technology, national polytechnics and secondary schools.

All the respondents had undergone training up to Masters level at Moi University. Therefore, it was necessary to find out which courses best prepared the teachers to teach at these levels. It was found that the courses: Advanced Mechanics of Machines; Advanced Solid Mechanics; Engineering Materials and Advanced Fluid Mechanics best prepared lecturers to teach at the degree level. At the Higher Diploma level, the courses: Power Systems Protection, Soil Structure, Thermodynamics, Engineering Materials, Fluid Mechanisms, Solid Mechanism, Mechanisms of Machines and Power System best prepared teachers to teach at this level. At the Diploma level, the courses: Solid State Devices and Integrated Circuits, Soil Structure, Thermodynamics, Engineering Materials, Fluid Mechanisms, Solid Mechanism, Mechanisms of Machines, Microprocessors, Control Systems, Power Systems, Mathematics, Plant Electrical, Estimating and Costing in Construction, Advanced Structural Design, Research Design and Methodology, Computer
Applications and Thesis best prepared teachers to teach.

The respondents were also required to indicate the improvements that would make masters holders in Technology Education to perform better in the subjects. For the degree level where Solid Mechanics was taught, it was found out that there was need for more time, deeper coverage and more practical lessons as envisaged by one respondent. At the Higher Diploma level, Drawing and Design, 20% of the total respondents said that more materials were needed like auto CAD, auto DESK and inventor. In Engineering Mathematics, it was proposed that the course be handled by mathematics lecturers and course content to be deepened. Course content expansion and change to practical approach was recommended for production technology, Solid State Devices and Integrated Circuit, Advanced. In addition, there was a suggestion for theses examinations to be fast. Delays made the candidates to lose opportunities in the world of work.

**Subjects taught that least prepared M. Phil students to teach at higher diploma level**

The main courses mentioned were Filter Signals and Digital processing, Power System Operation and Control, Systems Analysis and Design. The respondents advanced a proposal that there was a need to avail course early enough, introduce more practical lessons and redesigning of the course to be relevant to the world of work. Theoretical approaches were not enough.

**Courses that least prepared Master of Philosophy students to teach at diploma level.**

The main courses that seeming do not prepare the teachers for the diploma level were: Survey, Research Methods, Industrial Engineering, Instructional Methods for technology, Computer applications, Industrial Engineering and Law, Welding technology, Electrical Technology, Advanced surveying, Appropriate technology and construction of structures, Construction management and organisation, Interior design, planning and decoration.

**Positions held by graduates after the Masters in technology education program**

The research found out that the respondents held different positions after going through the M.Phil programme. They were Graduate Technical Teacher, Lecturer, Marketer, Technician, Institutional managers and Business people. As such it can be argued that the course prepared participants towards varied occupations.

**Skills requirements at the place of work**

The main skills required at the workplace were Research and Field work, Preparing schemes of work, lesson plans and teaching, Selling of electrical appliances, Ensuring smooth operation of the department, Buying and selling computer accessories, customer service and decision making.

**Courses learnt that best prepared the M. Phil graduates to carry out their roles**

Suggestions for improvement
The following Suggestions for making the M. Phil Technology Education graduates perform even better were proposed. Blending elements of Public relations and Human resource development, Use of marketing skills, Include AUTOCAD and other modern programs into all the sections courses, Incorporate practical lessons in all the relevant areas, Provide field trips for real world of work experiences and Match course offering to the jobs requirements at different levels

Courses that least prepared M. Phil Technology Education graduates for their roles
The following courses were outlined as being least useful in the preparation of the graduates for their roles at the workplace: Numerical Analysis, Power systems, Thermodynamics, Fluid mechanics, Strength of machines, Industrial organization and law, Industrial Process Engineering, Welding technology, Instructional technology and material, Computer application.

Additional courses recommended for inclusion in the programme
The respondents felt that some additional courses were necessary. These included; Wireless communication, Optical fibers, Interior design, Microwaves, Computer programmes, IT and Computer science, Quantity Survey, Production technology, Production Integrated and Computer aided manufacturing (CAM).

General comments by the respondents
There was need for a general comment from the respondents from which different comments were found. Most respondents 20% thought that there was need for revision and early introduction of courses. Some 13.3% said that there was need for shift from old ways of technical education to modern. One said shortage of resources in the university has a greater effect on the programme, another proposed need to arrange for seminars and industrial visits. Most staff are unqualified or lack experience in their area of teaching as reported by 6.7% of respondents. Research methods courses should be introduced at undergraduate level to prepare students for research studies at M. Phil. Finally there was a need to assist the M. Phil graduates in securing employment opportunities to motivate others to join the programme. It was also suggested that there was a need to reduce the number of courses being examined.

Conclusions and Recommendations
This section concludes by summarizing the key research findings. From the results, the position of the departmental achievements in comparison to the goals set at the inception of the department’s Master of philosophy programme was established. Also established were the strong points of the department’s postgraduates to guide future changes in the curriculum. However, the weaknesses of the department’s postgraduates to guide future changes in the curriculum were strongly considered in stipulating the recommendations based on the research objectives.

From the research findings, the following recommendations will help the department achieve its set goals for which it was established as well as prepare to meet the challenges of the next decade:
i) Thermodynamics, Engineering Materials, Advanced statistics and Fluid mechanics should be given priority at University level because it tends to attract more lecturers and is seen to be more helpful.

ii) The fact that M. Phil in Technology Education has registered so many students of late should be used to strengthen the programme so that more and more students are registered. More resources need to be put into the programme to ensure this.

iii) Technical drawing and Mathematics need to be emphasized in terms of resource allocation and teaching methods since most teachers like the subjects. They are viewed as marketable subjects.

iv) There is need to embrace practical approach in teaching M. Phil in Technology Education programme. The use of industrial trips, Industrial attachments, practical lessons were highly recommended.

v) Some syllabi need to be reviewed like for Soil mechanics and other courses dealing with Timber structures.

vi) Thesis should be examined faster for timely graduation.

vii) Focusing on the improvement towards changing technology today would help improve performance of curriculum development as a course today. There was need to avail course materials early enough, introduction of more practices and redesigning of the course to be relevant to electrical engineering.

viii) Instructional Methods for technology Education, Computer applications, Welding technology, Production Technology, Industrial Engineering and Fluid Mechanics should be taught at the undergraduate level first then advanced at the M. Phil level. Machines mechanism and Thermodynamics course content should be equivalent to B.Sc. in Production Engineering. The research also pointed out that the Foundation of Technology and Research Methods should also to be taught at undergraduate level.

ix) There is need for more practical lessons in the computer applications course.

x) In Industrial process Engineering, more time is needed to increase depth and breadth of coverage.

xi) Some additional courses like Wireless communication, Optical fibres, Interior design, Microwaves, Computer programmes, IT and Computer science, Quantity Survey, Production technology, Production Integrated and Computer Aided manufacturing (CAD) need to be included in the programme because technology is moving to that direction.

References
Exploring the what and why questions in Technology Education Research and Research Training

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This paper examines changes in technology education research and educational research more generally over recent years and the implications for technology education researchers and research training. It does this firstly through an examination of a number of recent developments in research technology. It then argues the case for greater use of combinations of qualitative and quantitative methods to provide more comprehensive and more believable answers to the kinds of questions being posed by educational and research bodies. The paper then describes a postgraduate research methods course that has been incorporating these approaches over the last three years and draws some conclusions about the key features of such courses.

Introduction

Educational research is undergoing significant change, with not only increasing pressures for the delivery of research outcomes on increasingly complex issues but also a greater demand by the users of research for researchers to deliver quality evidence-based research to support future decision making. This change was a central theme of the book on technology education research methods edited by Middleton (2008). Thus, current researchers and the emerging post graduate researcher are entering a very different work environment that calls for greater capacity to do research and greater flexibility and depth in their research skills.

As well as the changes in terms of the demands on research quality, the last thirty years has seen a move away from a dominant focus on quantitative methods using statistical analysis to more widespread use of qualitative methods, that support greater understanding of participants through naturalistic enquiry (Creswell, 2012) with interpretive/hermeneutic approaches advocated (Onwuegbuzie and Leech, 2005). One unfortunate by-product of the change has been the emergence of what might be termed the qualitative/quantitative divide. Salomon identified the problem in a 1991 paper and argued that quantitative and qualitative methods could and should complement each other and that thinking about them as being competitors was unhelpful. Salomon went on to argue that complementary meant more than just being allowed to exist together. Salomon argued that each could both inform and guide the other and in doing so, improve the quality of the research outcomes that result from their complementary use. Salomon argued that a better way to describe methods was to use terms like analytic and systematic and explains:

Our controlled experiments show that computer tools can offer the learner a mode of thinking that can be internalized and hence can provide at least one theoretical and empirically based rationale for their inclusion in the classroom. On the other hand, our systemic research suggests
that the attainment of any worthwhile effects by the inclusion of computers necessitates the redesign of the whole learning environment. It also suggests that once this is done, the relations of attitudes, abilities, activities, perceptions, and social relations with respect to achievement totally change in important and differential ways. No analytic study could have shown that. This, in turn, suggests new questions and new hypotheses, some of which need perhaps to be addressed by analytically oriented studies, or possibly by research that is guided by yet another paradigm. After all, the analytic approach capitalizes on precision while the systemic approach capitalizes on authenticity. But none is particularly good as a basis for generalization. (Salomon, 1991. Page 16)

A contemporary example to illustrate the utility of mixed method approaches is the study by Walmsley (2008). Walmsley wanted to explore the factors that led to classrooms where higher-order thinking was an outcome of the learning process. However, before examining classroom interactions, Walmsley had to be able to identify classrooms where higher-order thinking was being exhibited. Walmsley used a quantitative instrument called the Cognitive Holding Power Questionnaire (Stevenson, 1998). This is a survey that can be administered to whole class groups and provides valid and reliable data on student thinking that can be analysed statistically.

After administering the survey to a range of classes, Walmsley was able to select those classes scoring high on higher-order thinking and then use a qualitative method employing video stimulated recall techniques to establish why these classes were engaging in higher-order thinking. Thus, not only was the research improved by the use of mixed methods, it would not have been possible to undertake it without the combination.

As we are teaching students how to do educational research we must prepare them for the field – and the field is increasingly using mixed methods research. Thus Ivankova & Kawamura (2010) note that from a systematic literature review searching for the use of studies published as “mixed methods” there was an increase from 10 in 2000 to 243 in 2008, with the increase particularly rapid in recent years.

New Technologies
In addition to changes in the demands of those who fund and use educational research there have been changes in the kinds of technologies available to researchers. There are many of these but for the sake of this paper, only three will be used to illustrate the point. These include text-analytics, on-line surveys and video-data.

Text-analytics provide a mechanism through which textual discourse can be transformed into a more formalized structure that can directly aid the determination of valid and reliable conclusions, and also help identify subtle connections that would easily be missed in manual approaches (Edgington, 2011). The market for such products is rapidly expanding with one tool we use (SPSS Text Analytics for Surveys) supporting more reliable analyses and presentation of data such as extensive open responses in surveys.

On-line surveys have resulted in two advances in educational research. Firstly, they allow researchers to access much larger samples at little or no cost beyond their labour in constructing the surveys. Secondly, they have proven to be a source of very useful qualitative data. That is, most surveys include a section for comment after questions requiring ranked responses. With paper-based surveys, these traditionally provided little
useful data and were often not completed, however, researchers (eg. Yun and Trumbo, 2000 and Klieve et al, 2010) are finding that on-line survey participants are happy to provide quite detailed responses to these general questions. In addition, as participants feel secure in their anonymity with on-line surveys, they are providing responses that are regarded as having high levels of validity with Kiesler & Sproull (1986) suggesting that respondents will become relatively unconcerned with social norms and the impression they give others.

Equipment for capturing and analysing teaching and learning activities has extended the utility of methods such as stimulated-recall (Meade & McMeniman, 1992). In the study referred to above, Walmsley used a system of two video cameras that were synchronised and recorded to DVD in parallel to capture the activity of both the teacher and students in a learning activity. Walmsley was able to examine the parallel data to achieve a fine-grained analysis of the nature of the interaction between teacher and student and between students.

Research Training
The changes in the demands on educational research, the qualitative/quantitative divide and the availability of new technology provide the context for the informal action research project undertaken by the authors over the last seven semesters. The study was also informed by the belief that rigorous educational research was important and that the next generation of educational researchers needed to undertake research methods courses that left them with skills in a variety of qualitative and quantitative methods and equally importantly, the confidence to undertake research. Thus research preparation is regarded as an opportunity to prepare not only for the immediate research activities in postgraduate programs, but should be viewed as a “research apprenticeship” in which emerging researchers have the opportunity to hone their understanding, capacity and also their motivation for research.

This paper takes examples from those enrolled in formal research methodology training, students with whom the authors worked with through this process. The observed processes and experiences provide insights into their learning processes and also how the interactions between undertaking quantitative and qualitative components of a study can provide real synergies in the research process, adding to the thinking processes and particularly to the possible outcomes of such research.

Reconceptualising research training
This paper suggests the need for a reconceptualization of the role such courses can play, moving from the identification of tools for future use, whether quantitative, qualitative or a broader mixed methods perspective, to a more complex appreciation of the different tools and the role they can play in developing our researchers capacity to work in their craft. As a part of this approach, we examine how emerging researchers can develop, through emerging experience, an appreciation of the critical links between the research question they ask, the methodology through which they select to answer and also the opportunities through which further dimensions of this question might be addressed, with an awareness of the links to other research questions and strategies.
The course used for this study is that offered to Master of Education students. This was selected as it had both the greatest participation (run each semester with enrolments of between 25 and 40) and was also the most practical with all students undertaking two small pilot projects. The course is also offered in both on and off-campus mode and has a mixture of domestic and international students.

What was our starting point?
There were a number of ideas that informed the setting up and conduct of the course. They were in part determined by the composition of the student cohort, which is always diverse in terms of prior experience, cultural background, age, employment and confidence. Our response to this diversity can be described in terms of the learning environment and approach, course content and organisation, and course structure.

The learning environment and approach
The approach adopted in the courses was intended to be more one of a collegial learning environment than a formal classroom. Thus the lecturers, while coming with more experience, and also providing the significant content material to the group, adopted a participative and facilitative approach that recognised that they provided but part of the input, with significant learnings also coming through group interactions and individual learnings and prior experiences.

The underlying approach was about learning to use the appropriate means for finding evidence to answer or respond to a research question.

Course content and organisation
The course content, focussed on research processes, methodologies and also research output genres (reports and proposals) was run in parallel to the practical research activities being undertaken. For example, students are involved in a weekly 2 hour session. For each session an initial lecture/discussion was followed by a coffee break then a less formal tutorial session in which progress on the practical tasks was discussed. As the leaders of this process we may have a lot more experience than those participating, however, it provided a valuable insight to students to be aware that we also acknowledge that we are also learning. It is formally recognised, and regularly demonstrated that much of the learning in this course comes from the comments of those participating. As one student recently commented

Your teaching style had enabled me to grasp new concepts and it has been wonderful sharing the journey with our diverse group

This process, while relying on the involvement and interactions of students does not appear to be reliant on a “good cohort”. This format has been repeated for the last seven semesters with similar interactions if not very different groups and dynamics. There has been a generosity of spirit by many students, being prepared to share their ideas and learnings – while often learning at different levels. But because all participants are doing their own topics there is less of a risk of having to protect ones own ideas – we are not playing a zero-sum game!

The underlying element of our approach is trust that participants feel that they do not have to protect their ideas in case they are judged. But discussions start at the very basic level. What topic are you interested in?, then moving on to designing the survey and
collecting responses. In addition, there are extensive discussions within the group in parallel to similar email level discussions with the lecturers assessing responses and giving the OK for progression.

However, an interesting learning that we regularly discuss is getting a feel of what is possible to achieve and learning to scope a bit more realistic. Often we have students who have quite extravagant expectations of what can be achieved through research, even with very small research projects. Thus a significant learning for most students is to recognise the link between the research question and the method through which this can be addressed and in the process developing a better feel of what is possible to achieve.

One of the challenges for students moving into research is understanding what it is they are actually learning. Unlike many subjects where there is clearly defined content, methodology courses instead are really aiming to introduce students to the practice of research. This can be “learnt” through a number of interrelated strategies including:

- Becoming involved in the literature and placing one’s own research “in it”
- Planning a real research project
- Undertaking research
- Reporting on research

But these activities are largely formative providing a base for the real learnings, which we consider to be the readiness to enter and undertake more active and independent research practice. Perhaps the real things we are seeking for people to learn is an appreciation of the research process, a recognition of what is achieved, and most importantly to develop the confidence to ask questions, to feel confident in the research environment. These are practical outcomes generally from experience and thus a simulated, or managed research experience provides an effective means for helping students to teach themselves such aspects through their experiences. One of the exciting demonstrations of this learning is students identifying the next stage of their project – of further research questions that emerge from the initial step of research.

The approaches for this can range from the strongly theoretical to the practical – but all work with the intention of preparing students for becoming involved in research – whether predominantly as a researcher or a user of research.

**Lightbulb Moments**

One of the major differences between standard coursework subjects and those such as discussed here, where students are undertaking the practice of research, is that there is a shift from learning the known to exploring and appreciating the unknown. A common situation we have found is students who express great concern that “but that's not what I expected” The surprising but critical learnings for them is that this is good, that this might be where you find something new, open an opportunity to greater understanding. And the value of our teaching approach is such events are able to be captured and shared – thus in a class this may only happen once during a particular semester, but because of the sharing nature of the learning, all students are able to capture the benefits.

**What did we find?**

For this next section we describe the things that evolved over the course of the seven
semesters and how our students responded. We have described these in terms of structure, confidence, practical learning, finding a niche, and becoming an educational researcher – themes identified from comments provided through the confidential student course evaluation process.

Structure
A common approach to teaching research methods is to provide an introductory overview of research and research methods followed by two modules focusing on quantitative then qualitative research – with a final session discussing the mixed methods experience that has been undertaken. We initially reversed this order, teaching the qualitative methods first. We did this on the basis that education students would find the qualitative methods provided a gentler introduction prior to the quantitative methods. This worked reasonably enough, however, for a variety of reasons, we decided to reverse the order and teach the quantitative methods first. This provided unexpected benefits for student learning because the quantitative practical involved a small survey. Students found that the analysis of their survey data provided an issue they wanted to explore in their second practical task which involved an interview. Thus in planning the two research tasks a mixed approach is modelled. Students also frequently find this an appropriate way to write up the second, explanatory study with reference to the original quantitative results.

I liked the way that the content and assessment items were lined up. I appreciated doing the quantitative project first as it is more structured and makes the second project somewhat easier to deal with.

Gaining Confidence
Students are very familiar with reading texts, but undertaking research is not something that can be entirely done by formulae. There are many judgements and decisions that need to be made and timelines to be managed and generally real people to work with, as subjects colleagues or collaborators. Thus, there are a lot of unpredictable elements which takes students outside their comfort zone. This is often multiplied by people’s common misunderstanding of what educational research can involve. Many students are surprised to discover that researching teaching and learning practice is a normal part of educational research.

One of the common reflections from students in starting research methods courses is how this is so different. Perhaps Locke, Silverman and Spirduso (2010) capture some of this in their statement:

“Some of you will have growing confidence, and others will experience performance anxiety (“can I really do this?”)

What has been very positive in teaching research methodology is the overwhelmingly positive feedback we received from students as they progress through the course. They actually enjoy the experience, but much more import is that they feel it is very relevant and from doing it they feel confident, often very keen, to move on and do their research. We believe this is the result of our informal approach and basing the learning around practical projects, albeit of a very small scale.

Practical
When it all comes down to it undertaking research is an activity and one research methods students are preparing to undertake. Thus as they will need to do much of the research
getting a little “up close and personal” but in a safe environment would seemed like a good approach to learning and one we employed from the beginning.

Our experience is that they just learn because they read it, predominantly they learn because either they see that it works, or perhaps even more effectively, they see that something does not work. Our teaching approach emphasises that this is a “sandpit environment” where you learn and practice. And the assessment has a strong element of learning in it. The objective is to see if people are getting towards the next step of starting their actual research project with a supervisor.

The assessment was hands-on and allowed us to research in our own area.

The process of actually doing, rather than just learning about a research project was an excellent teaching tool. Learnt a lot.

The objective of the “experiential” style teaching is to help students gain an appreciation of what the research process is and what it will actually mean to do research. This moves from the first learning, in undertaking a review of literature, that all published papers are not the same, there are disputes and challenges and now they, as researchers, can critique – as they too will be critiqued.

Another element of the learning approach is that the instructors, while still acknowledging that they are learning, are further along the path than the students. Thus there is richness in the interactions with students, with the organisation of the learning capturing benefits from the collaboration between students. This is not a competitive environment and it becomes clear that they all have learnings that can be shared.

Another aspect of learning skills to do research, and particularly doing this in a relatively safe environment, is that it’s OK to try different approaches in the exercises. Thus rather than doing the basic many students get very motivated and try something they find exciting. Thus we receive lots of emails as they plan and progress through a different approach.

I’ve put a lot of effort into this assignment, and have also tried a new kind of approach and way
This is a reflection of a very positive student for whom this was a very different type of course – but one who was very prepared to really look at options in approaches and take great interest in how her project was going

Finding your niche

Another benefit of offering a broad “toolkit” is it raises the awareness that indeed there is a toolkit with a range of tools both quantitative and qualitative. A logical consideration then is to see that different questions can best be answered by different tools – with this experienced in defining the question and tool used. And just as there are critical alignments between research questions and the research methods through which they can be addressed, there also are alignments between researchers and methods – thus some people prefer some types of research – the methods and also the questions that means they will address.

One very satisfying response from a Masters student who was completing the course but not necessarily going on to undertake their own research:

I find the whole concept of narrative research fascinating.

Initially this was a student who was completing a compulsory course, but we often see a sudden awareness that this is fun – scary and exciting! This comment came with the
comment that he could now look to the future and see starting a PhD as something exciting. Thus without the awareness of what you might do it’s hard for students to really get excited about entering the domain of undertaking a major postgrad study.

**Becoming an educational researcher**

The field of educational research has changed significantly over recent decades with the shift in methods used quite marked. Thus preparing future researchers to have knowledge only of one approach will restrict their future options. This doesn’t mean that they should be looking at the expectation that they undertake any form of research approach but at the least they should be able to access the literature produced through the field of educational research and also potentially able to collaborate with other researchers – even if not undertake a method themselves.

Thus such a course can at least be considered as the filling of the toolkit with both communication tools (how to report either proposed or completed research, including discussing literature) and also an appreciation of the methods available and the type of questions they seek to answer.

I found this course very useful for doing qualitative and quantitative research. I could apply this to my real world experience as a language teacher.

**Conclusion**

In developing an approach to teaching research methods the initial intention was to do just that – to introduce students to a range of approaches through which they could do their research. The outcome of these approaches, also seen in the broader applications of some of our research students, is that in accepting to enter some of the less known and less obvious areas of research students are also learning more to think, to feel comfortable in doing research in feeling that in working in this area where facing the unknown largely independently is the regular, students are gaining those more subtle skills of the researcher. So the question we have explored is not just “how to get across a few research tools” but by taking students on a journey with a small backpack that we gradually fill, we have filled their future research backpack with more than a few research recipes we also have added a bit of capacity for innovation, exploration and depth and rigor. And also let them see there can be a lot of fun not only in reaching the end of the tunnel but in the journey as well.

This paper reports on the application of mixed methods approaches to such preparation using exposure to research through student development of small research projects in alignment with coursework on the methods. Feedback from students indicated both a strong appreciation for the approach and also recognition of valuable learning and some change in expectations on the accessibility and usefulness of methods.

**References**


