Explorations of best practice in Technology, Design & Engineering Education

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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.

Howard Middleton
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Gender and Technology Education: Some Theoretical Implications.

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This paper explores issues of gender as they relate to Technology Education in recent decades. It examines the theoretical issues that have shaped gender participation and engagement in this area of learning.

Since the 70’s when technology started to be seen as not the exclusive preserve of males, there have been efforts to address the stereotyping of areas of learning according to gender, with technology being a prime example of an area that had been regarded as a males-only activity. However, forty plus years on female students are still engaging in school studies that were traditionally regarded as gender appropriate, as are boys.

The examination is concerned particularly with post compulsory education students (typically years 11 and 12) from the point of view of the orientations of biological, socialisation and cognitive approaches. That is, how do students learn and function within Technology education and how do these factors feature in students' decisions about technology education?

Introduction

This paper explores issues of gender related to technology education in recent decades and discusses theoretical issues that may shape gender participation and engagement in the post compulsory schooling years within the context of technology education.

The issue is explored in terms of three factors which shape how girls learn and function in technology education. The first is the biological factor. As educators we may aim for gender neutral programs and teaching units. Is this what really occurs? Is it the reality in schools, in enacted programs and curriculum documents? The second factor explored is socialisation and the third are the cognitive approaches that are specific for girls.

One hope was that the digital age would help to create equality in terms of access to and involvement with, technology, however, research has shown that the digital divide has heightened inequality. A brief overview of the United Nations Program which aims to reduce inequalities in all fields is provided. Finally some recommendations for gender responsive programs which promote the sustainability of girls in technology education classrooms are outlined.

In examining the theoretical issues that have shaped gender participation and engagement when considering technology education, this paper adopts the most inclusive definition of technology education adopted by the Australian national curriculum writers; that Technology education encompasses the practical and creative technologies including information and communications technologies. (Australian Curriculum Assessment and Reporting Authority, 2012)

The paper takes a social constructionist stance that we acquire knowledge via the environment and that gender relations are socially constructed. It is then argued that, by changing the social and environmental factors from ones that reinforce stereotypical
behaviours to ones which better suit girls, their interactions, engagement and learning will substantially improve in technology education classrooms. By making the environment more female friendly we improve the social and cognitive ability of girls learning. These actions are argued will improve retention and participation rates of female students. Ultimately it is these rates which have an influence on the uptake (the flow on) into tertiary courses in fields such as engineering at universities.

Gender equality is one of the six goals of the global Education for All campaign that UNESCO launched in 2000, when the countries of the world agreed to eliminate gender disparities in primary and secondary education by 2005. The aim was to achieve gender equality in education by 2015, with a focus on ensuring girls’ full and equal access to and achievement in basic education of good quality. (UNESCO, 2012b)

The UNESCO Gender Equality Action Plan (GEAP) promotes three main outcomes at the organizational level:
• A progressive increase in the number and quality of gender-responsive and gender transformative programmes and initiatives in all sectors.
• Women’s empowerment and gender equality in Member States advanced through policy dialogue and programmes promoted by UNESCO.
• Commitment to gender equality institutionalized in the Secretariat and in programming.

Theoretical Issues
In examining the theoretical issues that have shaped gender participation and engagement in technology education the biological, social and cognitive domains need to be examined.

The Biological
Sex is a descriptive category used to designate female and male. Gender is a social category. (Rothschild, 1988) (p 45) Petrina discusses the fact that differences are not determined by biological sex. (Petrina, 2007) There are many examples of high achieving females world-wide. The issue is differences that are dependent on socio-cultural factors such as bias, overt discrimination, differential treatment, isolation, socialisation and stereotyping.

Ehrhart and Sandler (1987) noted that upbringing and socialisation play powerful roles in forming a child’s abilities and confidences: reinforced not only by parents and teachers, but also by the media- teaches children roles, attitudes and behaviours thought to be ‘appropriate’ for each sex. (Ehrhart & Sandler, 1987) In general boys are encouraged to be active and independent, to explore and to learn how things work. Girls are ‘taught’ to be passive, verbally oriented, and dependent. Boys receive chemistry sets, building toys, trucks and sports equipment; girls receive dolls, kitchen equipment, and sewing and embroidery kits. Parents’ expectations that their children’s interests and achievements will follow traditional sex roles will steer girls away from certain curriculum areas; in contrast, encouragement from parents for boys to succeed in math, science, and technology is crucial in student’s decision to take or not take these courses in high school. (Petrina, 2007), (Fleer & Jane, 1999, 2004).
Psychologists tell us that differences in socialisation are manifested in neurological and physiological differences between the sexes. Fuller suggests that the differences become hard wired over time and hence are not easily overcome. (Fuller, 2011) Stereotypes, as such derive from gender norms and sex roles not from gender itself.

**Social domains and feminist critique**

Feminist Critiques emerged in the late 1960's in response to the growing social critique of the directions of science and technology and originating on campuses with interdisciplinary courses with social content. (Rothschild, 1988) (p. 2). The purpose of feminist scholarship was to develop a body of work about women's lives and ideas and their contribution to society and secondly, to develop a systematic critique of existing scholarship and a distinct feminist theory and approach to knowledge. (p. 4) The 1970's saw the development of this research plus its linking with the curriculum. There was a slower emergence of feminist research and teaching in science and technology fields and with less visibility than the liberal arts fields. The STS (Science, Technology and Society) programs became known and linked to technological literacy. Two reasons may explain this. Firstly there were fewer women in these fields and secondly not only the culture but the subject matter in these areas had masculine associations. (p. 4) Technology fared a bit better than the scientific fields. Works highlighting feminist issues were published in the early 1980's and brought feminist perspectives to technology in three ways. Firstly through the history of technology, uncovering women’s contributions to invention and innovation which helped redefine what was seen as significant technology. Secondly research went into the relationship of women’s traditional work – as producers and reproducers – to technological development and change. Finally it explored and questioned the values and epistemological frameworks that underlie both the study and practice of technology. It is the transformative nature of the critique in this final area where studies of and about women in technology have emerged and made some positive changes notably through the writings of feminists such as Zuga and Wajcmen.

Spender, in her seminal work argues that men control language which in turn works in their favour. (Spender, 1980) Her thesis demonstrated that men have use and control of more positive language and thus ensured themselves the opportunities to use this from a power perspective. In her 1990 preface she speaks of the theory of good conduct broken by the suffragettes who have paved the way for some yielding of power. (xi) In examining positive and effective classrooms some analysis of gendered language and technology specific language used in the learning environment will be undertaken as part of a larger study in order to establish if the use of terminology does detract from female participation. Petrina would suggest that this is so in the United States. (Petrina, 2007)

Stanley, (1992, 1993, 1998) and her subsequent work on the history of technology cites many authors who talk of the silence of women in the technological developments throughout history. One notes over time that technical activities related to man are seen as technological and engineered whilst those related to women are craft and home making. Stanley (1992) demonstrates that historically and in fields of endeavour that the focus from female to male activities have altered. Singh refers to the discourse related to computer, the production, transmission and acquisition of school computing knowledge.
based on the Bernstein model. (Singh, 1997) That the social structure for this knowledge is a device which at the time was used as a relay or vehicle for power relations. Computers and digital technologies became the pedagogic device of the struggle and conflict between groups, students, parents and administrators who sort to control the production of the discourses. Bureaucratic agencies including the school support centres and software production services as well as classified personnel and school experts who would produce, transmit and acquire school computing knowledge controlled the mechanism. (p. 3 – 4)

The aim of the Federal and State Labor Governments during the 1980’s in Australia was to link the language of computing to the market place but also to produce technologically literate workers for the needs of industry and this was tied to the social justice platform of gender equity. (p. 3)

Wajcman, (2000, 2004) writing on techno feminism highlighted that at the start of this century we were at an intersection of feminist studies, techno-science and Science, technology and society. The newly emerging info-age of communications then and now lends itself to a bright future for technology that should not hinder gender. Wajcman argues that the concept of technology is based on male activities and traditions and those characterizations continue to define technology by affecting the design and development of artefacts which are tied to social networks. In Feminism Confronts Technology (Wajcman, 1991) she strongly puts the case for developing feminism in social science debates in Technology. The differential impact of technological change on women and men - focuses on examining social shaping of technology. Artefacts are shaped by gender relations and have meanings and identity. The exploration of the hierarchy of sexual difference affects the design, development, diffusion and use of technologies. Bijker had written of the gendered artefacts and the nature of sociological change from a gender perspective. (Bijker, 1995) Pinch and Bijker (1989) work saw technology as a reflection of society and therefore requiring a constructivist approach. (Pinch & Wiebe E. Bijker, 1989)

Stanley (1983, 1993, 2002) has developed the notion of gender and functionality within technology. Spender (1983) in analysing the power and control of language as against the artefacts and function of Stanley’s work claims that it is this gendered nature of control that is shaping education now. Blenkle, Clinchy, Goldberger and Tarule (Blenkley, Blythe Mc Vicker Clinchy, Nancy Rule Goldberger, & Jill Mattuck Tarule, 1986) in Women’s Ways of Knowing, despite its era questions the power and authority elements of women in society but projects that only certain students will grow beyond their dependence on the existing that is articulated in a male dominated society. The five perspectives from which females perceive truth and knowledge need to be acknowledged in order for them to thrive towards self-realization. These are women’s self-concepts, the power of ones’ mind, knowing and reason and the institutions they function within; families and schools. The interests of females learning is not necessarily vested in formal education but rather the inner self and the totality of living. (pp. 5-6)

The Blenkley et al discussion leads to the question of what may be the difference in how genders learn. Jon-Chao Hong, and associates in a project based qualitative research study concluded that there was little difference apart from time management and a lack of knowledge base on the girl’s part. (Hong, Ming-Yueh Hwang, Wong Wan-Tzu, Lin Hung-Chang, & Yau Che-Ming, 2011) This limited study did not seek the depth of feminist
critique. Danilova and Pudlowski (Danilova & Z. J. Pudlowski, 2010) says that one size does not fit all when it comes to technology and engineering studies. The shrinking pipeline could be due to the use of learning styles that attract some participants and not others. In appealing to teens Persson says we need to acknowledge that issues of gender, design and culture exist and should mould what values are placed on artefacts students wish to work with and relate to. (Persson, 2010)

To move forward Wajcmen says, ‘We need to bridge the common polarization in social theory…..Technology must be understood as part of the social fabric that holds society together; it is never merely technical or social. Rather, technology is always socio-material product – a seamless web or network combining artefacts, people, organizations, cultural meanings and knowledge’. (Wajcman, 2004) (p.106)

**Technology and cognition**

Feminist critiques have brought a broader perspective to the study of technology education. Weber and Custer in their 2005 study concluded that both genders entered Technology education courses with preconceived notions about the types of activities in which they would engage. The challenge for curriculum developers is to make connections between the skills and concepts of some under-rated subject areas and make them more appealing to one or both genders. Weber and Custer (Weber & Gerard Custer, 2005) (p. 69) recommended that there needs to be more research to better understand the dynamics of student preferences for technology related topics, activities and pedagogical approaches.

“Pedagogical considerations are also critical to sound gender-balanced curriculum design. Research has found that there are instructional methods, learning styles, and interests that can be characterized as distinctively female. (Brunner C., 1997; Zuga, 1999)

Petrina in discussing teaching methods for the Technology classroom claims that some groups may require differential treatment to have a fair chance to participate and perform. (p. 334) Equal outcomes may require differential treatment… we have to attend to the barriers as well as intervene in the status quo conditions to achieve equity and equality in technology studies. In the US as early as 1972 Title IX of the Education Amendments prohibited sex discrimination in all aspects of federally funded education programs. As recently as 2007 girls in US and Canada continue to be relegated to traditionally female programs, which ultimately impacts their earning power and job prospects. The National Women’s Law Centre in 2002 concluded that bias counselling, the provision of incomplete information to students, and consequences of career training choices, sexual harassment of girls who enrol in non-traditional classes and other forms of discrimination conspire today to create a system characterised by pervasive sex discrimination. (Petrina, 2007) (p. 3)

Biases are hidden and subtle as well as obvious. Sex-bias or sexist curriculum materials in technology tend to give girls the message they are not important. History of technology again portrays inventions and innovations made by men, and in most cases white men. Language that is not consciously gender-specific tends to default to the male in technology courses. (p. 335)

In reviewing gender and career aspirations McMahon and Carroll suggested that career development programs should begin at the primary school level. (McMahon & Carroll,
Ford, following on from the work of McMahon and Carol notes the retreat from feminist discussion which places girls and women at the centre of theory and inquiry in the area (Ford, 2011). The 1950’s witnessed an intensified growth which focussed on vocational aspirations of ‘generic’ adolescents and adults. Aspects of maturation and parental influence with a minor influence of gender and culture added to expectations of work and in turn study requirements. The prevalence of different occupational aspirations according to gender is linked to the stereotypical educational expectations from an extremely early age. Ford’s research study in 2011 again showed the gendered view of work stemming from the earliest years of education.

Subsequent decades of Australian government policy has sought to redress educational inequality. This includes the Karmel Report of 1973. Policy makers then recoiled from equity for girls into programs such as the Boys Lighthouse Programs which reclaimed any perceived disadvantage that may have changed the face of education but not the underlying social intent of educational provision. (Australian Government & Department of Education Employment and Workplace Relations, 2003; Karmel, 1973)

In Conclusion
This paper argues that there are three key factors that emerge from the research literature concerning the steps teachers and program writers can take to positively discriminate for girls in technology education classes. Initially it is the perception of the ‘trades days’ gone by and what parents remember of manual arts classes, cooking, sewing, Shop A and B that continue to drive subject choices and ultimately career choices for our current generation of youth. We must address the sex divide.

Secondly, modern technology education provides avenues for enhanced female learning in all these spheres and we are presently at a critical juncture when the national curriculum is being written and implemented. There is no better time to be commenting and making ones voice heard. Lerman, Mohun and Odenziel in 2003 in summarising their edited work of gender and technology provided some seminal insights into technology and gender. (Lerman N E., Ruth Oldenziel, & A Mahun, 2003) We should not focus just on females but it is crucial to look at the pairing of femininity with masculinity. Femininity is not the only social boundary used to render technological activity invisible. We need to heed the social ideologies and power and then address why some technologies acquire power status while others remain invisible. (p. 436 – 437) Technology as a system has the potential for the distribution of power but it is the importance of context in understanding technology, and the importance of technology in understanding society that takes us past the ‘old’ boundaries that we have been burdened with in the past.

Finally an awareness of the feminist critique, issues and values is crucial to assist educators to overcome the stereotyping that still occurs subliminally and in language discourses and finally in the enactment. One off programs to promote STEM and entry into engineering programs has not proved to be long term solutions. We as educators need to build notions of technological literacy at the earliest ages we can reach children and their families, in order to address the social perceptions that continue to haunt us. The UNESCO data of 2012 shows that gender is an important issue within Education For All - everywhere.
References


Technology clustering issues: Understanding problems in prediction

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Frequently, Industrial Design students at the tertiary level, and Design & Technology students at the secondary level, have similar problems in developing technology based solutions to major projects in their final year. Often they need to make design decisions in relation to clustering 'appropriate' technologies when developing and embodying their design proposals. Technologies have limited life spans and these life spans are getting increasingly shorter. In addition, due to socio-cultural and technological changes these student projects are becoming more complex. Consequently, students will need to understand problems associated with predicting appropriate clusters of technologies in solution development. While this paper will discuss some tools which may assist the designer in the design decision making process in relation to technology clustering, it is argued irrespective of prediction tools and strategies, which admittedly 'assist' design decision making, they fall short in terms of predicting relationships between technology clusters and the people who would use them. This paper presents the case that major projects being developed by university design students in their final year, and indeed high school D&T students can be supported by mapping strategies. These should address needs issues balanced against developing an appropriate discontinuity between technologies.

Introduction
Technologies and indeed technological change is moving forward at an ever increasing rate. In point of fact the literature surrounding various aspects of technological change suggests it is advancing at an exponential rate [See Kurzweil (2005); Schmidt (2008); Porter & Cunningham (2005)]. Often Industrial Design students at the tertiary level, and Design & Technology students at the secondary level, complete a major project in their final year. As technological changes are occurring at an exponential rate these student projects are becoming more complex, with greater emphasis on formally conducted research to set justifiable directions in development of innovative technological solutions. This paper will discuss aspects of the following three basic themes surrounding technological change and how they impact future design students: 1.) Technological change and innovation prediction issues 2.) Technical Innovation clusters and discontinuity 3.) Proposed mapping strategies to assist design students in the development of their projects.

Technological change and innovation prediction issues
In terms of growing technological innovation it may be argued the acceleration of the pace and exponential growth of the products of a technological evolutionary process extends beyond what has become known as Moore’s law. In the work of Kurzweil (2005) he argues, a series of successive S-curves relating to the life cycle of a paradigm moves faster and higher, showing an ongoing exponential trend. He is not alone in his discussions relating to technological complexity, technological growth and convergence. The earlier work of Waitley & Tucker (1986) discusses the three C’s; rapid Change - rising Competition - mounting Complexity in our world. Moreover, the work of Philatov et al
(1999) discusses the idea that a series of technological systems evolve over time forming a series of S-curves. The work of Schmidt (2008) argues much of our past has been shaped by a number of convergences having their beginnings as separate and independent lines of inquiry. Moreover, he notes that previous generations [even our most recent generations] would consider we are living and working in a “science fictional” age filled with complex converged technologies advancing rapidly.

For all that above, technological growth goes through three distinct phases of infancy, growth, and onto maturity/decline as depicted in Figure 1 below. The stage of Infancy of a technological system/development is when a new technological system/innovation appears as a result of a high-level invention [typically patented to exclude competition]. More often than not the technological innovation is primitive, inefficient, unreliable, and has many unresolved problems. Typically, owed to lack of financial and human resources development at this stage is extremely low, however, it typically provides some new functionality advancing the prior art. In order for the system to grow and gain acceptance and momentum moving forward, some small numbers of dedicated people who believe in the system's future continue to advance the technological innovations. Given that the innovation is in its infancy stage is difficult to predict the point of inflection at which the technology will move into the high-growth stage of the S-curve. The stage of the S-curves dealing with growth of the technological system/innovation advances when society and/or companies recognize the value of the innovation. It is at this time many of the problems have been overcome, performance and efficiency advance to an acceptable level. When this occurs people and organizations begin to invest money in the technological development. Consequently, this accelerates the innovations development, attracting even more investment. This in turn accelerates the technologies evolutionary growth at an exponential rate. Once this occurs a technological development may begin to mature allowing standards to be set and optimization of the design begins to occur. Usually in this phase low-level innovations advance the state-of-the-art tying it to a steady decline phase where the limits of technology have been reached and no improvements are made or indeed that is technology is no longer needed or has been replaced by a new technology. This is true irrespective of the paradigm, be it molecular, biological cultural, or technological.

Much of the technological change literature suggests that these changes are demand driven owed to ever changing sociocultural wants needs and desires which drive the growth [see: Aytac & Wu 2010]. In their work, within the technological forecasting literature, they suggest an approach thought to be effective in capturing the life-cycle patterns of products and the early demand signals for an innovation. Further their work, which takes a Bayesian probabilistic perspective, is thought capable of reducing the uncertainty in the demand forecasts by more than 20%. If Aytac & Wu (2010) is to be believed, we could take the position that a statistically normed probabilistic approach would assist in moving a design forward as we base our design innovations on Bayesian probabilistic outcomes and probabilistic conjectures. While determined probabilistic outcomes are comforting, in that they appear to lead to tangible results, in the context of design we often do not know precisely how a new innovative paradigm shifting product will be received in the marketplace.
A critical analysis of Bayesian theory reveals the need for consistent evolving data sets. In essence, these data sets are often based on sales of existing products, projected market share, and growth rate projections. The existing literature in relation to developing new technologically innovative products argues that in order to predict the demand for a new product, which does not yet exist, there is a need to critically analyse products that already exist. In essence these strategies typically look backward to look forward. There are a number of issues with this predictive conceptual model: 1.) It is usually based on existing technology paradigms, 2.) As Research and Development facilities are often extremely secretive in relation to next generation product design and development, it is extremely difficult to predict the nature of the release of competing technologies by a competitor 3.) New technologies drawn from many divergent domains may lead to “game changing” technological shifts in the marketplace.

![S-Curves of Technology growth, and Technology Clusters.](image)

Bayesian probabilistic conjectures may not be the best approach when seeking to develop a new technologically innovative product. A dominant perspective in many companies is one of evolutionary growth by incrementally developing technological products. A review of most evolutionary technological innovations [not revolutionary innovations] reveals that they are often based on a group [cluster] of innovations from domains considered to be normal to a particular product technology field as depicted in Figure 1 above. It is these technological clusters which move a technological development forward. While the work of Dereli et al (2011) suggests ways to enhancing technological clustering they rely heavily upon patent counts to do so. Moreover, they rely on a predetermined “neighbourhood” strategy for developing new clusters and not insights gained looking at divergent clusters.
drawing upon other domains. For example in the field of archery innovation, a new design of re-curve bow may utilise various sets [clusters] of new advances in materials technology. These technologies may be formed into technological clusters which support the growth and development of the product field, however, the overall design of the bow remains predominantly as it has for many years. Conversely, technological paradigm shifts may leave many companies vulnerable to loss in the marketplace. It may be argued a company who shifts the industry with “game changing” innovations will not only survive but may indeed thrive.

Continuing the Archery bow example above, the development and introduction of the design of the compound bow was seen as a technological paradigm shift for many companies and indeed archery itself. The technological clusters leading to and supporting the development and introduction of the design of the compound bow are different to those of the re-curve bow. In a real sense there is a discontinuity between the two very different bow designs and their associated technological clusters. This being the case, it is posited here that if a designer or design student is to learn to develop “game changing” innovations, a new technology research strategy and an enlarged design search space is needed for revolutionary technologically innovative solutions to develop. Given revolutionary designs may cause paradigm shift or what is known as discontinuities between products/markets it makes sense to discuss and explore aspects of this.

**Technical Innovation clusters and discontinuity**

Earlier we presented the notion that technological change is advancing exponentially often represented via S-curves in terms of growth. Additionally, this technological growth often has evolved by clustering various technologies in novel and innovative ways. Moreover this growth was considered to be demand driven. Drawing upon the notion, discussed earlier, that each S-curve is made up of diverse smaller S-curves of surrounding technologies it may be argued that in both the re-curve bow and compound bow example, rarely does a single group of technologies form the basis of these paradigm shifts. There are often various competing technological advances with their own new S-curves and their associated clusters of technologies driving them forward. In his work Foster (1986) suggests when technological discontinuity occurs it relates to the fact that S-curves almost always come in pairs when a new product or innovation emerges which serves to act as a “game changing” paradigm shift.

In referring to Figure 2 below the gap distance between a new S-curve with its newly formed clusters of technologies drives the shifts in a technological product area. In looking at the S-curves in figure 2 below, let us imagine the first S-curve on the left represents the growth of the re-curve bow and the S-curve in the middle represents the compound bow. Discontinuity distance [the gap distance between S-curves] is a representation of how advanced the new proposal may be. On top of deciphering the discontinuity distance between various S-curves, knowing where you are at along any of the S-curves is equally challenging. Identifying the discontinuity distance and location along any particular curve is a difficult task indeed.

In continuing with the archery example of the two different bow designs [re-curve bow and compound bow], if a designer is to develop a new paradigm shifting product it is important for a designer to be able to answer questions relating to how far the gap may be
between the two S-curves. Moreover, a designer must be able to identify which old and new innovative technologies need to be clustered if a new bow design beyond a compound bow were to be developed. Additionally, they need to know how big the discontinuity between their new proposal and the compound bow would be. There needs to be strategic management of the discontinuities, therefore there needs to be a strategy to allow an understanding of what the state of play is in the technological area and how to map a proposed cluster technologies to develop a new paradigm shifting S-curve. Each system component in a proposed cluster of technologies in a new design development has its own S-curve. Additionally, different components within a cluster usually evolve in accordance with their own schedules. It is argued different system components reach their inherent limits at different times resulting in a decline in utility for optimal in the overall design. Moreover, components that reach their limits early hold back the overall design. The elimination of these allows for continued improvement of the overall design. Consequently it is to know when to include or exclude various technologies in a cluster so as not to “hold back” a design. In short, identifying the components of the system that are “holding back” or are inappropriate for the development of the overall system is important. A frequent mistake in technology innovation development is the improvement of each of the elements or the inclusion rather than exclusion of some elements which would assist in limiting the forward movement of innovation.

Given the above discussion it is extremely important for a designer to be able to identify the current state-of-the-art of each possible component for either inclusion or exclusion in the technological cluster. This can only occur if designers practiced at identifying the current state of the art for each component in terms of where it is along its individual S-curve with respect to infancy, growth, maturity, or decline, especially if it is to be targeted to be clustered for the development of a new design. In figure 2 below, the ellipse in the infancy stage along the proposed trajectory of the large dotted line S-curve represents a set of technological clusters proposing a paradigm shifting technology. In order to develop a product proposal, a designer would make conjectures about combining various technologies together. The mini S-curves in figure 2 below, represent a proposed cluster of technologies which may contain older proven technologies [represented by the solid line mini S-curves] and new innovative technologies [represented by the dotted line mini S-curves]. These cannot be mapped by using data from the previous product areas and technological clusters as data for the proposed product does not yet exist. Consequently, Bayesian probabilistic theories cannot realistically be applied. It is the designer who determines the makeup of the technological cluster.
In order to develop a paradigm shifting product proposal, a designer would make conjectures about combining various technologies together, perhaps all new technologies, perhaps a new innovative configuration of older technologies, perhaps some combination of new and old technologies. This notwithstanding, if in the example case of endeavouring to develop a new bow design which moves beyond the compound bow, the designer must know where along the various mini S-curve trajectories a specific state of the art is located. In relation to the entire set of mini S-curves in the proposed cluster, the designer must know what to expect from the beginning, the middle and the end of these mini S-curves and the trajectory of the overall design proposal. It is very important that designer knows at least the general dimensions and limits and understands the implications of all the technologies grouped in the proposed cluster. It is also important that they learn to identify and manage the discontinuities between proposed overall design and the previous state of the art and the discontinuities between various technologies within and between the inter-clustered technologies. This begs the question of where we may find a strategy that would enable the designer to develop the capacity for creatively clustering various technologies in order to develop a design that would result in a discontinuity of the current state of the art in a product area. As many new technologies are protected by patents, and the core purpose of patents is to exclude others from using the patented technology, it makes sense to investigate this potentially rich information resource. Consequently, the following section will discuss aspects of this information resource.

**Tech Mining, Patents, and Problems with Innovation Prediction**

Within the literature relating to the concept of technology mining, is the core idea of
exploiting information about emerging technologies. The work of Porter & Cunningham (2005) in relation to “Tech mining” [their “shorthand” term] they argue that it is the application of text mining tools to science and technology information, informed by an understanding of the technological innovation process. Throughout their work they discuss how information from a variety of sources [patents, technology journals, science journals, Technology innovation databases, etc…] may be gathered structured and analysed. Moreover, they discuss what one may be able to do with the variety of technology information derived from the data sets when they are brought together in different ways. However, in general most of the queries relate to counting publications. In general, it is argued that frequency and pattern of the technology information reveals potential directions for new innovation based on a critical analysis of the patterns and technological trends. Trend analysis relates to an identification of trajectories based on an analysis of data relating to changing technologies. It is argued that by plotting a technological trajectory one may anticipate and develop new technologies along the plotted S-curve trajectory. In essence these are growth models and may be calculated based on publication data gathered. This has parallels to Figure 1 in that a technological cluster extracted from the S-curve at any given time may be analysed in order to project what the next technological development would be along that S-curve. However, while this may work to some extent for a given S-curve, this type of analysis may be less than helpful in relation to the development of a new design or new technology which causes a discontinuity to that trajectory. In essence this technique tells us little in relation to a new S-curve or new proposed technological cluster. This begs the question of what information and/or strategies might be best to assist us in the development of a technological discontinuity.

In their work, Porter & Cunningham (2005) suggest within Tech mining the chief problem is information overload. This notwithstanding, they offer some helpful analytical perspectives for basic analysis. They suggest that Tech mining can provide assistance when structuring the data along the lines of what they loosely call the 4P’s, the categories they discuss are as follows: product, process, predict, and prescribe. When applied to technology analysis they suggest a starting point would be a list. Further, they argue that a series of lists may be cross categorized. However, as suggested earlier focusing on the frequency of information, who generated the notion, where the information came from, and when it was developed may be valuable. However, it is generally valuable for projecting along an S-curve as opposed to generating a technology that causes a discontinuity. It may be argued that rather than focusing on literature in general, it may be prudent for a designer to review specifically patent literature. However, when Porter & Cunningham (2005) discuss issues surrounding patent indicators of Tech mining value, they suggest looking at the following indicators: concentration; uniqueness; concept clustering; distribution. It should be remembered however that their focus was on issues surrounding frequency and pattern of the various patents in a technology area held by various companies. Moreover, their focus was clearly on citation analysis. Consequently, while this goes some way to describe possible trajectory paths of a technology it still does not greatly help with generating technological discontinuities [i.e new inventions/new designs]. However, they do discuss a creative strategy called TRIZ. This is technology innovation strategy built upon the work
of Genrich Altshuller [see: Philatov et al (1999); Rantanen & Domb (2002); Savransky (2000); Otto & Wood (2001)]. The basis for this strategy emanated from a critical analysis of patents. However, their focus was clearly not on developing Tech mining tools. The focus was on developing a creative strategy for developing new innovative technologies. Consequently, it is important to understand the significance of various innovations and how they may be clustered as opposed to identifying the data and analysing how they were clustered and who clustered them. Hence, while we need to be aware that patent frequency and growth models may greatly assist in developing divergent thinking in designer or design students, key aspects of this are how and why we cluster them. Patent frequency analysis may reveal patterns but there are limits in terms of utility as designers abduct ideas, information, and technologies transforming them after reframing the relationship to other technologies in other domains. Patent frequency in a specific area does not reveal the cross connections between patents in divergent domains. As suggested earlier, it may be argued that we can develop a patent mapping strategy to assist designers and indeed design students to identify the current state of the art for each component in terms of where it is along its individual S-curve with respect to infancy, growth, maturity, or decline. This is especially if it is to be targeted to be clustered for the development of a new design this would serve to enhance their capacity for developing innovative designs.

**Proposed mapping strategies to assist design students in the development of their projects**

Frequently, Industrial Design students at the tertiary level, and Design & Technology students at the secondary level, have similar problems in developing technology based solutions to major projects in their final year. Often they need to make design decisions in relation to clustering ‘appropriate’ technologies when developing and embodying their design proposals. As suggested earlier it is the designer who determines the makeup of the technological cluster. Given the above discussion it is extremely important for a designer to be able to identify the current state-of-the-art for each component in terms of where it is along its individual S-curve with respect to infancy, growth, maturity, or decline. This is especially true if it is to be targeted to be clustered for the development of a new design. We argue that this can only occur if designers are practiced at identifying and positioning the current state of the art from various patent domains. Additionally, the designer / design student needs to practice identifying the discontinuity distance and location along any particular curve in order to develop a paradigm shifting product proposal.

It should be noted that while expensive and complex patent analysis software exists, as highlighted in the work of Porter & Cunningham (2005), in an educational context this is seen as less than appropriate. What is needed is a simple strategy. One way forward would be to have a designer/ design student make conjectures about combining various technologies together drawing from cluster groups of patented technologies. If we conceive of comparing the terms of infancy, growth, maturity, and decline to those of the phases of the moon, New, waxing, full, waning we may be able to categorise various patented technologies from divergent domains. This would allow divergent emerging, growing and mature technologies to be placed into exploratory clusters as shown in Figure 3 below.

![Diagram of the phases of the moon and patent distribution](image-url)
With the ease of access to patent information databases on the Internet [i.e. Google patents], students may access this information and then practice placing various patents from various domains into the “Moon Phase” categories highlighted above. This simple strategy would allow students to practice clustering divergent technologies in their various phases of the S-curve technology development life-cycle. While at first blush the students may appear to be “counting” patents, they are not relying on that count. It is important that as they develop their designs they learn to adjust and adapt their clustering strategies, mixing technologies from various domains. This is seen as allowing them to practice the development of innovative technological discontinuities.

Discussions/Conclusions
As design educators we are charged with the task of shaping the educational experiences of our students. Technological change is increasing at an exponential rate. This will impact our educational curricula in the future. In order to prepare for these changes this paper presented a simple way [“Moon Phase” strategy] for university design students in their final year, and indeed high school D&T students to learn to retrieve, identify, and manage patent information and the discontinuities between proposed overall designs and the previous state of the art. Moreover, they may identify the discontinuities between various technologies within and between the inter-clustered technologies. Furthermore, the “Moon Phase” strategy will allow the students to understand the significance of various innovations and how they may be clustered as opposed to identifying the data and analysing how they were clustered and who clustered them.

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Changing the emphasis of learning through making in Technology Education

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Planning the teaching of design process inevitably leads to the iterative process of design development broken down into finite steps during discussion, if not during an active design project itself. Design development is often focussed in the sketch development and rough modelling stage, with working drawings produced and final outcomes fixed before the student embarks on making a prototype. Making is valued in Technology studies as a medium for learning about the constraints and characteristics of different materials and processes, however, the additional benefits of learning through making in terms of its impact on design development can be overlooked. This paper considers the challenges and opportunities of expanding further the role of learning through making as a design development tool and broader implications of learning through making in Technology in schools.

1. Introduction
The success of social media, such as Facebook, Twitter and You Tube, has led to students and school pupils becoming increasingly immersed in online activities. As Web 2.0 (interactive online media) becomes the dominant paradigm for everyday interaction for this age group, interaction with people and objects in the real world has to compete with those that are web based and even forays into the real world tend now to be expressed through online sharing. With this immersion, there is a danger of a growing disconnect between this age group’s abstract view of the world interpreted through the Internet and their experiences of the environment they physically interact with. There is a possibility that these embryonic adults could become increasingly divorced from the mechanisms of their physical environment.

This possible disconnect has implications for design. More broadly it has negative implications for the environment and social values. As the distance between the understandings of individuals of how objects become manifest increases, so the connection between the individual and the objects they interact with decreases. Invested design, defined in Sustainable by Design [Walker: 2006], illustrates that increasing the connection between the user and the object improves the lifecycle of the object as the user is more likely to maintain the object, increasing its lifespan and improving its embodied energy.

In addition to the lack of emotional investment in the objects around them, any disconnect also reduces the sense of responsibility of the user. Objects that are made in a distant place, in ways that are unimaginable, as part of a mass production system that is beyond the control or influence of the individual removes the sense of control of the user and therefore the sense of responsibility – both for it being brought into existence and for its fate at the end of life. A lack of understanding of how objects are fundamentally
constructed results in an inability to repair objects and also reduces the likelihood that they will be disassembled and the materials reclaimed. A lack of basic understanding results in the undermining of any confidence in the next generations to even attempt to deconstruct objects. This is added to by aesthetics in commercial design that tend to hide the workings of an object to increase its perceived sophistication.

2. Empowering the user

To support a change in thinking and reconnect individuals with the objects they use, there needs to be more consideration of empowering the user through improving their understanding of the working and production of objects. On its most basic level, improving the visibility of the mechanisms of products contributes positively to empowering the general public, with products such as the Dyson Vacuum cleaner, with its cyclone technology on show, illustrating the approach [Dyson: 2012].

On a broader scale, the increase of a distributed manufacturing approach that places manufacturing in regional areas, supports the relocalisation of manufacturing globally and a smaller, more responsive approach to production overall would improve the connect between the user and the product and affect decision making and the relationship between the user and the product on a cradle to cradle basis, as described by McDonough [McDonough, Braungart: 2002] in his book on the reuse and reclamation of materials at the end of life, over a cradle to grave default.

For this approach to build, individuals need to be empowered to interact on a more fundamental level with everyday objects, to develop their understanding of construction and deconstruction, material behaviours and characteristics. This is beginning to happen in societies through initiatives such as MIT’s FabLab [MIT: 2012] with the internet ironically providing the communication tools to spread the ideas globally in a relatively short space of time. The basis for these initiatives is the empowerment of the individual in their relations to objects – using, maintaining, repairing, deconstructing and the reclaiming of materials. Hands-on deconstruction of electronic products, the building of component parts, the use of advanced technologies by non experts in customised design projects creates a new, grounded approach to understanding what goes into the production of everyday and complex user objects and the implications of their design and construction. If this continues, and the benefits of recent advances in additive manufacturing live up to their potential, the entire relationship of users to products, design and production, consumption and product service system thinking (where companies provide services using products over products, as discussed in Natural Capitalism [Hawkins, Lovins and Lovins: 2008]), could be reorganised in ways that reduce environmental impacts, improve quality of life for communities and empower the individual.

3. Learning through making

For a democratisation of design and production, emerging generations of users and decision makers need to be equally empowered. Their relationships to materials, processes, objects and their built environment need to be strengthened in the face of the disconnect of mass production and most recently Web 2.0. Technology education in schools provides an opportunity to enhance the connections between pupils and the
reality of the objects they interact with, rather than to add to that disconnect, and that requires a priority approach to the use of learning through making in schools that conflicts with what is happening in the training of teachers in higher education and the current use of workshop practice in schools.

3.1 Current practice in schools and the training of teachers in higher education
Learning through trial and error is a fundamental part of the design process and accepted as an invaluable tool in a designer’s skill set. An axiom of IDEO, one of the world’s leading design consultancies, is ‘fail often, to succeed sooner’ [Kelley, Littman, Peter: 2001], with studio modelling and workshop models a major part of that approach. James Dyson, for example, used studio modelling to create large numbers of prototypes in order to gain an understanding of how the cyclone principle could work for his design ideas. Even the Apollo program, one of mankind’s biggest technical undertakings, made use of wooden models throughout to test and develop design ideas.

Learning through making has been part of formal design education since the beginning of the 20th century and has its roots in the training of craftspeople since the Guild system in the middle ages. In some specific disciplines, such as furniture design, making is still the mainstay of formal education and students and students are introduced to working with resistant materials alongside design process. In most design teaching, however, and particularly in the teaching of Technology in schools, the role of workshop tasks in design development processes tend currently to loosely reflect industrial models, where students are required to execute the making of design models in resistant materials, such as wood and metal, only in the latter stages of a project.

This separation of the two realms of design and workshop has its roots in traditional industrial models that have developed since the industrial revolution. Wedgewood, credited with being instrumental in the development of the designer as a professional [Sparke: 2009], was aiming to reduce the influence of the individual craftsman on the consistency of the output by breaking down the making process into repeatable, small steps and so deliberately distanced the designer from the maker. Workshop making has therefore been predominantly associated with the execution of a near completed design, as designed by a professional designer and made by a specialist prototype maker. In copying this approach, the workshop and classroom are regarded as completely separate realms where design development is undertaken in the designing stages of a project only and then students move into the workshop to execute the ‘completed’ design. This approach is inconsistent with a student centred learning approach [Biggs, Tang: 2007] to making where the student develops their understanding by connecting with the construction of the object, rather than by emulating a mass production approach which is itself losing traction in industrial practice.

3.2 Rethinking workshop practice in education
Design development in the classroom combined with studio making without direct engagement by students early in the process with actual workshop exploration can only go so far for the student towards predicting how materials will behave in reality and what the challenges of working with specific processes will actually bring. It is difficult to see how students unfamiliar with materials and processes for a particular design development can be expected to predict how these materials will perform in a finished design. In the
dominant school model where students complete their design work using studio modelling and sketching to a ‘finished’ concept, then take the working drawings into the workshop for construction, there is still acknowledgement of design development in the final stages of workshop making but in order to support experimentation and Dee Fink’s definition of significant learning [Dee Fink: 2003], where the students’ perspective is altered by the experience, the inclusion of making at the final stage of the student project comes too late in the process. Often a connection with making itself, prior to sketch development work, provides the inspiration for initiating ideas for groundbreaking designs and even on a more basic level, that connection influences creative thinking in the development of all practical design projects from their first imaginings to their development into design ideas. Students need to be introduced to a ‘culture of making’ as this introduction will provide them with a genuine knowledge of materials and their characteristics and as a consequence their use. Rote learning through making pre-existing designs deprives students of the vitally important discoveries that come about through experimenting with materials, and equally taking a ‘finished’ design into the workshop restricts the opportunities for constructive failures in design and a workshop approach to exploration that is currently missing in the overall curriculum. Human evolution has been directly related to an ability to learn through making, progress through trial and error, and the development of tools that change the human relationship to the environment. This should to be encouraged at this time of disconnect, not abstracted.

The design process is well understood and documented, for example by Popovic [Popovic: 2004], as a combination of problem solving and reflective practice. A vital part of this design process is having some progress to reflect upon and students and professional designers alike can be at a loss for inspiration, feeling they have to complete one process before moving onto the next. The role of the informed, contemporary professional designer is to pre-empt or foresee potential problems with individual designs, using a combination of experience and knowledge gained through experimentation. It is difficult to see how students unfamiliar with manufacturing processes and different materials can successfully design products that then contain these very materials. It is arguably these forays forward into the various aspects of a project that bring back invaluable new knowledge to further inform and therefore develop design activities.

In contrast to practices in the progressive model of a project’s development, workshop activities should not be restricted to the latter stages of a project but rather should be introduced at the outset to expose students to a culture of making and experimentation. Instead of adhering to traditional models of industrial practice, learning through making should be a significant learning part of a much more holistic process with students being free to move between workshop and studio, with activities between these places to be much more integrated.

4. Challenges to an emphasis on workshop based learning through making

If learning through making is such a fundamental part of our development and progress a human being and is so intrinsically linked with an understanding of the surrounding world around, why are design educators in schools and higher education increasingly turning
away from it as a fundamental design tool? Reasons that need to be challenged by the educator include:

- The quality of the presentation of CAD & renderers to produce seemingly finished products undermining the perceived need for workshop construction.
- In an era of compensation culture having students working with potentially dangerous machinery presents increasing risk for educational institutions.
- Traditional making techniques are seen as outdated and no longer relevant by stakeholders.
- An overreliance in new design technologies creating perceived distance from manufacturing reality.
- Students’ reluctance to enter an alien workshop environment to undertake such work.
- Preference of students to work in virtual environment over a practical one.

Workshops are increasingly seen as rigid, dangerous places with the growing number of restrictions surrounding their operation. Students need to spend time in the workshops in order to feel comfortable and at home in that environment, to create confidence so that learning through making becomes second nature. The aim should be that students should feel as at home in the workshop as they do in the classroom. In order to do this, students should be introduced to tools and materials as early as possible - preferably as early as possible in their education generally - so that this confidence and knowledge can be developed and reflected on by the students in informing decisions.

The challenge presented to design educators is how, in the light of these challenges, to re-integrate and encourage learning through making and shift the emphasis of assessment to reflect the importance of that learning through making and away from ‘instant’, visualisation based design resolution.

5. **Using assessment as a tool for changing practice**

Assessment needs to be managed so that the vital nature of learning through making can be brought to the fore as an inseparable part of the design process. To do this, the assessment model must move the emphasis from ‘finished’ objects and the idea of ‘completely resolved’ designs, towards a weighting that rewards learning through experimentation. Assessment tasks that promote engagement of materials outside their traditional uses would be an example of how to foster a culture of making and experimentation. The expectation that students can learn about how materials react when manipulated based on research theory is akin to teaching someone to learn how to swim in a classroom. First-hand knowledge of the type gained through repeated exposure to materials and tools is vital for this type of knowledge to take root. Rather than reducing students time spent in the workshop we should be increasing it and promoting a ‘culture of making’ with students confident in their ability to make and design.

The highway code, published by the department of transport in the UK in the 1970s and early 1980s, contained a section in the back titled ‘If No Car’ and was a series of instructions on how the Learner driver could to teach themselves to learn how to drive if they did not have access to a car. Thankfully learner drivers no longer learn to drive this
way and this type of educational strategy has been discredited, but the example represents a poignant analogy for where design education could be heading as workshop practice is eroded rather than enhanced, taking the student experience ever further away from the reality of materials and their characteristics.

6. Conclusion
Teaching in higher education and in schools is currently dependent on a business model of practice. The reality is that workshops in either environment are expensive to run, litigation is a reality for both the institution and the individual educator, and alternative, virtual forms of the visualisation of products are seductively forgiving. With life lived through Web 2.0 as the dominant paradigm for younger generations, it is not surprising that the economic drivers of universities to move away from workshop practice, and the familiarity of the 3D CAD environment in contrast to the potentially dangerous environment of an unfamiliar workshop have aligned to move not only programs but student numbers away from practical based subjects towards virtual ones.

However, focusing on seductively forgiving 3D CAD models, not tested through reality and more fundamentally not informed in their development through workshop practice grounded in experimentation front and centre of their practice, will result in generations of adults who are divorced from the objects that surround and support them. Creating effective designers is not the only issue here. Creating connected users is the greater imperative. At a time when Technology in schools is threatened as a subject, it should really be expanded to be compulsory education for all pupils to ensure that successive generations are equipped to rediscover the benefits of connections to materials, processing and construction. The integration of workshop practice and learning through making into the fundamentals of designing is a vital part of this teaching.

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The value of mentoring: A strategy for beginning Design and Technology teacher retention.

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In Australia, 25 to 40 per cent of beginning teachers resign in their first 3 to 5 years of teaching (Berliner, 2001; Ewing & Smith, 2003). These figures are drawn from beginning teachers who have secured permanent employment. A lack of adequate support from school administrators and colleagues has been identified as a significant contributing factor in beginning teachers’ decision to leave the profession (Ingersoll & Strong, 2011). This paper draws on the findings of a qualitative case study of ten beginning Design and Technology teachers to strengthen the argument that effective mentoring is a key influence in facilitating retention in the profession beyond the identified three to five year period. The narratives of three beginning teachers are retold to investigate the interconnectedness between mentoring, the development of professional knowledge, identity formation and beginning teacher retention. It is concluded that to retain beginning Design and Technology teachers’ effective mentoring programs which provide personal and emotional support and opportunities for non-judgmental critical feedback on professional practice are necessary. The paper commences with an examination of the literature associated with defining the role of mentoring.

Introduction
The theory behind mentoring and induction programs is that teaching is complex and that some aspects of teaching can only be acquired in the context of a school (Feiman-Nemser, 2003). As a consequence there should be an obligation from schools to provide a supportive environment through which beginning teachers can further develop their professional knowledge and an understanding of their role as a teacher. Carter and Francis (2010: 250) describe mentoring as a process that:

- Mitigates teacher isolation, promotes the concept of an educative workplace and that leads to the creation or understanding of consensual norms in schools or faculty.
- Harrison, Dymoke and Pell, (2006) and Carter and Francis, (2010) strongly suggest that those who undertake the role of mentor have the potential to play a significant role in assisting beginning teachers in not only developing their professional knowledge but also their professional identity. As argued by Tickle (2000), mentoring of beginning teachers can provide opportunities for self-reflection through which knowledge and understanding are informed. As a result beginning teachers are able to continually shape who they become; that is, their professional identity.

- Defining the role of the mentor is complex and definitions are diverse. For example Clutterbuck states that;

A mentor is a more experienced individual, willing to share his/her knowledge with someone else less experienced in a relationship of mutual trust. (1992)

Clutterbuck’s definition places emphasis on the notion of coaching, or the passing on of knowledge to facilitate the development of specific skills or capabilities. In the context of
beginning Design and Technology teachers a simplistic analogy could reflect a model of master and apprentice with the master demonstrating technical skills. However, the literature clearly identifies that the role of the mentor is both multi-dimensional and complex. According to Harrison, Dymoke and Pell (2006) the spectrum of skills and attributes required of a mentor could include the following:

- guiding/leading/advising/supporting
- coaching/educating/enabling
- organising/managing
- counselling/interpersonal

However, the literature also suggests that more research is required to understand the ways in which mentors construct their roles. What the research does argue with clarity is that the success of the mentoring process is reliant on the relationship that develops between the mentor/s and the beginning teacher. Evidence suggests that the success of the process can be deemed to be ‘hit and miss’ and as a result McNally (1994) posits that less emphasis should be placed on the notion of assigning one mentor to a beginning teacher. Instead the provision of professional environments in which mentoring relationships can develop with a number of teachers should occur. The concept of significant others making a positive contribution to the transition of beginning teachers into schools is emphasised here.

Carter and Francis (2010:251) suggest that mentoring can engage both the mentor and the mentee/s in a dynamic, interactive learning process. However, the literature also warns that there is the possibility that a poorly organised mentoring process or acquiring a mentor who is not an appropriate role model can constrain the learning of beginning teachers (Ballantyne, Hansford, & Packer, 1995). More specifically in the field of Design and Technology Education mentors may find themselves limited in their knowledge of changing technologies such as advanced manufacturing or in contemporary constructivist approaches to learning. The consequence according to Ballantyne et al. (1995), is that the mentor becomes antagonistic towards the beginning teacher and in doing so the status quo of the school context is maintained. They argue further that:

The danger exists that mentors contribute to the professional socialisation of beginning teachers into the use of traditional techniques, rather than assisting the carry-over of progressive techniques into the classroom (1995:10).

The aim of mentoring and induction programs should be to provide a supportive and encouraging environment where beginning teachers can learn their craft, survive and succeed (Ingersoll & Strong, 2011). The result according to Ingersoll & Strong (2011) is that beginning teachers’ performance and retention are improved.

The study
The nature of the study was interpretive, in that it was characterised by a concern for the individual and the schools in which ten beginning Design and Technology teachers commenced their first year of teaching. The paradigms (Lincoln & Guba, 2000), worldviews (Creswell, 2007) or the beliefs that guided the research were based on the notion of social constructivism (Neuman, 2000; Lincoln & Guba, 2000; Schwandt, 2007).
The beginning teachers were viewed as seeking to understand the world in which they worked and the individually constructed meanings which they made were seen as being subjective. That is, they were related to individual experiences in a particular context and formed through a process of interaction with others.

The research was conducted in the school settings in which the pre-service teachers commenced teaching. The group consisted of one female and nine males. Beginning teachers were selected on the basis that they had all completed their study in the same areas of advanced technology, electronics and resistant materials, including wood and metal. The secondary schools in which they were teaching also represented a cross sector of educational systems located in both metropolitan and country locations. Data were collected via three semi-structured interviews and reflective e-journal entries over a one year period. What follows is an analysis of the connectedness and significance of mentoring in shaping professional knowledge, identity and retention.

All teachers in this study continue to teach, the majority in the same school in which they commenced teaching four years ago. Four of the ten teachers have also moved into Design and Technology leadership roles through which mentoring beginning teachers is part of their role.

Findings and Discussion
Findings from the ten case studies concur with the views espoused in the literature; that is, that mentoring is a key strategy for the effective induction and support of beginning teachers (Feiman–Nemser, 2003; Francis and Carter, 2010; Ingersoll & Strong, 2011). Mentors played a significant role in supporting the majority of participants to successfully transfer into school based settings. However, data revealed that the degree of formality in both assigning and assuming the mentoring role varied considerably between school sites. For example, only three of the ten beginning teachers had been officially assigned a mentor. In five cases a teacher or a number of teachers within the faculty voluntarily assumed the mentoring role. In two cases beginning teachers were not mentored in any capacity.

The findings of the study revealed three major mentoring roles that impacted on shaping participants’ professional identity, and on their role as beginning teachers. The mentoring roles included providing;

- Personal and emotional support,
- Teaching related assistance and advice, and,
- Critical reflection and feedback on professional practice.

Participants identified personal and emotional support as being one of the most valuable roles of the mentor. Participants valued a mentor who was approachable; someone they were able to talk to, to seek advice and at times confide their anxieties and limitations without fear of being judged. The three retold narratives that follow highlight the significant role that mentors played in shaping participants’ professional knowledge and identity in the early stages of transitioning into the role of teacher.

The significance of personal and emotional support is clearly evident in the re-told narrative that follows. Jason was assigned a mentor who was also the faculty co-ordinator. Jason identified the role of the mentor teacher as being instrumental in building his
confidence, supporting his personal well being and in shaping his professional identity.

The Value of a School Based Mentor

‘My mentor really cared about me and my teaching’.

Jason entered the Bachelor of Education, Design and Technology program as a school leaver. He had successfully studied year 12 Design and Technology scoring 20/20 in the year 12 SACE. It was the teachers at school that were his greatest influence to become a teacher. He always enjoyed school, particularly designing and making artifacts.

Jason commenced teaching with a one year contract at a Metropolitan Catholic Boys College and became a permanent member of staff in his second year of teaching. In his first year of teaching the school was undergoing a change of leadership, with the appointment of a new principal and deputy. Jason noted at the time that; ‘there is lots of change everywhere within the school ...I think change is good and I think it has been easier for me to come into a school that is transitioning. It means that there is change for everybody and not just for me’.

Jason felt that he commenced teaching with a strong knowledge and skills base in the subject of Design and Technology. However he felt he lacked confidence in his ability to teach in the ‘classroom’ setting that was the home group and religious study class. Jason made an obvious distinction between his teaching role in the ‘workshop’ environment and classroom. He states, “I am not the best at standing up in front of a class and continually talking. I prefer to work with students on their designing and making”.

Jason’s confidence in his teaching improved significantly throughout the first term, mainly through the support of his mentor teacher, who was also the co-ordinator for Design and Technology. Jason states; “My mentor teacher has been there to support me in everything. I would just ask and he knew the answers, he is the guiding hand”. However in the second term Jason’s mentor teacher took leave as a result of illness. During this time Jason recalls that, “I didn’t have anyone to fall back on, I felt lost at first. I didn’t realise how much I had come to rely on him at both a professional and personal level...I did get a bit more guidance as the term progressed...but it was never the same. The level of support was different my mentor really cared about me and my teaching he enabled me to get through my first term of teaching”.

For Jason the first few weeks of teaching were very emotional; it was a time of uncertainty and questioning his own teaching abilities, particularly in subjects with which he was not familiar. It was during this time that the role of the mentor became crucial in providing empathy and reassurance. The literature states that an integral part of the development of professional identity is the role of emotion. Britzman (2003: 22) argues that teaching is a deeply emotional process, and suggests that when teachers commence teaching they find that: one of the greatest surprises in learning how to teach is how deeply an emotional experience it is.

The centrality of the role of the mentor in supporting beginning teachers throughout this emotional period is clearly evident in Jason’s narrative. Although Jason continued to develop professionally as the year progressed he sorely missed the connection with a colleague who cared about him on both a personal and professional level.

Findings from this study suggested that mentoring relationships were strongest when participants and the mentor/s taught the same subjects, topics or year levels. This is evident in Brenton’s retold narrative.
Transition made easy—‘Smooth as Silk’

According to Brenton the school based initiatives and being mentored by colleagues from the same faculty made transition into teaching:

‘As smooth as silk; staff offered as much help as I needed. I was buddied up with a teacher from the Design and Technology faculty and with a year 8 home group teacher. The Design and Technology staff encouraged me to take risks and to make mistakes from which I could learn. All the teachers have been really supportive and welcoming, smiling, greeting me, asking about me how I am going...this has really made a big difference about how I feel when I am at the school’. (Brenton Interview 1 - In school phase)

An effective mentoring program, coupled with welcoming staff enabled Brenton to increasingly develop confidence in his role as teacher as the year progressed. Although Brenton was assigned a specific mentor he found that all staff within the Design and Technology faculty assumed responsibility in supporting his transition. The staff had established a positive organisational climate (Carter & Francis, 2010) in response to their recognised belief in the benefits of mentoring. In Brenton’s school there was an established ethos for supporting beginning teachers.

Brenton stated further that:

‘The guys that I work with, they have been so supportive. They have been great. At first I was kind of afraid that when I asked questions they would look at me like “come on mate, shouldn’t you know this?” There has been no hesitation; they just help me out. I also go and watch other teachers in my free lessons I still think about the prac we did at Uni in terms of giving instructions, being explicit’. (Brenton In-school phase, interview 1)

The evidence suggested that working in close proximity with a mentor/s who taught the same subjects or classes also enabled informal discussions and conversations to take place throughout lunch and recess breaks. It appeared that the day to day pressures of classroom teaching meant that finding the opportunity to set time aside for more formal or regular meetings was difficult. As evidenced in Brenton’s response teacher related assistance and advice was generally provided informally.

The value of whole school commitment to the support of beginning teachers was also evident for Travis. While Travis continued to be mentored by colleagues throughout the year, including members of the school leadership team, he believed that the school based induction for all new staff at the beginning of the year provided him with the opportunity to be successful in his teaching.
**Whole school induction - ‘Time to be prepared’**

Travis commenced teaching in an independent secondary college which provided beginning teachers with a week of intensive induction before teaching commenced. Travis described the first week at the college as being: ‘fantastic...we didn’t have students!’

Travis commented further that:

This allowed me to have seven days of professional preparation with my colleagues. It enabled me to get a hold of all of the awkward things like getting to know other teachers’ names, know where rooms are, understand behaviour management policies, in fact everything to do with the physical teaching environment' (In school phase, Journal entry 1).

As a result Travis stated that: ‘I was able to feel very comfortable when the students arrived. I think this is a fantastic reflection on the management of the school’ (In school phase, Journal entry 1).

While the narratives of only three participants have been documented in this paper, data from the ten participants revealed that mentoring or lack of played a significant role in building the professional knowledge and identity of participants in this study. For the two participants who were not mentored, the transition into teaching was described as a time of isolation and uncertainty. However these two participants continue to teach, one attributing the survival of the first year to the support of another beginning teacher on staff, the other to the support of the wider school community.

The transition into teaching was viewed by all participants as a time of uncertainty and for a number of participants a time of self-doubt. The personal and emotional support provided by mentor teacher/s and/or an induction process appeared to be pivotal in supporting participants during the first year of teaching. The role of mentors in providing teaching related assistance and advice, and opportunities for critical reflection and feedback on professional practice appeared to be instrumental in this process.

**Conclusion**

The research revealed that mentoring and induction programs were significant factors in shaping the professional knowledge, identity and ultimately the retention of beginning Design and Technology teachers. Through providing opportunities for personal and emotional support together with opportunities for non judgmental critical feedback on professional practice mentors were able to support beginning teachers through the complexities of beginning to teach.

**References**


Integrating web-based resources in Technology Education

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Technology education has unique resourcing needs, some of which can be conveniently and often more effectively met by web-based resources (WBRs) than by paper-based resources. However, integrating WBRs effectively into teaching and learning programmes requires a range of specialised skills and knowledge — what Koehler and Mishra (2009) have called technology, pedagogy, and content knowledge (TPACK). This paper reports on an interpretive study in which a group of seven experienced secondary teachers participated in a sustained professional development programme aimed at enhancing the ways in which they integrated WBRs into their technology education programmes (four teachers taught food technology, two taught textiles technology, and one taught structural technology). The focus of the paper is on how the TPACK framework was used by the researcher as part of the professional development programme, and how this programme supported the teachers in developing their understanding of effective teaching with WBRs. Examples of the impacts of the professional development on the teachers and their classroom practice are provided.

Introduction

The rapid growth of web-based resources (WBRs) and increasing access to these in New Zealand schools, and internationally, offers great potential for enhancing teaching and learning and also supports the vision of The New Zealand Curriculum (Ministry of Education, 2007), which explicitly refers to the major impact of information and communication technology (ICT) on the world and the considerable potential of e-learning to support effective pedagogy.

There is a range of understandings of the word ‘technology’, which can lead to misinterpretation when referring to technology education. For the purposes of this paper it is important to differentiate between ‘technology in education’ and ‘technology education’. Technology in education refers to the use of technologies such as computer hardware and software, data projectors, digital cameras, etc., in the classroom for mediating the teaching and learning process, whereas technology education, in the New Zealand context, refers to teaching and learning ‘about’ and ‘in’ technology. In this paper, the term ICT is used when referring to any item of computing or telecommunications technology, and WBRs when referring to resources accessible on the Web.

Studies investigating the potential of ICT to enhance learning highlight particular ways it can support student learning in different subject areas, how it may change pedagogical practices, and the challenges it may pose for teachers. English, Mathematics and Science have been commonly studied areas, and a wider range of subjects were included in ‘The InterActive Education Project’ in the United Kingdom (InterActive Education Project, n.d.). While studies of using specific ICTs in technology education, for example, CAD
software, are available, there are fewer examples specifically exploring the broader integration of WBRs in technology education.

Technology education has complex resourcing needs, in part because it is a relatively new curriculum area internationally, still cementing itself as a clearly defined discipline with its own subculture in schools. In addition to being a new area, the broad and interdisciplinary nature of the subject presents a considerable challenge to teachers in providing for the breadth of knowledge students need access to in their technological practice, as well as for expanding their own knowledge as teachers. The nature of the Internet – a rapidly expanding, rich repository of multi-modal resources – has the potential to effectively and conveniently meet many of the resourcing needs of technology education. For instance, rapid and flexible access of WBRs meets the need for ‘just in time’ access to information to support the diverse knowledge needs of students undertaking technological practice, which often cannot be predicted. Furthermore, the need for technology students to work within relevant and authentic contexts also demands current information and access to communities of practice – needs that can again be conveniently met by WBRs.

Although access to and use of ICTs in schools is increasing, teachers are not necessarily well prepared to integrate it effectively with other classroom resources and in reality their predominant use often focuses on technocentric and teacher-directed applications such as PowerPoint and learner-friendly websites rather than more student-centred approaches (Harris, Mishra, & Koehler, 2009; Ho & Albion, 2010). In addition, technocentric approaches do not pay sufficient attention to opportunities for rethinking learning and education (Papert, 1990).

Hughes (2005) identifies three categories of approaches to ICT integration, which help highlight the more radical change in practice needed to achieve the transformative vision for ICTs in education: (a) replacement of previous resources, for example, textbooks, (b) amplification of previous tasks, for example, enhancing presentations or completing tasks quicker, and (c) transformation of teaching and learning. The first two approaches, reflecting a technocentric view, predominate in teaching, and result in little change in practice. For some writers it is no longer a question of whether teachers should integrate ICT but how to use it to transform teaching and learning (Angeli & Valanides, 2009).

There is much evidence that a number of barriers constrain teachers’ use of ICT in the classroom, such as: lack of access, lack of confidence and skills, and lack of time and appropriate training to improve their skills (Baggott La Velle, McFarlane, & Brawn, 2003; Hennessy, Ruthven, & Brindley, 2005; Lai, 1997; Mumtaz, 2000). As Koehler and Mishra (2009) point out, many teachers trained before digital technologies were used in education and therefore do not have any prior experience of how these technologies may be integrated and often do not appreciate their potential value in education.

Technological Pedagogical Content Knowledge
The importance of pedagogical content knowledge (PCK) to effective teaching, first introduced by Shulman (1987), is widely recognised. However, as Mishra and Koehler (2006) argue, the rapid expansion of digital technologies requires knowledge beyond what is defined in Shulman’s construct. The concept of Technological Pedagogical Content
Knowledge (TPCK) (Koehler & Mishra, 2008; Mishra & Koehler, 2006) has emerged more recently and offers a useful framework for understanding the broader knowledge base required by teachers to integrate WBRs into their teaching. TPCK, now known as Technology, Pedagogy and Content Knowledge (TPACK) (Thompson & Mishra, 2007), expands on Shulman’s PCK construct to incorporate a third core knowledge component – Technology knowledge (T). ‘T’ knowledge in this construct refers to knowledge of ICTs and their use, as distinct from technology education, defined earlier.

As with PCK, rather than being a separate body of knowledge the relationships between C, P and T knowledge are complex and nuanced (Mishra & Koehler, 2006). As shown in Figure 1, adding ‘T’ knowledge to the construct introduces three new intersecting areas of knowledge to PCK: technological content knowledge (TCK), technological pedagogical knowledge (TPK) and in the central area where all areas intersect, technological pedagogical content knowledge (TPACK). The importance of the individual subject, classroom and school context is also represented.

Research Design

This study involved the development and implementation of a sustained intervention programme aimed at enhancing the ways in which secondary school technology teachers integrated WBRs into their teaching. There were three phases to the intervention, as shown in Table 1, spanning three school terms.

Table 1 - Intervention phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>Purpose</th>
</tr>
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<tbody>
<tr>
<td>1. Group Workshop</td>
<td>To provide initial professional development and establish a collaborative relationship between all group members.</td>
</tr>
<tr>
<td>(May, 2010)</td>
<td></td>
</tr>
<tr>
<td>2. Implementation</td>
<td>To plan and integrate WBRs into a unit of work, implement the unit of work, and reflect on and evaluate the outcomes.</td>
</tr>
<tr>
<td>(May to December, 2010)</td>
<td></td>
</tr>
<tr>
<td>3. Evaluation</td>
<td>To share and evaluate the experience and learning with the whole group and to discuss key knowledge required for effective integration of WBRs in technology.</td>
</tr>
<tr>
<td>(December, 2010)</td>
<td></td>
</tr>
</tbody>
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The intervention design and analysis were based on Bell & Gilbert’s (1994) framework for teacher development, which emphasises the importance of addressing teachers’ personal, social and professional development for sustained change in practice (see Table 2).
This was an interpretive study using a case study methodology. Data were generated through individual interviews, group discussion at workshops, classroom observation and field notes, and document analysis. An initial semi-structured interview was conducted with each teacher participant prior to the first workshop, after which they were given an academic paper to read and reflect on with respect to their own practice. The paper introduced TPACK (Mishra & Koehler, 2006) as a framework for understanding the components of teacher knowledge that contribute to effective integration of WBRs. This was an initial introduction of new theoretical ideas (Bell & Gilbert, 1994; Timperley, Wilson, Barrar, & Fung, 2008).

Table 2 - Stages of teacher development, adapted from Bell & Gilbert (1994)

<table>
<thead>
<tr>
<th>Personal development (attending to feelings)</th>
<th>Professional development (developing ideas and actions)</th>
<th>Social development (developing collaborative ways of relating to others)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Accepting an aspect of teaching as problematic</td>
<td>1. Trying out new activities</td>
<td>1. Seeing isolation as problematic</td>
</tr>
<tr>
<td>3. Feeling empowered</td>
<td>3. Initiating other development activities</td>
<td>3. Initiating collaborative ways of working</td>
</tr>
</tbody>
</table>

Findings

Seven experienced technology teachers from three secondary schools participated in the research. Here we present initial findings from two of the teachers, Malcolm and Margaret (pseudonyms), from two different schools. Malcolm specialised in teaching structural technology and Margaret in food technology. These two teachers were selected because they were from very different school and subject contexts, and both demonstrated a significant shift in thinking. Initial findings reinforce the importance of supporting teachers through three stages of personal, social and professional development, in order to effect sustained change.

Teachers’ Initial TPACK

Prior to the intervention Malcolm and Margaret both showed limited TPACK mainly because they lacked experience and skill (TK) in using WBRs. Malcolm’s access to computers and the Internet in his department was, in his words, “hopeless, absolutely hopeless”. He didn’t use WBRs at all in his classroom but relied on students to use them at home. He recognised some affordances of WBRs for technology education, mainly associated with accessing information and enhancing presentation. However, his lack of experience and lack of in-class access seemed to him to be insurmountable barriers and were limiting opportunities for him to further develop his TCK and TPK.

Margaret used WBRs occasionally in her classroom and was happy to ask colleagues and students for help with technical difficulties. However, she only had three computers in her room and this was limiting her use. She found school computer suites difficult to access and did not feel comfortable teaching in these with a whole class. Her use of WBRs
was predominantly very teacher-directed: mainly for narrowly defined student research and occasionally using YouTube videos to show processes.

Limited experience and access constraints were limiting both teachers’ ability to develop TK, TCK, TPK and ultimately TPACK.

Initial Personal, Social and Professional Development
Margaret and Malcolm were experienced, competent teachers, striving to do their best for their students and committed to keeping up with change. They believed in the value of using WBRs in their teaching, particularly in light of revisions to the curriculum that require a more explicit focus in technology education on the nature of technology (Ministry of Education, 2007). However, they both felt they needed to improve their own skills before they could use WBRs effectively in the classroom. This was a motivating factor in committing to the research, which they felt would provide new knowledge as well as the impetus they needed to put in the time and effort required to develop their skills. In the first workshop they were encouraged to meet other technology teachers experiencing similar difficulties and valued sharing their experiences with others and getting feedback. They appeared enthusiastic and committed to learning, an indication of their initial personal and social development.

Their initial professional development was facilitated in the first workshop, which attempted to bridge the gap between the reality of the classroom and more academic theoretical ideas. Using the TPACK framework to collaboratively analyse an example of their own practice helped the teachers to visualise the discrete components of knowledge and skills that contribute to effective integration of WBRs. This affirmed the CK, PK and PCK they already possessed as experienced teachers and allowed them to identify their own professional development needs in the other areas. Key concepts identified in the research literature were introduced to provide new ideas and strategies for participants to draw on, such as the concept of affordances and constraints of WBRs, the critical role of the teacher in managing all the features of the classroom environment including WBRs, and examples of scaffolding strategies.

Ongoing Personal, Social, and Professional Development
Malcolm and Margaret began addressing constraints and trying out new ideas very quickly after the workshop. Malcolm’s focus was a Year 10 class (14 year olds) and he began by booking his class into computer suites around the school, despite the challenges this involved. He also identified an unused data projector in the school and asked to have this mounted in an adjacent classroom along with a screen. This was agreed to but not actioned until two terms later. Although the wait was extremely frustrating he found that his students’ response to using WBRs was so positive that he was encouraged to persevere. In his words: “I must say … that when things went right, it was awesome to use this as a tool to support the work I am doing … and can see the huge benefits that this method will bring to my teaching”.

Margaret’s focus was a Year 9 class (13 year olds) and she started by using one of the school’s pods of Computers on Wheels (COWs) in her classroom, which she had not used before. After her first few experiences she found them easier to manage than she had
expected and was surprised by the increase in student engagement. Specifically, she felt students began to accept computer use as the norm and relevant to their learning, whereas before they viewed one-off lessons in a computer suite as an interruption to practical work. Margaret was really inspired by the positive outcomes and felt empowered to use WBRs more widely in all her classes. This was a huge step in her personal development: “It’s developing confidence in realising that sometimes you’ve got to let go that teacher position and enable the kids to do some of the teaching … it doesn’t all have to come from me, that’s been a huge learning curve”.

Both teachers took control of their own personal, social and professional development, in part by establishing and gaining valuable support from other collegial networks. Malcolm joined his school ICT professional learning group, which helped his development of TK. In Margaret’s department two other teachers were also participants in the research. This created a separate professional learning community, which provided extra support and momentum. Margaret’s school also had a very effective and regular staff ICT professional development programme in place, and this offered another source of knowledge and skill development for Margaret.

The teachers were looking forward to sharing experiences with the other research participants in the final group meeting, reflecting the importance of this social aspect in sustaining their participation and development. The learning journey of both teachers showed clear and interdependent progression through personal, social and professional aspects of their development.

Teachers’ Development of TPACK

The teachers’ TPACK developed gradually as they tried out new ideas in the classroom. With each new experience using WBRs they built on their TK, which in turn helped them identify and provide more scaffolding for students in this area. Their positive experiences inspired them to use WBRs more frequently and they felt more confident in their management and interactions with students using WBRs. The more they used them, and recognised the learning benefits for students, the more knowledge they developed of affordances of WBRs for learning in technology education (TCK). Similarly, through trialling new ideas and reflecting on outcomes, they were building a knowledge and skill base that allowed them to identify when particular content could be better supported by WBRs than traditional resources, and to use them more flexibly and spontaneously in their teaching in response to individual student needs (TPACK). For example, Malcolm was able to respond spontaneously to a student’s question raised during discussion about veneer. He had previously downloaded a YouTube clip for another class, but because it was relevant he was able to seize the moment and show it to this class:

It might have been for a unit on furniture veneering … but I can always locate it and hang it on for them and make it light hearted and justify their enquiry … and it’s great and the response is really good.

Margaret found her whole teaching approach changed dramatically. Comparing how she taught the same unit of work previously, Margaret explained:

They would have been bored out of their tree and it would have been short, sharp and teacher-directed. Now they’re asking the questions, not me. I’m doing much more feed forward and
encouraging them to do the thinking. So I’m really a support person rather than a teacher. It makes them take ownership of their learning.

This represented a significant shift from thinking about ICT as an information source to direct students to for independent use, to viewing it as a cognitive tool among other tools and resources in the classroom, to draw on as and when it is most appropriate for individual student learning.

Both teachers were intending to integrate WBRs into their programme planning for the following year. They no longer considered the WBRs to be ‘optional add-ons’, but were planning to source and link them with content wherever they perceived it appropriate.

**Discussion and Conclusion**

Initial findings from this research suggest the TPACK framework may be useful in helping teachers to identify ways they can enhance their use of WBRs in their teaching. Including TPACK within the overall professional development framework of this study, appeared to contribute to teachers’ developing a sense of ownership of their own learning needs and determining the pace and nature of changes they would implement (Bell & Gilbert, 1994).

When these teachers implemented changes and experienced positive outcomes, initial barriers became outweighed by benefits they perceived for enhancing teaching and learning for all students. The teachers were empowered to broaden their use of WBRs and more regular use also appeared to change the dynamics of the classroom, fostering more student-centred, co-constructive pedagogies. This represented a breakthrough point where they began to “consciously and unconsciously find ways to orchestrate and coordinate technology, pedagogy, and content” (Mishra & Koehler, 2009, p. 17) in their day to day teaching, reflecting their development of TPACK.

These teachers had moved, in varying degrees, along a continuum from familiarisation and utilisation of WBRs to integration and reorientation (Hooper & Rieber, 1995). Hooper and Rieber describe integration as the point at which the teacher begins to designate tasks to the technology and it is no longer expendable. Reorientation represents transformation from a teacher-centred to a student-centred philosophy, and a point where teachers shift from feeling the technology has to be mastered beforehand and integrated in a controlled way, to encouraging and expecting students to use it in ways that may not be anticipated.

This was a small study and therefore these findings may not be generalisable to a wider group. However, the findings, from two different teachers with different backgrounds and in different educational settings, do suggest that with particular components included in a professional development programme, teachers can be supported to reach a breakthrough point in their thinking about WBRs where they are empowered to continue their own ongoing learning.

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Development of a Teacher Education program and virtual lesson game for information studies

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In Japan, “Information Studies” was established as the core subject area for informatics education at the upper secondary school level in 2006. Few Information Studies teachers have sufficient pedagogical content knowledge (PCK) in this field, as many have merely shifted from other subject areas, such as mathematics, and the method of instruction for this subject area has yet to be studied extensively. Therefore, the teachers tend to emphasize activities such as computer/software operation, making presentations, and discussions after searching the web. They think it is sufficient to develop the students’ problem-solving ability and promote digital citizenship, as long as the occasional activities that simulate the context of using information and communication technology (ICT) are carried out. We believe that students should be taught how to solve problems utilizing “informatic” and systematic thinking, and be provided the technological knowledge necessary to understand the features of ICT. Students need to acquire the ability to choose an adequate alternative, considering both the merits and demerits of ICT use, including cyber safety and ethics. For this purpose, we have developed gaming instructional materials for students. In this study, we develop (1) a teacher education program that prompts Information Studies teachers to improve their lessons and (2) a virtual lesson game by redesigning our gaming materials.

Introduction

Issues of Teacher Competencies in Information Studies

The need for informatics education has been highlighted in many countries. In Japan, it is conducted mainly in compulsory technology subject areas: “Industrial Arts and Home Economics” in lower secondary schools and “Information Studies” in upper secondary schools. Students learn how to utilize information and communication technology (ICT) for problem solving and are able to apply what they learned to exercises of other subject areas. However, Information Studies teachers emphasize computer/software operation, multimedia design, making presentations, holding discussions after online research, or other activities, such as memorizing the latest technical knowledge and judgment rules for cyber safety and ethics. This practice has led the Central Council of Education (2008) to point out that the existing instructional method of informatics education in Japan does not cultivate the students’ problem-solving ability.

There are a couple of reasons behind the Information Studies teachers’ inability to conduct appropriate lessons. Firstly, since this is a newly established subject area (begun in 2005), the teachers are merely migrants from other subject areas, such as mathematics and vocational subject areas, and the method of instruction for this subject area has not yet
been thoroughly studied. Secondly, in Japan, the quality of education is controlled by using national curriculum guidelines set by the government to check and authorize textbooks; i.e., the quality of education is managed largely through lesson contents. Due to this approach, Japanese teachers think that the lesson’s objectives are sufficiently served if they instill knowledge or offer activities that simulate the context of daily life. We believe that the national curriculum guidelines and approved textbooks are not enough to manage the quality of school education in Japan. The objectives of education have changed from providing knowledge to developing intellectual skills, but teachers lack the pedagogical training to effectively reach this goal. Their approach should consider the model of cognitive process, as well as the relationship between this process and the knowledge, rules, procedures, values, ethical codes, etc. that students are expected to learn.

To improve this situation, we referred to the research conducted by Ishii and Matsuda (2003), which proposed an education program that would prompt teachers to utilize ICT in their lessons or teach informatics. According to the study, teachers must realize three main goals: they should (1) recognize that the objectives of education have shifted from providing knowledge to developing intellectual skills and problem-solving abilities, (2) understand the features of appropriate lessons that foster the required skills and abilities, and (3) redesign their lesson plans accordingly. Though Ishii and Matsuda’s research intended to train teachers in existing subject areas, not Information Studies, there are nevertheless common reasons for the inability to give adequate lessons between informatics and other subject areas.

**Our Research on a Design Framework of Gaming Materials for Information Studies**

To improve the current situation of Information Studies instruction in schools, we have conducted research on the construction of a design framework of gaming materials for information studies (Figure 1) while developing some games and confirming their effects (Hirabayashi et al. 2011, Hirabayashi & Matsuda 2011, Matsuda el al. 2012).
We believe that the design framework of gaming materials can be used as a framework of lesson design. It has the following features:

- Our framework has been constructed in order to integrate Tamada and Matsuda’s method for cyber ethics education into Matsuda’s method for informatics education. The former teaches cyber ethics judgment based on the combination of three types of knowledge (Tamada & Matsuda 2004), while the latter teaches 13 items of informatic and systematic thinking (Matsuda 2003) for utilizing ICT in problem solving.

- Our framework consists of four subprocesses for problem solving and one for reflection, as shown in the rectangles: goal setting, technical understanding, rational judgment, derivation of optimized solution, and review. These categories are based on Savery’s framework of Problem-Based Instruction (Savery 2009).

- We clearly showed students where each of the 13 items of informatic and systematic thinking and three types of knowledge should be applied in the task of problem solving (see the balloons in Figure 1).

- Our framework rendered the whole process into a cycle in order to offer students the opportunity to solve similar problems under various conditions. It also introduced the challenge of flexibly applying their skills to changing circumstances.

- We considered it important to assess how students have demonstrated sufficient knowledge of ICT, how they have harnessed informatic and systematic thinking, and the range of merits/demerits they take into consideration in the problem-solving process.

Figure 1 Design framework of gaming materials for Information Studies (Matsuda et al. 2012)
process, as well as weights and trade-off relations among merits/demerits when the students evaluate the various possible plans. For this purpose, the game remains as underlined elements to the variables in each oval, and these elements are examined as to whether the weights are consistent with the students’ evaluation of each idea in the review process.

We had developed instructional games corresponding to the first three of the four units in one of the two subjects of Information Studies (Ministry of Education, Culture, Science, Sports, & Technology 1999). In the first unit, students learn about digital technology and the utilization of multimedia technology. Therefore, we selected the topic “Designing an Effective Presentation” for the game. In the second unit, because students learn about utilizing the communication network, we developed an “Internet Auction” game. In the third unit, students learn about personal authentication; encryption, rules, and laws related to information security; etc. Moreover, the unit objectives are to acquire knowledge and learn methods of building group consensus regarding rules and policies. Therefore, we selected the topic “Security Policy.”

**Purpose**

In this research, we develop a teacher education program that prompts Information Studies teachers to improve their lessons, using the teacher education program of Ishii and Matsuda (2003) analogically. As they suggested, firstly, we must convince teachers of the necessity of improving their lessons after analyzing their pedagogical misconceptions. Secondly, we should encourage teachers to assume the role of students and play our “Security Policy” game, which will fully familiarize them with all aspects of the game and provide them with insights into the student perspective. Finally, we should ask teachers play a “virtual lesson” game that we developed in this research to simulate a lesson on “Designing an Effective Presentation,” in order to evaluate the adequacy of their decisions and provide feedback on improving their lesson plans based on our design framework.

**Method of Prompting Teachers to Recognize the Need to Improve Their Lessons**

The first goal of Ishii and Matsuda’s program was to prompt teachers to recognize that the objectives of education have shifted from providing knowledge to developing intellectual skills and problem-solving ability. To achieve this goal, they discussed teachers’ misconceptions and misunderstandings about informatics education, proposed instructions in promoting the correct understanding, and examined their effects. The results of their experiment were as follows:

- Although the leading teachers of each school were well aware of the information published by the government, they did not necessarily possess sufficient understanding of its pedagogical meaning. For example, they did not grasp the need for intentional instruction in ways of thinking and problem solving, the difference between informatics education for all and ICT education for people who are to become ICT engineers, etc.

- Student teachers did not even know about published information. For example, they did not know the objectives of informatics education, the difference between
informatics education and the ICT use for instruction, etc. Because some leading teachers who did not know enough about these things could not achieve the subsequent objectives of this program, we should examine how Information Studies teachers achieve this objective.

- As we described previously, many Information Studies teachers have come from mathematics and vocational subject areas. Unfortunately, many of those who did not achieve the objectives were teachers of these subject areas. They tended to conclude that the objectives of informatics education and/or problem-solving ability could be cultivated, as long as problem-solving activities using ICT were offered.

The points discussed above are similar to the issues on Information Studies described in the report of the Central Council for Education (2008). Therefore, it is necessary to iron out these misunderstandings according to the suggestion of Ishii and Matsuda. However, we have to change the example used to persuade teachers to understand the necessity of intentional instruction because the targets of their practice are teachers of various subject areas. Further, Ishii and Matsuda used a case to teach the performance of the horizontal bar, but the targets of our program are only Information Studies teachers.

For this purpose, we decided to show the results of our practice lessons to examine the effect of games developed using our design framework (Figure 1) and compare the effect of Tamada and Matsuda’s method of cyber ethics education with another method that instills many rules for several cases (Tamada & Matsuda 2004). After showing the results, we can explain the necessity to teach the framework of problem solving and cyber ethics/safety judgment, as well as informatic and systematic thinking, intentionally.

Method of Promoting Understanding about the Features of Appropriate Lessons
The second goal of Ishii and Matsuda’s program was to prompt teachers to understand the features of appropriate lessons in informatics education. Because the target of their program was teachers of existing subject areas, its objectives included the removal of the gray areas that cause the teachers to confuse informatics education with the use of ICT for instruction. However, since the target of our program is only Information Studies teachers, it needs to focus on prompting them to understand following things:

- Difference between informatics education in existing subject areas and that of Information Studies
- Difference between getting a better solution using the learned way and getting a good enough solution by seeking a better way
- Difference between informatics education for all and the education of information processing or computer science to produce computer engineers
- Necessity of intentional instruction for the utilization of informatic and systematic thinking in problem solving
- Difference between informatics education in Technology (Industrial Arts) and Home Economics at the lower secondary level, and Information Studies at the upper secondary level.

Although the last item described above was not covered in Ishii and Matsuda’s research, the report of the Central Council of Education (2008) stressed that this point was not clear.
and instruction in Information Studies should focus on cultivating students’ problem-solving ability by increasing the use of ICT. Therefore, we need to add this point to our program.

All above points are concerned with constructing the pedagogy and pedagogical content knowledge (PCK) of Information Studies. Regarding this issue, media literacy educators consider informatics education an extension of the 3Rs, with a focus on understanding information critically (American Association of School Librarians and the Association for Educational Communications & Technology 1998). However, we argue that this objective should be taught as informatics education in existing subject areas because it is more important to use the domain knowledge of existing subject areas to understand information critically. We understand that informatics became necessary with the advancement of ICT, and students should thus learn how ICT works in order to fully understand its features. For this reason, we believe that the pedagogy of Information Studies should be constructed based on that of technology education.

In addition, we believe that the pedagogy of Information Studies should be newly constructed, and not be based on that of information processing or computer science education, for it to promote computer engineers. For example, the United Nations Educational, Scientific and Cultural Organization (1994, 2002) proposed an informatics curriculum for secondary schools. The curriculum, developed by the working group of the International Federation of Information Processing (IFIP), emphasized the use of ICT tools in each domain (subject area) or how to use each ICT tool, such as word processing, spreadsheet, and database, in problem solving. As far as we know, this type of curriculum has failed to cultivate the students’ problem-solving ability at higher education levels in Japanese universities.

A reason for this curriculum’s lack of success was that it was developed for vocational education and emphasized training to operate the software. This is the very topic pointed out in the current issue on Information Studies. We think that the method of information utilization should be taught ahead of the software. For example, students should learn the effective reuse of documents, programs, and data of a certain existing work, as well as the better way of storing information—whether in tabular or chart form—for easier reuse later.

Another reason is that using a certain type of software is a requisite for problem solving in this curriculum, even though problem solving in the students’ daily life involves many choices, such as not to use ICT. For example, in this curriculum, students might learn the operation of the search/replace function of certain software. However, an actual problem does not emerge to test the operational skill of the specific function, but happens instead when a user wants to know how many times a certain phrase was used, check whether he/she used a specific pair of phrases consistently to differentiate nuances across situations, find the files in which a certain phrase was written, and so on. In these instances, therefore, the need to use the search or count function depends on the situation. In fact, even the decision to apply the search function presents many choices—whether to use the said function of a word processor, filer, and so on. Furthermore, various methods to show the results of the search function are used in different software programs, such as jumping directly to the place where the specific phrase is used, highlighting all the places
Matsuda’s informatic and systematic thinking supports this flexible way of thinking, and we consider it necessary to construct new pedagogy for informatics education based on this idea.

Hirabayashi and Matsuda (2011) revealed that students who lacked confidence in their ICT knowledge tended to generate few and inadequate ideas that were inconsistent with their own goals set at the “Goal Setting” process. Therefore, teachers should teach ICT knowledge well before implementing this type of problem-solving activity so that students are properly equipped to deploy this knowledge in their problem solving. However, the above discussion indicates that it is necessary to reconsider what kinds of knowledge to tap and how they should be taught.

Ishii and Matsuda (2003) suggested that showing examples was effective in proving teachers’ misunderstanding. Therefore, our program strives to provide them with an opportunity to learn as students through our game. In addition, we show various examples that indicate difference between adequate and inadequate explanations. We will determine whether to use the “Designing an Effective Presentation” game or the “Security Policy” game after comparing their effects practically.

Method of Promoting the Redesigning of Lesson Plans: Developing a Virtual Lesson Game

At the previous step, our game was assumed to be used by teachers in their capacity as students. At this step, on the other hand, we plan to develop a new virtual lesson game with the assumption that its contents are shown in a lesson conducted by a teacher. The purpose is to prompt teachers to examine an instructional method from a teacher’s viewpoint. We develop the game by using the Simulated Teaching Game mode of Matsuda’s Instructional Activities Game system (Matsuda 2005).

In this game, we assume the teachers’ failures (listed below) suggested by Ishii and Matsuda (2003). Our new game offers the teachers opportunities to evaluate their decision making and then give feedback to them corresponding to the results.

- Unable to intentionally instruct the framework of problem solving by using ICT
- Forgetting to utilize informatic and systematic thinking in problem solving as a lesson objective
- Forgetting to provide students with trial-and-error opportunities and to intend to use a specific method or guide to a specific solution
- Forgetting to provide students with opportunities to generate various alternatives
- Unable to estimate appropriate lesson situations

We need to carry out two simulated lessons and ask for different types of decision making in each lesson. One is the lesson for teaching the framework of problem solving (Figure 1) and the utilization of informatic and systematic thinking in each process. In this lesson, we need to evaluate and improve their decision about the first, second, and fifth points shown above. Another is the lesson providing students with chances to apply the methods and ways of thinking learned in the first lesson, thereby promoting the utilization of what they learned. It is thus crucial that teachers expose students to as many problem-solving activities as possible. Here, we need to focus on the third, fourth, and fifth points shown.
above.

We use the “Designing an Effective Presentation” game to develop a virtual lesson game. The reason for using this game is that many teachers teach this content now with emphasis on training in the use of several software tools and a method of impressive presentation, which is not appropriate in Information Studies. Because the game was designed to perform problem-solving activities repeatedly in changing situations, the first cycle is made into the lesson that introduces a method of problem solving. After the second cycle, the purpose of the lesson changes to providing students with exercises to apply the method they have learned. Before this lesson, teachers need to instruct knowledge about multimedia technology. Therefore, we need to construct a new PCK for Information Studies and provide teachers with choices of contents and method of instruction about multimedia technology including both adequate and inadequate ones.

Employing game material, such as our game, encourages students to indulge in problem-solving activities, but it is advisable to use a worksheet case to adequately control their activities. Therefore, in the game, we offer teachers choices as to what kind of worksheet is appropriate for each lesson. In these cases, the students’ self-evaluation and mutual evaluations become especially important. Though Matsuda et al. (2012) made a rubric to help in the students’ self-evaluation of their utilization of informatic and systematic thinking in problem solving, we will make other rubrics as choices that focus on other aspects, such as the goodness of products and impression of presentation activities.

Discussion and Future Perspectives
In this paper, we examined the teacher education program promoting the professional development of Information Studies teachers. Our aim was to improve the teachers’ lessons and enable them to cultivate their students’ problem-solving ability through the use of ICT. In particular, in order to resolve the teachers’ misunderstanding that Ishii and Matsuda (2003) suggested, we discussed what kind of explanations and exercises will be effective. In addition, we designed the virtual lesson game for carrying out the exercise in which teachers choose the appropriate information presentation and teaching method.

We plan to hold a 1.5-hours lecture for Information Studies teachers in Ibaraki Prefecture early in August and have a chance to conduct a one-day workshop for Information Studies teachers in Aomori Prefecture early in September. We will be able to conduct our whole program and then perform formative evaluation in the latter case.

Using these results and the results of practice lessons that employ the game materials designed by our framework, we need to construct the new pedagogy of informatics education. We also have to make apparent the PCK that includes what students should learn and their misconceptions and misunderstandings that prevent the adequate use of ICT in problem solving. These studies will be the testing grounds of our lesson-design support/training system (Matsuda et al. 2008), which is expected to make teacher education methods in Information Studies more efficient.

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References


Generic green skills: Can they be addressed through Technology Education?

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One of the ancient scripts tells the story of a traveller who met three people on the road and asked them what were they doing? One answered – turning stones, another, - earning money and the third one replied that he was building a church. Although all of them were doing the same job, their intentions were different.

Introduction
The close link between education and economic development established by the 1980s was viewed by governments as a way to increase the relevance of education for economic purposes. A number of measures taken by governments to ensure this link included the introduction of technology education (across all levels of schooling) into the academic curriculum and the increasing presence of vocational courses at the secondary level. As the introduction of technology education sits within this economic imperative (although it performs its emancipatory functions as well), it is argued here that the development of technology education needs to be in line with economic changes.

Current economic restructuring with the purpose of attaining a cleaner, more climate-resilient, efficient economy that preserves environmental sustainability and provides decent work conditions is visible on the global scale. These economic changes require removal of some existing jobs, establishment of new jobs and a change in the nature (or greening) of others. The Asia Business Council Report predicts that the number of new or refashioned green jobs created by 2030 could reach 100 million worldwide, which is estimated at 2% of the future workforce. Although green growth is a relative new-comer as a driving force for employment and training, it has become clear over the last few years that many jobs are changing as green skills are introduced. Technology education need to catch up with these economic changes, therefore it is important to understand what kind of skills, capabilities and attitudes we are targeting as there is an important role for technology education learning within this greening agenda.

Economic development and the greening of economies
It is essential to acknowledge that differences in the level of economic development and in the drivers behind skills change will influence the ways technology education could address the green agenda. Often, economic development is described through three stages: factor-driven economies (stage 1), efficiency-driven economies (stage 2) and innovation-driven economies (stage 3) with a transition phase between each stage. This classification is based on the measurements of national economic competitiveness that provides comparative statistics for ‘evidence-based’ policy development, including education.
Commonly recognised drivers of skills and occupational change associated with green economic restructuring include: i) changing natural or built environments; ii) policy and regulation; iii) technology and innovation; and iv) markets for green industries and consumer habits (ILO/CEDEFOP, 2011). These four drivers have different influences on greening of the economies of countries that are at different stages in their development.

Countries characterised by factor-driven growth face the main economic challenges of using land, labour and capital efficiently. Competitiveness derives from low-cost production and ease of access to external markets. Manufacturing is related to the production of low-value-added goods and services. For them, the first two drivers may play a greater role than the others.

Countries characterised by efficiency-driven growth build their economies on export manufacturing and outsourced service exports. Production is focused on high-value-added goods and services. Competition relates to high quality production based on imported technology. For them, the first two and the last drivers are more significant for greening their economies.

Countries characterised by innovation-driven growth generate a high rate of innovation, adaptation and commercialisation of new technologies, designing products and services at the global technological frontier. These countries are influenced by all four drivers, and particularly, the technology and innovation drive.

Although a number of drivers might be present in each particular country, some of them can have more impact than others. Therefore, the technology and innovation drive is more influential within innovation-driven economies such as Korea; markets for green goods and policy regulations influence the economy in China at its efficiency-driven stage of development; changes in natural environment drive changes in Bangladesh (a factor-driven economy). Within the global economy the process of greening could also be stimulated by the rules and regulations of other countries. The economic development of the Asia-Pacific region, for example, is very much dependent on exports, particularly to the EU, therefore, the production of green goods and provision of green services will be stimulated by the EU laws and regulations.

Australia’s economic development is leading to the innovative-driven model that shapes specific requirements for skills development. Introduction of technology education was justified through the opportunity to develop such ‘skills’ as problem-solving capabilities, team work, creativity, use of technologies through the context of designing and making. The emergence of green economic restructuring puts additional demands on the composition of skills addressed through technology education in each country model/type.

Technology education and employability skills

Opportunities to develop problem-solving capabilities, team work, creativity and the use of technologies within the context of designing and making are mentioned as goals in many technology education syllabuses around the world. Although they are not called employability skills, that is, the ones that are included in vocational training programs and variously referred to as core, employability, generic, key or life skills/competencies, they
are very closely related to them. These ‘generic technology education skills’ play a significant role in ensuring that young people have the necessary skills/competencies to enter and participate in the workforce.

In Australia, for example, the Australian Chamber of Industry and Commerce and the Business Council of Australia define these skills as employability skills, “skills required not only to gain employment, but also to progress within an enterprise so as to achieve one’s potential and contribute successfully to enterprise strategic directions” (2002, p.3). This framework identifies eight main employability skills that have a broader application as they are relevant to a variety of tasks in personal, social and work contexts. These skills can also help individuals to cope with change. Other countries in the region have followed a similar pattern. In 2006, the Singapore Workforce Development Agency identified ten foundational skills that are applicable across all industries. Since then, courses targeting these areas are being included in learning programs, particularly for those who do not have any formal qualifications. Since 2001, qualifications in the Philippines have been based on three types of competencies: basic (generic work skills), common (industry specific) and core (occupation specific). Some examples of basic competencies are: leading workplace communication, leading small teams, developing and practising negotiation skills, solving problems related to work activities.

The importance of these core/generic competencies have been demonstrated by Australian employers’ requiring employees who are creative problem-solvers, and innovators and able to update their knowledge and expertise on a continuing basis. Employers are looking for employees who are adaptable and who have skills beyond the technical; 33.1% of employers consider employability skills to be the most important factor when employing graduates. Their multi-dimensional nature being comprised of “know-how, analytical, cultural and communication skills, and common sense”. [These] can help to provide an active and reflective approach to life for the employees. Therefore, the importance of developing these generic capabilities through technology education to increase chances of school leavers in adjusting successfully for livelihoods and employment should not be underestimated.

Technology education is not the only academic subject that responds to economic development needs. A comparative study between Scotland, Germany and Poland examined prevocational models applied in these countries aimed at achieving a better understanding of the world of work and providing students with experiences and learning within ‘near-work’ environments. A pre-vocational curriculum was identified as a range of competencies covering the broad economic and business environment, firm specific knowledge and a range of core competencies and general skills. The curriculum was offered as a separate subject area within the school (Scotland) or integrated within existing subject areas (Germany and Poland). The pre-vocational curriculum was integrated with the Civic Education (Poland) and within Social Sciences and Geography-Economics-Politics (Germany).

The study identified a match between different types of economies (the liberal market economy - Scotland, the coordinated market economy – Germany, and the mixed market economy – Poland) with the structure of the syllabus and the competitive core competences identified for each of the countries. In the case of Scotland, the emphasis of
the pre-vocational curriculum was on general and transferable personal skills as per a core competencies model. Self and social competencies as internal locus of control, risk-taking, communication ability and team ability were most important. In Germany, the wider economic and market environment and social and collective competencies prevailed over competencies in business. These competencies were knowledge-based in the field of trade and globalisation, teamwork abilities and communication competencies (the role of enterprises within the debate on economic restructuring and globalisation and the new developments of new technologies). In Poland, the priority was given to the wider market economy, including aspects of the labour market and industrial relations. The most dominant competencies were: labour market, communication ability, monetary system, government policies, income, and indicators of the economy. Self-competencies and competencies related to the level of individual firms gained very little attention in Poland. In each country there was a very weak link between the prescribed and the taught curriculum within the schools as teachers had decided to prioritise certain aspects of the curriculum and exclude others (Scotland and Germany) or the teachers were not trained adequately enough to teach the subject area and/or had insufficient resources to do so within an already overcrowded curriculum (Poland). The results of this study demonstrate the importance of the cultural and economic contexts in identifying and influencing the nature of pre-vocational education, including employability skills development. Therefore, although many technology education syllabuses state similar things in terms of development of students’ capabilities and skill, learning in technology education classes should be culture and context-specific. In the Australian liberal market economy an emphasis on general transferable personal skills needs to be addressed in technology education.

**Technology education and Education for Sustainable Development**

How does the need to address economic development issues in technology education relate to SD? I have argued elsewhere that SD is the most appropriate framework for curriculum development in technology education and that two essential bases for ESD pedagogy in technology education are:

- weak anthropocentrism as the ethics behind ESD that focuses on human well-being to be achieved in harmony with nature; and
- a combination of value change and technical fix approaches

Throughout the history of humanity, the relationship between humanity and nature has been one of the most important existential and philosophical issues. In traditional cultures the unity of humanity and nature has been presented within an overall perception of the world; some indigenous cultures still preserve this view. Through historical development, particularly in the West, technological development and an increase in technocratic ideology, linked with the expansion of human power through technical control (Habermas, 1968/1971), has greatly contributed to environmental and social problems and, as a consequence, to the emergence of a discourse about SD.

The differences in views of the relationship between humanity and nature are partly rooted in different philosophical and moral conceptions of appropriate ways to conceptualize these relationships. On the opposite sides of the debate are ecocentric...
environmental ethics and ‘deep ecology’ (which attribute intrinsic value to nature and suggest that humans should live according to nature), and anthropocentric or technocratic environmental ethics (which attribute instrumental value to nature and suggest that humans should use and manage nature wisely).

Weak anthropocentrism, the environmental ethic that promotes the mutual flourishing of human and non-human nature (for a full discussion see Pavlova, 2009), characterizes the founding principle formulated in the ‘Caring for the Earth’ strategy of IUCN, UNEP and WWF (1991). Among the nine principles for Sustainable Living formulated in the strategy, one provides the ethical base for all the others: Respect and care for the community of life, meaning duty to care for other people and other forms of life now and in the future.

Therefore, a conceptualization of sustainable development within a framework of weak anthropocentrism which involves valuing of the ‘other’ (human and non-human), can provide a basis for the development of pedagogical approaches within ESD in technology education.

Green economic development could be narrowly interpreted as industrial ecology that does not represent a sufficient response to the challenge of the modern world, because reductions in the environmental impacts of national economies do not necessarily translate into improvements in the quality of life for all. This narrow approach (a ‘technical fix’) might treat only the symptoms, not the disease and root causes. Rather, to achieve changes towards sustainability, a ‘value change’ is required. A fundamental change in underlying values and attitudes that would characterize a radical shift in our thinking is part of the transformative journey for achieving sustainability. Technology education is well positioned to apply both approaches (technical fix and value change) framed by the ethics of weak anthropocentrism. This approach defines the types of green skills to be included in technology education and the ways of inclusion.

**Green skills for greening economies**

In many countries job creation in renewable energy, retrofitting of existing buildings, mass transportation, wastewater management and environmental conservation is in progress. So, multiple initiatives are in place to train for greener jobs. However, different level of economic development and other factors influence the ways green skills are interpreted and developed. Figure 1 presents the relative importance of specialised; ‘top-up’ and generic skills for greening economies. The CEDEFOP (2010) study suggests that the retraining required for workers to convert to an occupation in an entirely different, greener industry will not occur on a massive scale. The majority of skills development responses are related to up-skilling, or adding to existing core skills to enable a person to fulfil a new occupation. Topping-up skills could be firm or industry specific for structured economies and job-specific for informal and non-formal economies and could be addressed through existing education and training system.
CEDEFOP, 2010

Generic green skills are required in almost any occupation to understand and appreciate the issues and demands of green growth. Specialised green skills that relate to new green occupations are deemed to be country specific, as what is in one country may be topping up on existing skills but could be the development of new training packages for newly established occupations in other countries. In some countries occupations related to renewable energy, waste management, green business management could be new. Education priorities for green skills development will vary depending on the stage of economic development of the country. For factor-driven countries a large proportion of non-formal green skills training and entrepreneurial training could be appropriate. However, to stimulate efficiency improvement, some training at a higher level is required (e.g. skills development in the renewable energy sector in Bangladesh). For efficiency-driven countries the development of low-level vocational skills required by skilled workers should be balanced by the higher level green skills required for technicians. Innovation-driven countries need to put more emphasis on the high skills required by engineers and scientists to stimulate development of new green technologies, so a well-developed higher education system will be linked to research (e.g., EU countries are putting a special emphasis on STEM – science, technology, engineering and mathematics).

This paper argues that generic green skills should become a part of generic/employability skills, then these ‘enriched’ employability skills could help to address successfully economic needs of greening.

**Technology education and generic green skills**

What is the nature of generic capabilities for Australian technology education within a green agenda when technology and innovation are the main drivers for economic...
development and a liberal market economy is prevailing? Why is it important for technology education to address this call for green skills development? What type of skills should be addressed?

Currently discussions on greening skills are mainly related to vocational education and include both generic and specific skills. This paper argues that generic green skills need to be addressed in TE as they constitute new, 'enriched' employability skills. A green economy requires the development of generic green skills (among other skills) that are in demand in almost any occupation (Pavlova, 2011). These generic green skills help to prepare the future workforce to understand issues of green growth (including environmental, social and economic aspects), to interpret environmental legislation, to increase energy and resource efficiency to enable the processes involved in greening the economy. Several generic green skills are presented below as candidates for the generic green skills list, however, research is required to shape the list more accurately (adjusted from Pavlova, 2011):

- Environmental awareness and attitudes and willingness to learn about sustainable development, issues and challenges of SD;
- Coordination and management skills for holistic and interdisciplinary approaches towards design solutions to meet economic, social and ecologic objectives;
- Entrepreneurial skills to seize the opportunities of low-carbon technologies;
- Innovation skills to identify opportunities and create new strategies to respond to green challenges;
- STEM skills: general understanding of the role of the science, technology, engineering and mathematics' contribution to the process of greening economies and societies;
- Analytical thinking skills: As business and industry move towards a genuinely sustainable model it will be necessary to understand the thinking behind a closed-loop economy and how this differs from the traditional linear model of economic development.

These generic green skills will enrich employability skills currently addressed through technology education. They will also operationalize ideals of sustainable development. The re-orientation of individual values towards greener development empowers technology education students with new visions of reality and the means to achieve them. Technology education could provide important means to focus on human agency to develop green skills by effectively changing awareness, perceptions, attitudes, understandings and behaviours relating to the natural and social environment and in developing responsibility and connections with the natural, social and economic settings.

**Summary**

If we go back to the ancient story stated at the beginning, TE moved away from MA (turning stones) to TE that addresses employability skills (economic imperative, competitiveness and increase in earnings). Now, the next move is required towards TE with enriched (green) employability skills, the one that has a vision of a better world where multiple initiatives are in place to enhance green growth.
A new national curriculum in Australia is taking shape and sustainability is an important consideration for organising the curriculum. Development of generic green skills shaped by the ethics of weak anthropocentrism together with government initiatives aimed at green growth will help to achieve aspirations to move towards a greener economy. However, skills development for greening needs to be carefully planned at the country level to account for differences in economic and social conditions. For Australia, generic green skills could be linked with employability skills that need to be addressed through a number of subjects including technology education.

The inclusion of generic green skills into TE curriculum will help to address economic needs of countries and to stimulate personal developments of students. Environmental awareness, challenges of SD, holistic approaches to design, innovation and analytical skills, STEM skills compacted in green employability skills to be developed in the context of designing and making. Social, technological, economic and environmental aspects of design addressed through technology education will help countries to address challenges of transformation to a greener economy.

References


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Determinants of good practices in technology education

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What is a good practice, what is the best practice? Are there bad practices? Are we talking about teachers’ practices, students’ practices, pupils’ practices, the practices of curriculum developers, education administrators, people within or outside the school system - practices in classrooms, practices in developing the curriculum or learning materials? Do we emphasis the epistemological approach or do we put more emphasis on the ontological approach? What is the relationship between content, context and concept learning? Do we want to emphasize individual learning or co-operative learning? This paper will discuss the determinants of good practices and introduce results emerging from an extensive technology education development project. During the project criteria to evaluate the best practices were developed through various studies and practical experiments. Also some preliminary results from the on-going study of an abstract problem solving project are presented.

What influences good practices?
The authors have long felt that the vast field of technology education and pedagogy needs some analysis and discerning investigation. Educators obviously need tools to determine good practices. We therefore planned a model (Figure 1) of various determinants which we believe have an impact on teaching and learning processes. This is a tentative model which will be modified according to future study results and is open for discussion by scholars. Most obviously more determinants will emerge as the research proceeds.

Figure 1 demonstrates how some concepts can be seen as distantly removed from each other, but instead of this distance there should be more discussion, overlapping and collaboration between the practices in order for the learner to experience the “good practices”. By applying project working methodology, in which the learner(s) plan the project from the outset to the final outcome, and by consciously diversifying the projects to cover as wide an area as possible, an extensive variety of “good practices” may be achieved. It is essential to note that the learning objectives should always lead the way in project working.

Ideas for the model of determinants of good practices have been withdrawn from several sources. For instance DeVries (2005, pp. 3-4) and Feenberg (2006, pp. 6-10) discuss the philosophy of technology. The relationship between curriculum, learning materials, society, learners and organizers of education have been dealt with for instance by Marsh (1997, pp. 95-103, 130), Rasinen (2000 p. 129-131) and UPDATE, 2009. deVries (2010, p. 24), Rossouw, Hacker and deVries (2011) reflect the interconnection between content, context and concept. The concepts of problem solving and co-operative learning have been described by for instance by Murphy and Hennessy (1999, 2001) and
Seitamaa-Hakkarainen (2010). However, the model is a product of several discussions and thinking of the authors of this article.

![Figure 1 Determinants of good practices](image-url)

The statements of good practices will obviously differ if we ask the question of a person whose approach is focused more on “knowing about things” generally speaking, i.e., epistemologically oriented, or of a person who is more interested in existence or the meanings of being, i.e., ontologically oriented. Or could it be that good practices can be a combination of the two or a consensus of the two viewpoints?

Education administrators and the surrounding society have their expectations of school education. Also curriculum and learning materials and learning environment regulate what goes on in schools. They affect and give focus to what can be regarded as good practices. Curriculum is always a compromise of political and educational perceptions.

In the classroom there is co-operation taking place between teachers and pupils and the definition of good practice may differ from the viewpoint of these two groups. The objective is naturally for the pupil to achieve the aims of the learning session or the curriculum. The practices, therefore, should be good particularly for the learners.

One way of stating the intended learning outcomes is to list the various contents to be studied. It has been realized, however, that a mere list of learning contents does not necessarily lead to the desired results. The contents should be studied in a relevant context. If the contents are studied in practical situations, in a proper context, there is reason to believe that learning is more meaningful to the learner and learning takes place. (deVries,
Rossouw, Hacker and deVries (2011) have expressed their views on the connection of context and concept learning. They suggest that “by teaching concepts in a variety of contexts gradually the learner will start to recognize the more generic nature of the concepts and be able to apply it in new contexts” (Rossouw et al., 2011, p. 423).

If emphasis is put on individual learning rather than learning of co-operative skills, the good practices will be expressed in a different manner. Final assessments, testing of pupils and monitoring of learning achievements may lead to the aim of achieving good marks in the final assessments for individuals only, and the social and co-operative aspect may be neglected.

Until quite recently it was quite common for pupils to copy the teacher’s model during craft lessons. The move from craft education towards technology education has also changed learning methods and pupils are increasingly encouraged to apply problem solving strategies.

**The UPDATE project – best practices**

Several European Union (EU) partners cooperated in creating a framework for analyzing technology education in order to enable a comparative analysis of the technology education curricula at primary level in the countries participating in the UPDATE Project. During the project criteria to evaluate the best practices were developed through various studies and practical experiments. UPDATE (Understanding and Providing a Developmental Approach to Technology Education), which was funded by the sixth framework programme priority (Science and Society), began in January 2007 and ceased in December 2009.

Proposals for best practices were collected by the end of the second year of the project. Through various studies (Rasinen, Virtanen, Endepohls-Ulpe, Ikonen, Ebach, & Stahl-von Zabern, 2009; Dow & Dakers, 2008; presentations at the UPDATE meeting 2009) criteria to evaluate the best practices were presented. The list of ten criteria is as follows:

- **Support of positive attitudes towards technology studies**
  In order to motivate pupils to pursue technological studies it is important that their curiosity is awakened at the early stages of education and that interest and motivation is sustained throughout schooling and after this. The first step is to raise pupils’ awareness of the technology around them. It is extremely important to note that it is a question of positive attitudes towards technology studies, not solely towards technology itself. A critical approach must be maintained.

- **Promoting knowledge and understanding**
  The pupils should learn how to analyze and classify the technology around them, search for and find solutions to technological problems, familiarize themselves with various materials, tools and equipment and also understand some concepts connected to technology. In addition pupils should understand the various viewpoints on using technology.

- **Promoting equality by giving opportunities to differentiate the tasks**
  Various studies (Murphy, 2006; Sanders, 2001; Rasinen et al., 2009) state that gender has to be taken into account when planning educational project tasks. Girls might
often associate technology and the way of working with the masculine, rather than the feminine. Therefore, teachers should pay attention to providing pupils, especially girls, with opportunities for choosing what they want to create. (Virtanen & Ikonen, 2011.) Naturally the age level must also be considered. On top of these considerations, pupils' cultural and ethnic background must be taken into account.

• **Collaboration, communication**
  Many pupils seem to find various forms of co-operative learning an effective learning strategy when solving technological problems in theory and during hands-on sessions. One of the results of the study of Dow and Dakers (2008) was that after the activities a higher number of pupils stated a preference for working in groups rather than in pairs or alone.

• **Recognition of problems to be solved**
  Pupils should be guided not only to solve problems but also to actively observe their daily living environment in order to identify problems. They should not accept solutions found by somebody else, but find out solutions meaningful to themselves. Therefore, teachers should not give ready-made models or solutions to the pupils.

• **Problem solving skills**
  During the school years attention should be paid to finding various ways and strategies for studying problem solving skills.

• **Encouraging creative problem solving, inventiveness, innovativeness, integration between various subject areas/themes**
  Pupils should be encouraged to solve problems in a creative and innovative manner, and to be inventive. Teachers should see the curriculum in a holistic manner and work in a theme-oriented way. Play, exploration, discovery, imagination, open ended tasks and encouraging pupils to find various solutions to a specific problem will assist pupils in being creative.

• **Experiences / sense of success and accomplishment; strengthening of self-esteem, empowerment**
  If pupils experience positive feelings of success, feel that they have accomplished the task in hand, their self-esteem will be reinforced and this feeling of empowerment will give them strength for new challenges.

• **Skill practice**
  Naturally, without the know-how related to tools, equipment and materials, it is difficult to accomplish any task in technology education. Therefore, ever deepening skills have to be studied when proceeding from lower to upper grades. This is relevant not only for hands-on skills but also for designing and thinking skills.

• **Self-assessment**
  Learning should be self-directed where assessing one's learning process should be an integral part of the studies. Once involved in a technology project, from planning to final product, learners should assess their learning process, the meaningfulness of the activities, the functionality of their solutions, and the ethical perspective, for instance, environmental sustainability.

The structure of the presentation of good practices in the UPDATE findings is different
from the conceptual framework presented in Figure 1. However, there are several overlapping and common sectors in the two.

**Problem solving in technology education**
The rationale for creative problem solving learning projects is based on the concept of Problem Based Learning (PBL), where pupils are encouraged towards creativity, innovativeness and inventiveness. According to Ikonen (2008) there are three kinds of problems that can be tackled in technology education:
1. problems that have only one solution or a small number of solutions (e.g., mathematical problem solving tasks)
2. everyday life problems, “real problems” (no right or wrong answer, e.g., "how to keep my desk tidy")
3. abstract problems, where the idea is to learn problem solving skills

Features of problem solving skills include, for instance, the following: ability to recognize problems, ability to accept feelings of frustration, innovativeness, playfulness, creativity and flexibility.

**Trick Track - an example of a good practice**
Virtanen and Ikonen (2009) conducted a study of students' perceptions on the learning of problem solving skills through the Trick Track project. The emphasis was also on co-operative learning. A total of 59 students, 10 men and 49 women, participated in the study. Later on the study expanded to include 140 students but the results have not yet been reported. Because of the limited number of participants no generalizations can be made at this stage. The study was implemented by asking 2nd-year teacher education students completing a basic course in technology education to fill out a questionnaire at the end of the Trick Track project session. Students experienced the learning process before filling in the questionnaire. The instructions for the project were:
1. The task is to build a Trick Track for a metal ball by making good use of the frame and given materials
2. The ball must do a few tricks and keep on rolling as long as possible
3. Previously studied skills must be put into practice: basic metal working techniques (cutting, bending, filing, sawing, marking, bending acrylic, pop riveting); also use of machines (drilling and spot welding)
4. Work in groups of three persons (co-operative working strategy)

There are an endless number of possible applications. This provides students with challenges but also with opportunities. The main objectives of the learning session are to solve problems through experimental learning and gain experiences of success by performing hands-on activities, but also to accept feelings of frustration. The students will learn co-operative learning strategies, innovation strategies, understanding of the technical world and application of their know-how of materials, tools and equipment in practical contexts. In short, the objective is to combine the learners' know-how with inventive solutions. The learning experience will hopefully create positive attitudes towards technology education studies.
**Students perceptions of problem solving task**

Virtanen and Ikonen (2009) examined various aspects of the students' views. Here we present only those dealing with what students regarded as best for their personal learning and pedagogical viewpoints.

In general, more than 50% of the students evaluated this kind of project as a good practice for using various materials, tools and techniques. In addition co-operation and working in a group was mentioned in several students' answers. An interesting difference between the answers of women and men was that 6/10 (60%) of males, but only 12/49 (24%) of females, mentioned creativity and finding new solutions. (Virtanen & Ikonen, 2009.)
Figure 3 What was best from the pedagogical point of view (Virtanen & Ikonen, 2009).

Half (51%) of the female students mentioned that pedagogical understanding of the problem solving process was developed during the project. The second most frequently mentioned aspect among women and men was cooperation, working in a group (social aspect of learning). The difference between the answers of women and men was in creativity, sussing out and playfulness. Only 12/49 (24%) of females compared with 4/10 (40%) of males mentioned this as the pedagogically best aspect of the project.

The results of this study also seem to have congruities with the conceptual framework (Figure 1) and the criteria of best practices developed within the UPDATE project.

Discussion

The conceptual framework presented at the beginning of this article describes some general considerations which may have an effect on how best or good practices are interpreted. There is no doubt that they are reflected in the criteria of best practices which were developed through several studies conducted during the UPDATE project. The determinants of good practices derive from the thinking of the present authors, who have also carried out research in the UPDATE project. Therefore, it is quite possible that the UPDATE findings are also reflected in the framework figure, although not deliberately. The authors are also together involved in teacher education. Close co-operation certainly affects the thinking and teaching of the three researchers. It is, however, interesting to
note that although good practices have been approached from three different angles (determinants of good practices, UPDATE criteria, Trick Track), there are many overlapping domains.

It can be argued that the idea of project working could be seen as an appropriate strategy for implementing good practices. In Figure 1 it lies at the center of the framework and also seems to be well represented in the Trick Track approach. Problem solving and related skills, such as innovative actions, are found to be essential in all three analyses. Interestingly, identifying of problems can also be clearly found in the UPDATE and Trick Track data and implicitly in the framework (Figure 1). Co-operative working and studying skills are valued by EU partners as well as by Finnish students. It is difficult to achieve the objectives of project working without the know-how related to materials, tools and techniques.

There are still today schools where pupils are individually copying the teacher's "good old model". Schools providing general education should no longer think back to old pre-vocational education, but bravely shift the direction of education towards today's and tomorrow's society. The purpose of this paper has been to offer some suggestions on how to identify good practices appropriate to the activities and daily routines of particular schools.

References


Professional Development Needs for Technology Education

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Technology education professionals continue to work to improve their school subject. Authors discuss the results of two research studies undertaken to determine major professional development issues that the profession may seek to explore for the betterment of this school subject. The results are assembled from two Delphi method studies. One study panel was composed of 32 international technology education researchers representing 20 countries. A similar study was undertaken with a panel of 17 U.S. technology education researchers. Reported are 13 topics that might lead to further professional development work for this school subject.

Introduction

The importance of designing, developing, and implementing research-based professional development activities has been well documented in the literature over past two decades (Darling-Hammond, 1998; Glickman, Gordon, & Ross-Gordon, 2004; Lieberman & Miller, 1999). Some efforts have even resulted in “models” of professional development to address these needs (Avery, 2009; Custer, & Daugherty, 2009; Glickman et al., 2004). These models, purportedly, are based on best practices as the literature is replete with examples of what constitutes good professional development practice.

The genesis for the authors’ interest in professional development evolved from their initial work on two separate studies that sought answers to identifying research needs for technology education (Martin & Ritz, 2012; Ritz & Martin, 2012). Their two studies complemented one another in both purpose and scope. One study sought the professional judgments of an international panel of 32 researchers representing 20 different countries (excluding the United States); the second study gathered feedback from 17 researchers, all from the United States. As data for the two studies were collected using a four round Delphi method, it became apparent that some of their identified and highly ranked research issues were not actually research issues at all, but they were developmental issues.

Developmental issues may best be addressed through an organized professional development program or activity. Professional development may conjure up an array of images about what constitutes best practices in both pre-service and in-service education. As used in the context of this study, however, a development activity involves individuals working together to address a specific problem in their profession. For example, a development activity may be associated with reaching consensus on (a) curricular issues, (b) marketing strategies, (c) political strategies, (d) professional development programs, or (e) recruitment strategies. The goal of a development activity is to reach consensus among the participants. It may or may not result in a tangible product such as a formal document.

The researchers present the important research-based professional development needs
to support the efforts of professionals who work within the technology education school subject. It is not the researchers’ purpose or goal to identify and present professional development models or best practices to address these needs.

**Review of literature**

Human development can be defined as a function for enhancing people on their physical, intellectual, and social levels. In this study the researchers were interested in all three of these areas of development of people who work with technology education as a school subject. Much of the literature on human development related to education has focused on the pre-service development of teachers and then their professional development (in-service) after they enter the teaching profession. Both are focused on enhancing human development. Pre-service education focuses on how (method) and what to teach (content). In-service is used to refine these skills and abilities. In the initial preparation of teachers, teacher educators and school mentors increase the intellectual, physical, and social development of candidates on the content to be passed on to learners through technology education, how to design and make using technology to solve problems, and on enhancing social perspectives on the impacts that technology has on societies, cultures, and the environment.

In-service education often focuses on strategies that lead to improved student learning, how to integrate new technologies into curriculum, and in recent years (a) how to better assess learners and (b) how to use technology education to reinforce students learning in the core subjects (Wright, 2002). Additional professional development occurs as a result of attending teacher professional conferences, by reading professional publications, and through involvement in professional association committee work.

In an earlier study by Ritz (2012), it was found that countries experience different developmental issues relating to their technology education programs. He categories these issues as (a) image or understanding, (b) curriculum, (c) teacher preparation, (d) teacher professional development, and (e) political change and funding. For his study, image and understanding issues were defined as opinions on concepts of something that is held by others. Curriculum was defined as a program for the preparation of learners; a group of related courses, often in a special field of study. Teacher preparation was defined as the process of preparing teachers. Professional development implies an intensive approach to improving people to more effectively prepare those they teach or supervise. Political change occurs when the government, in this case ministry or department of education, changes the requirements for schooling and the funding associated with the education of its population.

In conference papers from PATT-25 held in London (Stables, Benson, & de Vries, 2011), numerous papers were published related to ongoing research in technology education. For example, Koyce and de Vries wrote about images of upper secondary school children and their views of engineering. Mioduser and Kuperman also discuss image when they researched children’s perceptions of artifacts. Virtanen and Ikonen wrote about image when seeking to encourage girls to study technology in primary education. For purposes of professional development, these writings support that technology educators from these countries are continuing to work to improve the image and
understanding of technology education by children and others.

From the same edited book (Stables, Benson, & de Vries, 2011), writings are available that address professional development needs related to curriculum studies. Bailey addresses shaping the initial primary teacher training program by including computer control in the curriculum. Hacker, Rossouw, and de Vries discuss adding concepts to the engineering and technology curriculum, so teachers will not solely focus on teaching engineering activities but include important concepts that are needed by all learners. Again, curriculum change is a major topic in the professional development of technology education teachers.

Professional development in teacher preparation is also addressed in the same conference publication (Stables, Benson, & de Vries, 2011). Atkinson, Knox, and Hardy describe the differences in technology teachers trained as undergraduates from those trained as post-graduates. Forrest, Fox-Turnbull, Granshaw, Miller, O'Sullivan, and Patterson discuss how they reached consensus in developing resources for pre-service technology teacher preparation in New Zealand. Again, determining improved ways to prepare technology education teachers does include professional development for faculty members in technology education teacher preparation.

Teacher professional development activities are also included in the PATT 25 publication (Stables, Benson, & de Vries, 2011). Antonopoulou writes about using story-making in design and technology teaching for elementary aged learners. Barak conveys his successes with a graduate course for mathematics, science, and technology education teachers, where he includes using hands-on laboratory activities to teach technological concepts for all teachers to use. Chikasanda, Williams, Otrel-Cass, and Jones discuss how student's perceptions towards technology (PATT) can be used as a professional development tool by technology education teachers. Again, teacher professional development can be a significant topic when our profession speaks of ways for improving its delivery for teacher development and the teaching of children.

Another area where professional development activities assists technology education professionals is to better position this school subject for weathering political change and its related funding measures. As reported within Stables, Benson, and de Vries' (2011) publication, de Jager discusses the latest changes impacting technology education in South Africa, while McLaren identified the various types of technology programs that are not uniting in Scotland's efforts to create a Curriculum for Excellence. As can be gleaned from PATT-25 proceedings, when government officials meddle with educational policy, professional development efforts can be used to adjust to or alter these changes.

With so many directions and circumstances, it is difficult for technology education professionals to decide which developmental issues to take a vested interest and which to do nothing about. Often educators just work through one crisis after another without a plan for how to stay on course. The important message is to be prepared and stay ahead of impending change. Through the findings of two research-based studies, the authors will discuss topics that the profession may choose to move forward to prepare for the demands to be placed on technology education during the second decade of the 21st Century.
Research procedures

In two studies conducted by Martin and Ritz (2012) and Ritz and Martin (in press), they sought to identify major research needs for technology education. The target populations for their studies consisted of (a) 17 individuals from the United States, each of whom had previously been named recipients of the Council on Technology and Engineering Teacher Education’s (CTETE) Teacher Educator of the Year award and (b) 32 individuals from 20 different countries (excluding the United States) who had been nominated to participate in the study through a peer nomination process. In their letter of invitation to participate in both studies, Martin and Ritz stated the following as the purpose of their studies:

To assist those who practice research within the technology education school subject (technology education, technology and engineering education, etc.), we are undertaking a study to determine those topics that leading professionals who work in this area believe need further examination. . . . We believe that continued research is healthy and can be a basis to support the need for our school subject. Unfortunately, at this time we are just not sure of the leading topics that collectively the profession feels need to be researched and we need your assistance.

In their two studies, Martin and Ritz also noted that identifying research issues in technology education to inform decision making is not a new topic for the profession, but it is one that constantly needs the attention of those individuals who teach the technology education school subject. For example, throughout the history of CTETE, five CTETE yearbooks (Israel & Wright, 1987; Porter, 1964; Reed & LaPorte, 2010; Rowlett, 1966; Van Tassel, 1960) have been devoted to research. In addition, the Center on Education and Training for Employment, funded through the U.S. Department of Education, has sponsored studies that reported on what research had been conducted in technology education with reflections upon what needed to be further researched by members of the profession. These analyses were conducted by Dyrenfurth and Householder (1979), Householder and Suess (1969), McCrory (1987), Streichler (1966), and Zuga (1994). The PATT and TERC conferences have been highly successful in reporting research and related activities in technology education and the Sense Publishing series has added significantly to the body of literature on research and best practices in technology education.

The Martin and Ritz (2012) and Ritz and Martin (in press) studies used a four round Delphi method to gather input from the two separate groups of panelists. In Round 1, for example, the researchers instructed the panelists to respond to the following two research questions:

1. Research Question 1: What is the most important issue that needs to be researched related to K-12 technology (and engineering) education?
2. Research Question 2: What is the most important issue that needs to be researched related to preparation for teaching this school subject?

In Round 2 of their two studies on Research Needs for Technology Education, they sought to draw consensus on the topics the panelists believed were important to establish a better knowledge base for the technology education school subject. To assist the panelists, the researchers instructed them to use a 5-point Likert scale (e.g., Most Relevant Issue, Significant Relevant Issue, Moderate Relevant Issue, Limited Relevant Issue, Not Relevant Issue) to rate the importance of each issue identified in Round 1. Once the panelists'
responses were received, a point value was assigned to each part of the scale (e.g., Most Relevant Issue = 5 points . . . Not Relevant Issue = 1 point).

In Round 3, the researchers provided the panelists with statistical data for each issue gathered from Round 2, specifically the mean, median, standard deviation (SD), and interquartile range (IQR). Also provided to the panelists was a reminder of their individual Round 2 responses to each issue that had been originally identified in Round 1. The panelists were instructed to consider all the statistical data that were provided to them and either confirm their original (Round 2 response) rating of each issue or modify their ratings.

As the study evolved through the first three rounds, it became apparent through formal and informal feedback from the panelists that some topics originally identified as “most important issue that needs to be researched” were not really research issues but was development issues that could best be addressed through an organized Development Activity. Round 4, therefore, provided the panelists a final opportunity to either confirm each issue as a research issue or change their original recommendation to a development issue. To assist the panelists in making their final recommendation, the mean, median, SD, IQR, and CV (coefficient of variation) were provided for each issue.

Findings
The target populations for these two studies provided valuable input to identify development activities that should be undertaken by individuals who practice the teaching of technology. When analyzing the data from the two studies, the researchers arbitrarily decided that for an issue to be considered as being addressed “best” through a Development Activity, 51% of the panelists had to recommend it in their responses.

As a result of input received in Round 4 from the United States’ panelists, a review of the issues identified as Development Activity for Research Question 1 revealed that seven issues met the 51% threshold. These seven issues are the following:
1. Perception of technology and engineering education
2. Contributions of technology education
3. Content that is valued
4. Social confusion between technology and science
5. Value of research
6. Serving all learners
7. Identify a unique focus for this school subject

However, if the researchers applied the same criteria used for the studies on Research Activity issues (i.e., a mean score greater than 3.50, an IQR of 2.0 or less, and a CV of 0.50 or less), only one (14%) of the seven issues for Research Question 1 met the criteria for a Development Activity. This issue is “content that is valued.”

As a result of input received in Round 4 from the panelists of the “international” community, a review of issues identified as Development Activity for Research Question 1 revealed that nine issues met the 51% threshold. These nine issues are the following:
1. Adding meaning to technological literacy
2. Understanding thoughtful human inventiveness
3. Practice in technology and engineering education as a school subject
4. Ambiguity of the technology and engineering education teaching area
5. Inconsistency in international definitions of technology education
6. Internationally acceptable standards for technology and engineering education
7. Clarification of the aims and purposes of technology education
8. Identification of a broader framework for K-12 technology/engineering education
9. Quality of the school subject for technology teachers

However, if the researchers applied the same criteria used for the studies on Research Activity issues (i.e., a mean score greater than 3.50, an IQR of 2.0 or less, and a CV of 0.50 or less), only six (67%) of the nine issues for Research Question 1 met the criteria for a Development Activity. These six issues are the following:
1. Adding meaning to technological literacy
2. Understanding thoughtful human inventiveness
3. Practice in technology and engineering education as a school subject
4. Ambiguity of the technology and engineering education teaching area
5. Clarification of the aims and purposes of technology education
6. Identification of a broader framework for K-12 technology/engineering education

In both of their studies, the researchers followed the same procedure that had been used in analyzing data for Research Question 1 when analyzing data for Research Question 2. The panelists from the United States identified four development issues in Round 4 for Research Question 2; that is, 51% of the panelists believe these four issues could best be addressed through a Development Activity.
1. Need for refined content and process standards
2. Strategies to teach engineering design
3. Appropriate teacher preparation model
4. How do students and teachers learn technology and engineering

However, when the researchers applied the same criteria used for the Research Activity issues (i.e., a mean score greater than 3.50, an IQR of 2.0 or less, and a CV of 0.50 or less), only two (50%) of the four issues for Research Question 2 met the criteria. These issues were (a) “need for refined content and process standards” and (b) “strategies to teach engineering design.”

The panelists representing the international community identified eight development issues in Round 4 for Research Question 2. These eight issues are the following:
1. The effects of a (good) technology programme on learners
2. How teachers in training can be taught to use mathematics and science in their teaching
3. The pedagogy of teaching designing for secondary students
4. Designing programs leading to student understanding of the nature of technology
5. Designing programs to make technology “teachable”
6. Developing curriculum and pedagogy for thoughtful human inventiveness
7. Delivering a research-based teacher preparation curriculum
8. Addressing sustainable development through technology education

However, when the researchers applied the same criteria used for the Research Activity
issues (i.e., a mean score greater than 3.50, an IQR of 2.0 or less, and a CV of 0.50 or less) to the Development Activity issues, only four (50%) of the eight issues for Research Question 2 met the criteria. These four issues are (a) “the pedagogy of teaching designing for secondary students,” (b) “developing curriculum and pedagogy for thoughtful human inventiveness,” (c) “delivering a research-based teacher preparation curriculum,” and (d) “addressing sustainable development through technology education.”

**Discussion and conclusions**

In summary, the Development Activity issues that need to be addressed by educators who teach the technology education school subject in the United States are the following:

1. Content that is valued; $M=3.53$, Med.$=4$, SD$=0.87$, IQR$=1$, CV$=0.25$, rated development by 56%
2. Need for refined content and process standards; $M=3.94$, Med.$=4$, SD$=0.97$, IQR$=1$, CV$=0.25$, rated development by 69%
3. Strategies to teach engineering design; $M=3.77$, Med.$=4$, SD$=0.83$, IQR$=1$, CV$=0.22$, rated development by 56%
4. **The Development Activity issues that need to be addressed by international educators who teach the technology education school subject are the following:**
   1. Adding meaning to technological literacy; $M=4.24$, Med.$=4$, SD$=0.74$, IQR$=1$, CV$=0.20$, rated development by 52%
   2. Understanding thoughtful human inventiveness; $M=4.07$, Med.$=4$, SD$=0.80$, IQR$=1$, CV$=0.20$, rated development by 71%
   3. Practice in technology and engineering education as a school subject; $M=3.76$, Med.$=4$, SD$=0.87$, IQR$=1$, CV$=0.123$, rated development by 55%
   4. Ambiguity of the technology and engineering education teaching area; $M=3.86$, Med.$=4$, SD$=0.69$, IQR$=1$, CV$=0.18$, rated development by 55%
   5. Clarification of the aims and purposes of technology education; $M=4.00$, Med.$=4$, SD$=0.93$, IQR$=2$, CV$=0.23$, rated development by 58%
   6. Identification of a broader framework for K-12 technology/engineering education; $M=3.55$, Med.$=3$, SD$=0.91$, IQR$=1$, CV$=0.26$, rated development by 52%
   7. The pedagogy of teaching designing for secondary students; $M=3.62$, Med.$=4$, SD$=0.90$, IQR$=1$, CV$=0.25$, rated development by 52%
   8. Developing curriculum and pedagogy for thoughtful human inventiveness; $M=3.62$, Med.$=4$, SD$=0.82$, IQR$=1$, CV$=0.26$, rated development by 65%
   9. Delivering a research-based teacher preparation curriculum; $M=3.59$, Med.$=4$, SD$=0.91$, IQR$=1$, CV$=0.25$, rated development by 71%
10. Addressing sustainable development through technology education; $M=4.07$, Med.$=4$, SD$=0.80$, IQR$=1$, CV$=0.20$, rated development by 52%

The panelists from both studies (N=49) demonstrated through four rounds of the Delphi method that they are willing to compromise and reconsider some of their recommendations they had originally believed were research-based issues to research-based development issues that could best be addressed through a Development Activity.
Summary

A considerable amount of work remains in defining and incorporating best practices when implementing the Development Activity issues identified in this study. It behooves members of the profession to approach the research-based professional development needs of its members in a very practical and methodical way. What may work for one population of professionals may not necessarily work for another population.

In the spirit of openness and with a supporting nature for a positive future of the profession, the authors are making available all data, including descriptions of each Development issue, related to this study on Research-based Developmental Needs for Technology Education. Data may be retrieved from the following URL: http://www.ctete.org/#resources.

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Culture in the Technologies Curriculum: Learning from Aboriginal Australia for creating preferred futures

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The cross-curriculum priorities to which all learning areas in the Australian National Curriculum must attend as outlined in the Draft Shape of the Australian Curriculum: Technologies (ACARA, 2012) are: 1) Aboriginal and Torres Strait Islander histories and cultures; 2) Asia and Australia’s engagement with Asia; and 3) Sustainability. While the relevance of ‘sustainability’ to the overarching idea of ‘engaging in preferred futures’ was acknowledged in the draft Technologies curriculum (ACARA, 2012, p.12), the relevance of ‘culture’—implicit in the first two priorities—was not acknowledged. This paper addresses the conference theme of ‘what constitutes good learning in Technology education’ by proposing that understanding our cultural relationship with technology offers new ways of thinking about design and technology pedagogy. Drawing from my PhD research into technology transfer and education for Aboriginal students in remote desert communities, the paper asserts that the discourse of technology as a socially shaped phenomenon renders our cultural relationship with technology invisible to the dominant Western imperative. Guided by Cultural-historical theory and Critical pedagogy, a cultural conception of technology disrupts the dominant discourse to illuminate the Entanglement of human, technological and cultural development with implications for the idea of ‘creating preferred futures’.

Introduction

The context of remote desert Australia where many of the most disadvantaged Indigenous Australians reside further problematises the question of ‘what constitutes good learning in Technology education’. Solutions that suggest ‘good learning’ for students on the more densely populated coastal fringe of the continent tend to have less relevance for Aboriginal students from culturally diverse backgrounds; particularly for those who live in small and widely dispersed settlements dotted across harsh arid terrains. Although technology students from coastal communities may aspire towards futures in construction, manufacturing, information technology, commercial or agricultural industries; such opportunities are limited for technology students in remote desert Australia.

The paper opens with the overarching idea of ‘engaging in creating preferred futures’ from the Technologies curriculum, then explains the research problem from my PhD research. The next section discusses the way Critical based theories and alternative modes of thinking challenge Western notions of ‘preferred futures’ to inform ‘real world’ problem solving. The paper then provides a brief introduction to Cultural-historical theory and discusses the two ways it informed research, and concludes with some implications for considering culture in the technology curriculum. To discuss this work I introduce two terms into the technology discourse: Technecology and Entanglements. Technecology represents the way human societies have extended and transformed natural ecologies into technological-ecologies comprised of natural and human-made objects. Technecologies
can be seen to comprise a complex Entanglement of human cultures, artifacts, practices, institutions, knowledges, and identities. In my study, these terms were framed according to Cultural-historical theories of learning and development in the context of human, cultural and technological development.

**Engaging in creating preferred futures**

According to the *Draft Shape of the Australian Curriculum: Technologies Consultation Report (ACARA, 2012, p.10)*, the overarching idea of ‘engaging in creating preferred futures’ has been widely supported by respondents to the draft Technologies curriculum. Although globalisation has raised awareness about the problems associated with technological development and progress, contemporary educational systems, curriculum writers, and technology teachers are confronted by the prospect that the challenges their students will face in the future remain unknown. As Robinson (2011) asserted,

> “We are living in a world that is changing faster than ever and facing challenges that are unprecedented. How the complexities of the future will play out in practice is all but unknowable. Cultural change is never linear and rarely predictable” (2011, p.1).

What is known is that the matrix of accelerating change has a vortex of technological development at the core. As a technologically dependent society, our social lives and daily practices can be seen to be entangled in a world developed by previous generations. Each generation has subsequently been enabled and constrained by this technology in the way it creatively responds to contemporary issues that arise. Cultural psychologists (Cole, 1978) acknowledge that subsequent generations of humans have continued to develop the material culture accumulated from previous generations, a process of “ratcheting” (Tomasello, 1999) made possible by human ingenuity. The ratcheting of human-induced forces in cultural and technological development can be seen to contribute towards the ‘unknown’ element of future challenges that students face.

To focus on sustainability in the proposed Technologies curriculum is therefore appropriate in the context of ‘engaging in creating preferred futures’; and this understanding may be fostered through development of students’ technological literacy and ‘designerly thinking’ (Cross, 2007). Underpinning this assurance is the perspective that, counter to technological determinism, technologies are shaped by social forces (Mackenzie & Wajcman, 1999). Less prominent in technology literature but equally valid for educational contexts which continue to become more culturally diverse, is the claim that technology may also be seen to be shaped by cultural forces.

**Remote desert Aboriginal settlements**

My study conceptualized technology as a cultural phenomenon in order to contrast the different ways Aboriginal and Western societies responded to their environments to support cultural survival. This conception extended technology discourse beyond social shaping towards one that acknowledges the cultural nature of technology. A cultural conception of technology exposes the way cultural identities have shaped and been shaped by the worlds they inhabit, and potentially supports learning for technological literacy that has relevance for the preferred futures of students from diverse cultural backgrounds.

Covering almost half of the land mass of the continent, desert Australia is marked by
numerous small, widely dispersed Aboriginal settlements. Geographies that isolate
communities from each other and from major settlements, and from the technologies and
economies of mainstream Australia, challenges conventional notions of settlement and service delivery necessary to support settlement infrastructure. Failure to maintain infrastructure has impacted severely upon the health, well-being, livelihoods and lifestyles of Aboriginal Australians; and has contributed significantly towards desert people being reported as more disadvantaged than other Indigenous people from across the 'developed world' (Human Rights and Equal Opportunity Commission, 2008). Inadequate housing and hardware that fails to function has contributed significantly towards the disadvantage experienced by Indigenous Australians in remote desert regions.

The problem of managing and maintaining housing and infrastructure in remote desert communities has been the focus of academic research (Memmott, 1994; Sanders, 2000; Altman, 2009; Seemann, Parnell, McFallan & Tucker, 2008), and concern of successive Commonwealth, State and Territory governments for many decades. Researchers (Seemann, Parnell, McFallan & Tucker, 2008) suggested that Aboriginal empowerment might alleviate this disadvantage if secondary education programs developed technological literacy that fostered holistic technological understanding, and my study examined this suggestion. However the dearth of research to support how this pedagogy might be beneficial, and the relatively poor access to secondary education experienced by the majority of desert adolescents (Young, Guenther & Boyle, 2006) were prohibitive. The deficit discourse of “capacity development” (Seemann, et. al., 2008) associated with this suggestion has also been widely discredited by both Indigenous education researchers and Critical Pedagogy theorists (McInerney, 2009) in recent literature. In addition, enthusiasm for the discourse of ‘cross-cultural technology transfer’ from the 1980s has “waned considerably” (Selinger, 2009) since it has been recognised that imposing technologies on minority groups has largely failed as a community development strategy.

Critical theories to disrupt dominant discourses
The failure of a scientifically and technologically advanced society to support desert livelihoods, where previously ancestors of desert people survived as the world’s oldest continuing culture (Allen & O’Connell, 2003), illuminates the shortcomings of scientific thinking as a problem solving strategy. The problems associated with desert housing have not been isolated instances of the way dominant decision makers, thinkers and designers attempt to solve complex ‘real world’ problems. Concerns about climate change, poverty, food security and environmental degradation are further well-known examples of why current technological literacy and designerly thinking needs to shift to accommodate alternative perspectives for engaging in creating preferred futures.

To disentangle the messy, complex, “wicked problems” (Rittel & Webber, 1973) typical of real world scenarios, it is useful to draw from ways of thinking that challenge the dominant hegemony of scientific logic. Feminism, non-dominant knowledge, Indigenous Knowledge, and Traditional Ecological Knowledge provide alternative lenses through which the world may be interrogated. Critical theory based approaches support examinations of broader power structures that may otherwise go unrecognised; and are useful for increasing awareness of the way these structures control and distribute
resources; particularly where the interests of non-dominant or disadvantage minorities are concerned. Drawing from the work of Paulo Freire, Critical Pedagogy has expanded critical approaches into the classroom to empower students by exposing the power relations between dominant and minority cultures, and encouraging students to question these relations (McInerney, 2009).

When considering equity, futures and sustainability, technology educators might encourage students to ask “whose cultural knowledge” is reflected in tools and artifacts, and “whose interests” are being served with respect to the environmental, economic and political aspects of development. Paulo Freire argued that “progressive educators need to understand how children read the world” (McInerney, 2009, p.31), and his ‘critical consciousness’ aims to engage students in dialogue where they are encouraged to connect their “everyday concerns” with broader social structures and relationships (McInerney, 2009, p.33). For technology education, reading the world can be translated into reading the technological world or \textit{technecology}. This form of ‘technological literacy’ presents opportunities for students to explore and question the historical trajectory that led to the development of artifacts of interest to them, the technologies that reflect students’ sense of connection to the world, identity and social justice.

\textbf{Conceptualising technology as a cultural phenomenon}

The cultural-historical tradition provides two interwoven strands that support understanding in the entanglement of human, cultural and technological development. Both strands of cultural-historical traditions continue to develop a large body of scholarly research that has the potential to inform technology education.

The first strand of human development supports ways of thinking about learning for technological literacy and design thinking in technology education. In the literature a growing number of technology educationalists (Fleer, 2008; McCormick, 2006) advocate for sociocultural theories. This trend follows the general upsurge of interest from education in the work originating with Russian psychologist Lev Vygotsky and his contemporaries, which has continued to expand since it was introduced to Western scholars (Cole, 1978). Much of the interest in technology education has focused on theories influenced by this tradition such as situated cognition (Brown, Collins & Duguid, 1996), learning through participation in communities of practice (Lave and Wegner 1991) and models of apprenticeship (Rogoff, 1990).

This first strand guides understanding in the learning and development of the human as a member of the cultural group, with a large focus on literacy and ‘tools of the mind’ (Cole, 1978). A fundamental assertion of this thinking is that ‘learning leads development’. While learning to live in a complex technological society may be considered the responsibility of the family for children growing up in the ‘dominant’ Australian society; for Aboriginal children growing up in remote desert and cross-cultural contexts, where the house is a relatively recently introduced technology, the idea of learning leading development contends that education has a role to play in the learning associated with living in, managing and maintaining housing. However from a critical and cultural perspective, it is also clear that for this education to be successful, it needs to find ways to encourage rather than compromise students’ cultural identity.
The second strand of cultural and technological development informs the cultural nature of technology. It recognises the diverse ways that cultural groups historically develop, relate to, learn to participate in and contribute towards, material culture. Humans design and create tools and artifacts in response to available resources; and ratcheting describes the emergence of outcomes from creative enterprise which supports the co-development of cultural knowledge that has underpinned the technological ‘progress’ of societies. Adapting to multiple and diverse environments has been a human characteristic that explains our evolutionary survival as a species, and how we have optimised that ability to adapt creatively to populate and inhabit most corners of the Earth (Contreras, 2010). Unlike species born with a biological or genetic predisposition to a limited range of ecologies, human adaptation can be seen to be a cultural response expressed through activities of a technological nature. The notion of ‘entanglements’ appreciates the diverse ways that different cultural groups have appropriated resources in order to develop technologies and associated practices that support survival. In Western societies, mobility enabled migration to different ecologies, which led to the appropriation and adoption of shared ideas, new technologies and cultural practices. The theory of acculturation (Berry, 2005) illustrates that the entanglement of multiple human cultures has enriched the potential for human societies to succeed, which suggests that Western cultures have much to learn from Aboriginal ways of being.

Traditional desert Aboriginal societies were highly mobile in order to access resources of food and water when and where they were available. As there were no flowing rivers in Central Australia, the search for water dominated relationships to the land. The ability to ‘read the landscape’ was highly developed, and memories about sources of water in rock-holes and sand-hill wells was recorded through stories they created (Keen, 2004, p.33). These memories were part of their Dreaming, which served to maintain social cohesion and organisation by determining who had rights to resources such as knowledge about water locations, and to skills necessary to make specific technologies. Technologies tended to be highly portable, with multiple functions for efficiency (Keen, 2004), and technical knowledge interrelated with social and environmental knowledge (Seemann & Talbot, 1995). Unlike the accumulation of material possessions that Western cultures tend to value in relation to the ‘learn and earn’ ethic structure of society, the values and structure of traditional Aboriginal cultures that were sustained for sixty thousand years emphasised relations to kin and country.

There is a tendency for contemporary education to focus on Aboriginal societies as static, traditional entities. This perspective fails to recognise that Aboriginal cultures are thriving, particularly in remote desert communities, where many people participate in hybrid entanglements of Aboriginal and Western influences. The cultural-historical approach asserts that each generation of cultural identities learns from their previous generation, to participate in and adopt the technology, and associated knowledge and practices necessary to participate as cultural agents. Where people strive to make meaning out of the environment and utilise resources, they do so through sustaining cultural patterns of practice, and when crises or opportunities present themselves, explore new ways to re-establish cultural patterns. The profound consequence of European settlement was that technologies, cultural traditions and associated practices that co-evolved to
sustain Indigenous Australians were disrupted. This is particularly salient given the survival of Australia’s first peoples as the longest continuous group of cultures. From a scientific perspective, this quantitative evidence suggests that in comparison to Western technological development, traditional development was socially and ecologically sustainable.

**Conclusion**

The Cross-Curriculum Priorities proposed for the Australian Curriculum are ‘Aboriginal and Torres Strait Islander histories and cultures’; ‘Asia and Australia’s engagement with Asia’; and ‘Sustainability’. Responses to the *Draft Shape of the Australian Curriculum: Technologies Consultation Report* showed that while these priorities were largely supported and understood, the ‘Matter for improvement’ feedback suggested some concerns about how these priorities would translate to classroom practice (*ACARA, 2012*). The first two cross-curriculum priorities have strong cultural underpinnings. The discussions in this paper suggest some starting points for thinking about culture in relation to technology, and in relation to the overarching idea of engaging in preferred futures.

Remote desert regions have proved to challenged Western thinking, particularly in the fundamental area of housing. Conceptualising technology as a cultural phenomenon supported the study of two cultural groups in an attempt to understand this problem. Continuing to develop an understanding of our cultural relationship with technology has the potential to expand the way we think about our relationship with each other, and with the resources of the ecologies that we share. It offers possibilities to support education for cultural development, where learning leads development of technological literacy and designerly thinking. While the validity of this proposition is evident for children growing up in a complex mainstream technological society, it is even more urgent for Aboriginal Australians.

Reduced to a curriculum designed to appease contemporary industrial or economic needs, it is not surprising that policy makers continue to negate the value of Technologies as a field of study in the 21st Century. If it was recognised that learning for technological literacy is a process of *learning to become* cultural participants, it becomes evident there is a fundamental need for this education to optimise our health, lifestyles and well-being, as much as for maximising our educational, employment and livelihood opportunities. The proposition is that if we acknowledge the technological nature of the world created before us and upon which we depend, then learning to negotiate, manage and participate in that world becomes a necessity for survival. It follows that capability for not only maintaining but also for modifying, designing and contributing towards future technecologies makes an education in design and technology imperative. Thinking this way justifies the assertion that the development of technological knowledge, understanding, and capability, is significant for human development. Likewise, it is probable that the inability to understand the cultural relationship between people and technology has led to fundamental gaps in policy and practice that continue to disadvantage non-dominant cultural groups such as Aboriginal Australians. Moreover, *learning to become technological is necessary to participate in, and contribute towards the future of a complex and dynamic sustainable technecology.*
References


The Significance of Early Childhood Teachers’ Conscious Awareness of Technology: Australian and Singaporean perspectives

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The recent Australian early childhood learning framework (DEEWR, 2009) defines technologies as including ‘much more than computers and digital technologies used for information, communication and entertainment’ (p.46). However, previous research has indicated that a majority of early childhood teachers identify technology as being mainly computers (laptops, Ipads, PCs) and other digital and electronic artefacts (for example, mobile phones, cameras, CD players, digital recorders, interactive whiteboards, etc). Further, as many perceive technology in this relatively limited manner, they are inclined to believe they are doing little to support children’s technological skills and understandings – despite that fact that they are offering children daily experiences that are rich in the potential for developing technological thinking. This paper, informed by cultural historical theory, reports on research conducted with early childhood educators in Victoria (Australia) and in Singapore, and argues for educators’ conscious awareness of their current practices, together with a deeper understanding of both the content of technology and specific pedagogical content knowledge. It proposes that, in turn, this may lead to more informed judgments about the technology experiences the educators are offering their children - resulting in greater support for learning.

Introduction:

In 2009, the Department of Education, Employment and Workplace Relations (DEEWR) introduced the first national early childhood curriculum in Australia, Belonging, being and becoming: the early years learning framework for Australia. In this document, technologies are described as being ‘much more than computers and digital technologies used for information, communication and entertainment’ (p.46). However, no specific guidance on how technologies could be perceived and implemented in early childhood is provided. Meanwhile, in the Singaporean Kindergarten framework, Nurturing Early Learners, the Ministry of Education (2003) states that '(t)echnology (computers, television, digital cameras, etc.) plays a significant role in all aspects of Singaporean life today. While there may be potential benefits from the use of technology by young children, technology should supplement rather than replace highly valued early childhood activities which promote collaborative play, learning and creativity’ (p.34).

As in many other early childhood curriculum frameworks (see, for example, Turja, Endepohis-Ulpe & Chatoney, 2009), neither of these documents explicitly outlines the nature of technology, and thus there is little guidance for educators to determine appropriate content, pedagogical knowledge, nor pedagogical content knowledge in
relation to technology in early childhood. As Turja et al. (2009, p.354) state, ‘(t)he inclusion of technology education in the curriculum of ECE is still a new idea in many countries, and teachers are often confused by what technology education would mean at this age’.

Several authors (for example, Fleer, 2011; Mawson, 2011; Milne & Edwards, 2011) have described the very rich technological experiences many young children typically (and competently) engage in outside of school. At the same time they assert that many early childhood educators do not effectively utilise or build on existing knowledge and skills within the classroom. As an example, while young preschool children today are exposed to a vast range of digital technologies, many of their educators do not possess the same understanding and skills in the use of technologies. Thus there may be a mismatch between young children’s abilities and interests, and those of their educators – many of whom could be described as ‘digital immigrants’ (Zevenbergen, 2007; Mawson, 2011).

Consequently, as Fleer (2011) and Gibbons (2006) have suggested, early childhood curricular may need to be re-conceptualised to take into account an emerging technologically constructed childhood.

On the whole, many early childhood educators are not confident in their subject knowledge in technology (Siu and Lam, 2005; Benson, 2008; Campbell, 2010; Robbins, 2010, 2011; Robbins, Babaeff and Bartlett, 2010), and consequently may be reluctant or unable to support children’s learning in this area. An informed observer may be able to recognise that technology is embedded in many of the activities (beyond computers) with which children engage in an early childhood centre - for example blocks and construction sets such as Lego and Duplo, art and craft activities, science activities, woodworking, cooking and food preparation (Robbins et al., 2010; Turja et al., 2009). However if educators do not possess current knowledge of technology education, they tend to follow their established and familiar activities, ‘without progress toward more conscious technological aims and learning processes’ (Turja et al, 2009, p.357). What may be lost is support for children to develop understanding of (and skills with) objects, materials, design concepts, processes, systems, and technical ways of working. Milne and Edwards (2011), for example, have related how young children may be able to talk about the materials with which some things are made – but not of the properties of those materials, or the process by which those objects were made. There are obviously implications of this within a context such as Australia, where there is an emphasis within the early years framework on intentional teaching (teaching that is ‘deliberate, purposeful and thoughtful’ [DEEWR, 2009, p.15]), and the Singaporean context, where principles of facilitating, supporting and extending children’s learning are promoted (MOE, 2008).

The study:
Aims:
The study reported in this paper aims to examine how early childhood educators in Victoria and Singapore define technology, and the extent to which they explicitly and consciously provide technological experiences within their programs and engage in intentional teaching of content, processes and skills associated with technology.
Participants:
The participants in the study were thirty-two rural, regional and urban early childhood
educators in Victoria, Australia, and ten early childhood educators in Singapore. All were female, and possessed a range of qualifications from a one year certificate in children’s services to a number of degrees (including a four year bachelor of early childhood education), or a degree and diploma. The majority of participants were currently working – in child care centres, preschools, kindergartens and independent schools. The age range of the Victorian educators was 21 to 61 years of age (median age 41), and of the Singaporean educators was 26 to 51 (median age 37). For the Victorian educators their years of experience working with children ranged from 2 to 38 (median years 13), while in Singapore it ranged from 4 to 18 (median years 8).

Methods:
Participants were recruited in Victoria from publically available lists of early childhood centres, and in Singapore through personal contacts. All completed an initial background information sheet outlining qualifications, age, number of years teaching, present type of institutional setting, current position held, and previous training in technology. This was followed by a semi-formal interview (lasting from 30 minutes to more than an hour) focusing on issues such as the participants’ definition of technology, types of experiences they provided for children which they believed supported children’s learning in technology, whether they specifically planned for technology, their general philosophy or approach to teaching, and whether or not they had engaged in any study or professional development in technology. Further information was sought on activities they might provide for the children that offered the potential for engagement with materials technology, food technology, and design technology, among other areas and processes of technology.

Theoretical framework:
The theoretical framework guiding the study is cultural-historical/sociocultural theory. This assists us to examine and understand how thinking is situated in social, institutional, historical and cultural or contextual settings (such as early childhood centres), and to consider how learning in technology is mediated by others, and by artefacts and cultural tools (Vygotsky, 1987). It emphasises the dialectical relationships between teaching and learning, and particularly educators’ own conscious awareness of content knowledge in technology, understanding of technological processes and of pedagogical content knowledge in technology, and the notion of intentional teaching (DEEWR, 2009) - or deliberate, purposeful and planned teaching.

Findings:
In both Victoria and Singapore, when asked to define technology, a majority identified computers (22 [69%] in Victoria; 8 of the 10 in Singapore), or other digital technologies (24 [75%], and 7 out of 10). Other categories named in Victoria included machinery and tools (9 [28%]), materials (6 [19%]), designing and making (7 [22%]), games, toys and music makers (5 [16%]), science and technology (4 [12.5%]) and ‘other’ (14 [44%]). In Singapore, one identified machinery and tools, 2 designing and making, and 4 ‘other’, while none mentioned materials, toys and games, or spoke of a relationship between science and technology.

Interestingly, very few of the educators in either context were using computers or other digital technologies to support children’s learning. A variety of reasons was given for
this, though many in Victoria stated that it was ‘because they’re things they have at home’ (U8), or that computers do not fit within the ‘play-based’ approach that the centre adopted. Implicit in some of the responses was the sentiment that the educators lacked skill or confidence in using information technology – though in a few instances it was explicitly conveyed; for example:

‘...we’re probably not very technologically inclined here. As I said, the four of us are all useless, we come to the computer and something happens, we have to ring a friend...’ (U16).

A similar attitude existed among some in Singapore, for example: ‘They’re very fearful to me, as they are to my teachers’ (S1). Other explanations provided in Singapore included that the management or principal did not wish the children to use them.

It was only a small number in both contexts who viewed technology as being ‘more than computers’ (DEEWR, 2009, p.46). One in Victoria, for example, stated

‘I guess it depends what you call technology. I would say that technology is the tools that you use when you are using clay; it would be the things that you are using when you are doing cooking...I had some books out so I would say that’s technology ‘cause that’s a tool that they’re using. I downloaded a whole lot of pictures from the internet of different creatures, I would say that’s technology because it’s the resources that we’re using and the children wanted to make houses...so we went outside and collected sticks and some tan bark and broke some little twigs off the trees with leaves on and the children made bug habitats so I would say in a roundabout way that all of those things are technology’ (R14). Another in Singapore stated that, ‘For me, my personal understanding and use of it, is technology for children would be about their critical thinking skills...their higher order thinking skills. You know their ability to sort of plan – use planning, thinking and design and then evaluate what they’ve made. So that when they grow they’ll be able to implement those skills in a much more complicated way’ (S3).

Further questioning revealed that many of the educators included a range of other technologies in their work with children, but most were unaware of the nature of technology within these experiences. For example, when asked to describe the sort of materials and tools they provide for children to use in their art, collage and ‘waste materials’ work, a majority identified a variety of materials they regularly offer. In Victoria, 26 (81%) said they used recycled or scrap materials, 12 (38%) used natural materials such as leaves, twigs, stones, and 19 (59%) spoke about materials such as paper, paint, crayons, chalk, and clay. A further 12 (38%) described the tools they provided, including scissors, brushes, and staplers. Only a few appeared to be deliberately discussing with the children the properties, origin and use of those materials. One, however, responded,

‘…well technology could be about the way things are made too – isn’t it? Like glass and clay and wire and (we) do a lot of that at X so we talk about where things come from and what they are used for...’ (R16).

In Singapore, 5 mentioned using recycled or scrap materials (2 in a very limited manner), and 5 using natural materials. Eight, though, provide mainly (store-bought) materials such as coloured paper squares, paint and crayons.

All 32 of the participants in Victoria, and 10 in Singapore, regularly provide wooden blocks and construction sets for the children. When asked whether the children were encouraged to design or plan constructions or artefacts, 8 (25%) in Victoria responded that they explicitly do so, either through verbal planning or drawing designs - mainly in the blocks area, with one also doing so in the woodworking area. Two in Singapore spoke
briefly of occasionally asking children to draw a plan on the computer before building with a construction set, while one spoke extensively about designing, planning and critical thinking.

‘We have clipboards for children to plan. And we intentionally create spaces for planning such as easels and clipboards. And we sometimes even set up a planning table, especially if children are working on a project. And then we have cameras in every classroom for children to photograph the process that allows them to reflect… And we have a lot of natural materials as well because we want children to be innovative and not only use one way to sort of show their thinking…’ (S3).

In addition, In Victoria, 21 (66%) often provide some food or cooking experiences for the children (beyond the normal snack or lunch time). Eleven of these 11 (34%) focused on what might be termed food technology - food preparation, ingredients, following steps in a recipe, source of foods, culturally significant food, safety, hygiene, healthy eating, availability of foods at certain times of the year. In Singapore, 8 stated they occasionally provided an experience with food, but generally focused on mathematical skills such as counting and measuring.

Discussion:
Given the relative maturity of many of the participants in our study (median age 41 in Victoria, and 37 in Singapore), it is perhaps not surprising that few use computers or other digital technologies to support children’s learning. It could be surmised that many of them might not have grown up in a digital era. The study confirmed the findings of others (see, for example, Zevenbergen, 2007) that many early childhood educators see computers as inappropriate and unimportant – problematic in an increasingly digitised world. What is interesting, though, is that 14 of the Victorian educators stated that their planning was based on the children’s interests, yet many of these also said they did not think it necessary for the children to use computers or other digital artefacts within the classroom because they have them at home. In Singapore, some of the participants spoke of their fear of computers, or the lack of time to use them within a program that focuses heavily on literacy and numeracy, and a perceived need for the children to have worksheets to take home to parents. Perhaps if some of these educators were to undertake some professional learning, they might develop some new perceptions concerning the scope of technology, and more confidence in using computers and other digital artefacts with the children as an aid to their learning.

More broadly, it would seem that few of the participants in either context appear to be consciously aware of the potential for learning about technology embedded in many of the activities they provide on a daily basis for children. In turn, hardly any appear to intentionally support children’s learning about the nature of technology in general, and about technological processes and procedures. This is not surprising given that the curriculum frameworks in both settings provide no specific guidance on the nature of technology within early childhood settings, nor how educators might include this in their programming. In addition, nineteen of the participants in Victoria and 2 in Singapore indicated that they had not undertaken any study in technology as part of their initial training – or any subsequent professional development. In hindsight, it would be interesting to know something about the nature and extent of the technology previously
undertaken by the others (13 in Victoria, 8 in Singapore); How was technology perceived and taught? Were a broad range of technologies addressed, or was the focus on information technology? Was the technology a stand-alone subject, or taught along with other curricular areas such as maths and science, and if so what percentage of time and emphasis was given to technology?

In some instances, though, the interviews provoked the beginnings of a new awareness of the nature of technology. For instance, during a chat about different strands of technology at the completion of one of the interviews, one rural participant enthusiastically sought out some photos of her children engaged in block building and using gardening tools, exclaiming, "So this would be technology, wouldn't it?" Another, while reflecting on the scope of information technology, suddenly announced, "Oh, Braille would be technology!"

Closer examination of several of the transcripts revealed some interesting examples of the interviews themselves possibly mediating the beginnings of new perceptions of technology. That is, the interviews and reflections around the shared conversations served to bring to the fore the educators’ existing understandings— in some cases challenging their thinking and creating for them a tension between their current practice and their knowledge (or lack of knowledge). As a result a number indicated their desire for some further learning about technology.

We do not claim that conscious awareness of technology was established within the short time frame of the interviews—merely the possibility for a beginning. However, what is highlighted is the importance of on-going learning about technology, and a constant back-and-forth examination of the relationship between knowledge and practice. Existing ideas about activities such as working with blocks, with various materials, with construction sets, and participating in woodworking and food experiences need to be continually challenged so that a transformation in thinking can occur, and in turn greater intentionality in teaching about and with technology, and a greater consciousness of self as an educator (see Figure 1). As Vygotsky (1987, p.190) states, “(t)o perceive something in a different way means to acquire new potentials for acting with respect to it”.
Intentional teaching has been described as ‘the opposite of teaching by rote or continuing with traditions simply because things have “always” been done that way’ (DEEWR, 2009, p.5). Rather, it is ‘deliberate, purposeful and thoughtful’ (ibid), and focuses on shared thinking, problem solving, and teaching strategies that challenge and extend children’s thinking. We argue that this cannot be achieved unless conscious awareness of the content of technology (or any other area of the curriculum), and specific pedagogical content knowledge, has been developed. Teaching may be more purposeful where educators can continually reflect on their past and their present practices, and the knowledge base that informs their thinking. Further, these reflections are heightened when they can be shared with a knowledgeable other. Unfortunately, due to the relatively isolated nature of many

Figure 1 Developing conscious awareness to enhance opportunities for intentional teaching.

Intentional teaching has been described as ‘the opposite of teaching by rote or continuing with traditions simply because things have “always” been done that way’ (DEEWR, 2009, p.5). Rather, it is ‘deliberate, purposeful and thoughtful’ (ibid), and focuses on shared thinking, problem solving, and teaching strategies that challenge and extend children’s thinking. We argue that this cannot be achieved unless conscious awareness of the content of technology (or any other area of the curriculum), and specific pedagogical content knowledge, has been developed. Teaching may be more purposeful where educators can continually reflect on their past and their present practices, and the knowledge base that informs their thinking. Further, these reflections are heightened when they can be shared with a knowledgeable other. Unfortunately, due to the relatively isolated nature of many
stand-alone early childhood settings, this is not always possible; hence undertaking on-going professional development and support is important.

**Conclusion:**
This paper has reported on a study conducted into Victorian and Singaporean early childhood educators' perceptions of technology. It was found that many of the educators in both contexts mainly identified computers when asked to define technology. At the same time, most were reluctant to use them with children. Further, nearly all were not consciously aware of the scope of technology, nor the technological activities and artefacts they routinely provide in their programs. Hence the opportunities for intentional teaching of technology are lost. The importance of on-going professional development, reflection, and conscious awareness of the content of technology and specific pedagogical content knowledge has been highlighted.

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**References:**


What are the expectations of learning in food technology examination courses for pupils aged 16 years in England?

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This paper builds on previous research exploring what secondary school pupils in England should learn in a modern food technology curriculum. A conceptual framework for was developed and used to collect data on the views of a range of stakeholders (Rutland, 2009, 2010a; 2010b; 2011).

The framework was used to analyse a small sample of food technology schemes of work for Key Stage 3 (pupils aged 11-14 years) in English secondary schools. The key findings indicated a need for a broader and more challenging curriculum and a wider range of appropriate designing strategies. Weakness were progression and continuity from Key Stage 2 (children aged 7-11 years) and a need for understanding of the underpinning scientific and nutritional knowledge. Pupils should be informed consumers and learn about new and existing food technologies, food sources, sustainability and the role of the food industry and government agencies. (Rutland, Owen-Jackson, 2012).

This paper presents the findings of an analysis of the specifications from four Awarding Bodies for General Certificate of Education (GCSE) Food Technology examinations for pupils aged 16 years. Although, there were many positive expectations of pupils’ learning in a modern food technology curriculum there were some areas of concern. These included an emphasis on 'drawing' as a designing strategy, a lack of consistency and clarity in the depth and breadth of knowledge and understanding of scientific concepts and industrial practices required in some of the specifications together with a general lack of expectations for pupils to be informed consumers with an understanding of the impact of eating highly processed food and the role of the food industry and government. A key issue, as previously identified, was the need for progression across the age phases.

Key words: food technology, conceptual framework, Award Body specifications, scientific concepts; industrial practices; informed consumers, consistency, clarity; progression.

Introduction

The two key issues underpinning this ongoing research into the teaching of food technology in England are the perceived importance of pupils learning to cook as a life skill and the potential contribution of food technology in design and technology (D&T) that includes academic rigour. The Office for Standards in Education (Ofsted 2006, 2008), noted a lack of clarity regarding the nature of food technology, a need for a more intellectually challenging curriculum, with more in-depth nutritional knowledge and greater scientific understanding and technical rigour (Ofsted, 2011).

Previous research (Rutland, 2009; 2010a; 2010b; 2011) developed a conceptual framework for food technology that was used to collect data from a range of stakeholders. It consisted of a) designing and making food products b) underpinned by an
understanding of the science of food and cooking and nutrition c) an exploration of both existing and new and emerging food technologies in d) the context of the sustainable development of food supplies locally, nationally and globally and e) an appreciation of the roles of the consumer, the food industry and government agencies in influencing, monitoring, regulating and developing the food we eat. A critical analysis of examples of current secondary schools’ food technology schemes of work for pupils aged 11-14 years used the framework to evaluate existing practice, as Her Majesty’s Inspectorate (HMI) have indicated that schools face a considerable challenge modernising the D&T curriculum, including food technology (Ofsted, 2011).

The key findings indicated that pupils aged 11-14 years need a broader and more challenging food technology curriculum that prepares all pupils for robust examination courses at Key Stage 4 (14-16 years), including a wider range of appropriate designing strategies to make sound design decisions. There should be progression and continuity from the primary Key Stage 2 (children aged 7-11 years) in the products pupils design and make and the scientific and nutritional knowledge and understanding that underpins their work. They should learn about new and existing food technologies, food sources and sustainability and have an understanding of themselves as consumers and the role of the food industry and government agencies in their lives (Rutland & Owen-Jackson, 2012).

Current research project.
This project analyses the requirements of GCSE Food Technology examinations taken by pupils aged 14-16 years against the conceptual framework for food technology. Four Award Board specifications were reviewed: i) Assessment and Qualifications Alliance (AQA); ii) Edexcel, derived from the words "educational" and "excellence", Pearson Education Ltd; iii) Oxford, Cambridge and RSA Examinations (OCR) and iv) Welsh Joint Education Committee (WJEC). Each Awarding Board specification has an externally marked examination paper, contributing 40% of the mark, and internally assessed course work reflecting 40 hours of controlled, informal supervised work, contributing 60%.

Analysis of each specification against the framework for food technology
A Design strategies
In the OCR specification one unit focuses on designing and making, the Award Board provides a theme and candidates develop their own design brief and specification. They are required to design a product through trialling and testing and the focus of the unit is on research and investigation skills, drawing skills where appropriate, modelling/trialling and evaluating. Candidates are required to demonstrate cultural understanding, creativity and design skills. In another unit that focuses on making products, candidates are required to design for a need, developing ‘creative and original design ideas’ and conduct product development where their designing skills are assessed. The design should focus on user needs and make use of product analysis, sensory analysis and nutritional analysis for product design/development but does not require the use of a wide range of design strategies. One positive note is the reference to looking at ‘trends’ in product development.
The WJEC specification refers to fewer design strategies, mainly product analysis and awareness of user needs though candidates are required to use research strategies to find information and to design products to meet user needs, with reference to a range of issues. Two practitioners are studied (specified by the Award Board) to consider the work that they have undertaken and their influences. Neither of these two specifications refers to recipe modification, but this is likely to occur during the product development phase of candidates’ work.

The AQA specification states that candidates should be creative and innovative when designing and understand design principles of form, function and fitness for purpose when using design briefs for manufacturing in quantity. The designing skills listed are generic and not specifically for food, but the teacher is provided with guidance on expected design strategies in the sections on materials and components, design and market influences and processes and manufacture. They include analysis and evaluation of existing products, critical reflection and identification of sensory properties to develop their own products and the use of sensory tests for sensory analysis. The use of nutritional analysis software is cited to examine the properties of ingredients and food products and model ideas prior to making. Modification of recipes is included by changing flavour, texture, shape, finish, ways of cooking and the nutritional content by testing and evaluating the final design.

The Edexcel specification requires a design that is well planned and easy to make, with a clear specification and production process that meets the needs of a target group. Designing as a creative process is fundamental to D&T and requires the analysis of a brief to clarify and justify design needs, research of identified needs using product analysis to produce realistic, technical and measurable specification points and including sustainability. Initial ideas must be realistic, workable and demonstrate an understanding of ingredients, processes and appropriate techniques. The term ‘annotation’ is used to communicate, experiment and review ideas through thumbnail pencil sketches, computer generated image and ‘user group’ feedback. Development sketches and photographic evidence should be annotated to evaluate design proposals with formal working, exploded and pictorial drawings with technical details of ingredients or components and the stages of manufacture detailed in production plans or charts.

The specification requires an understanding of the uses of ICT in the food industry product manufacture, sensory and nutritional analyses, but not in product development generally. Computer aided design, modelling using spreadsheets, computer aided manufacture using a bread maker, edible icing printers and microwave ovens are all mentioned and computer- integrated manufacture (CIM), where stages in the food production process are integrated and controlled by computer systems.

A key issue, as identified in previous research is a reliance on ‘drawing’ as a designing strategy and an expectation to ‘draw’ design ideas for food products. There was little reference in some specifications to design strategies for food product development that are more suited to food technology such as product evaluation, attribute analysis, image boards, user trips, sensory analysis, computer aided nutritional analysis and modification of recipes.

B Making
OCR, WJEC and AQA specifications require candidates to develop the full range of skills, with the addition of sauce-making in two Award Boards and fruit, vegetable and cereal-based dishes in WJEC. A key difference in the Edexcel specification is that knowledge and skills of food technology focus on ‘home’ or ‘industry’ separately and the actual range of skills required for ‘combining food materials’ and preparing foods is not clear. The sections on food preparation techniques in the home lists tools such as hand, small electric equipment e.g. scales, graters, pastry brush, knives, their uses, advantages, disadvantages and safety issues of food. Food preparation in industry or the manufacture of foods requires an awareness of the stages in the commercial manufacture of food products using machinery to clean, peel or sort and, size reduction through pulping, dicing, chopping, mixing and combining and blanching. These are all techniques and processes that can be used in the home and in initial stages of industrial product development.

The OCR and AQA specification, through the controlled assignment tasks, requires candidates to engage in all the stages of product development, whilst the WJEC specification refers only to the use of a specification when designing and making. The Edexcel specification for product development/manufacture and analysing products are again related to either ‘home’ or ‘industry’. ‘Food processing techniques’ for the home include moist or dry methods of cooking, frying, microwaving and other processing methods such as shaping, forming and piping. Whereas, in industry food processing techniques use large machines such as silos, pumped materials through pipes, larger versions of domestic equipments such as mixing machines, rollers, conveyer belts, travelling ovens, blast freezers and chillers. There is no attempt to clarify the stages of food product development and understand basic principles and the similarities or differences between food processes and preserving techniques used in the home and industry. Product testing is mentioned in the AQA and Edexcel and requires candidates to devise and apply test procedures to modify and reformulate ingredients, qualities or methods.

Candidates for AQA need to understand and use information on packing and food labels, apply them to their own products and understand why foods may be packaged in different forms to extend shelf life. Edexcel required knowledge of packing and labelling in the food industry, the functions of packaging with special reference to modified atmosphere packaging (MAP) and tamper-evident seals. The OCR specification makes little reference to packaging, except in relation to candidates knowing about trends in packaging and labelling and developments in packaging to improve the shelf life of manufactured products. The WJEC specification requires candidates to know about packing and legislation and standards, the functions and properties of different packaging materials and being able to identify key information on product labels.

When making design decisions, OCR requires candidates to be aware of the relationship between good design and technological knowledge with particular requirements for technical, aesthetic and marketing decisions. The WJEC specification focuses on technical aspects such as nutrition and marketing design decisions and AQA and Edexcel covers technical, aesthetic and constructional design decisions with only AQA considering marketing and how products would be sold and how much they would cost.
Regarding food choices, both OCR and WJEC specifications require candidates to know about healthy eating and the relationship between food and health. OCR, in addition, requires candidates to be aware of the impact of cultural issues and special dietary requirements on food choice and to investigate nutritional and dietary needs for target groups, the needs of clients and consumers and understand of how multicultural factors have influenced food production. Edexcel expected candidates to know about current health issues and dietary guidelines and individual nutritional requirements in pregnancy, infants, toddlers, adults, senior citizens, illness and convalescence.

The key issues are a lack of clarity and consistency required in the depth and breadth of knowledge, understanding and skills for combining food materials. One Awarding Body emphasised knowledge of large scale equipment and industrial practices at the expense of understanding of the general processes used in food product development. There was a lack of clarity and consistency across the Award Bodies of the concepts of food product development, product testing, packaging, making design decisions and food choices.

C Understanding the science of food, cooking and nutrition
Both specifications for OCR and WJEC require candidates to know about the properties, functions and characteristics of ingredients and foods in order to make appropriate design decisions and OCR also requires a knowledge of raising agents, a range of cooking methods, heat transfer and the effect of heat on foods. The WJEC specification is much more detailed in its requirements, candidates have to select ingredients/foods for their organoleptic qualities, to be aware of the scientific principles underpinning a range of functions of ingredients and cooking methods, the effect of cooking on foods and be able to know and use appropriately a range of finishing techniques.

AQA expects candidates to know the functional properties of starch, sugar, protein and fats and the structure of colloids, solutions, suspensions and gels and know about the impact of functional properties on desired outcomes and terms such as gelatinisation, elasticity, shortening, aeration, emulsifying and coagulation. However, Edexcel focuses on different methods of cooking through the correct use of equipment and mentions frying and microwave cooking. Types and the principles underpinning raising agents was not covered in AQA but fermentation is included in Edexcel.

All specifications require knowledge of nutrients and the nutritional content of foods, but none make reference specifically to nutritional requirements such as Reference Nutrient Intake (RNI), though dietary reference values (DRVs) are mentioned by Edexcel.

The key issues in this aspect of the framework are a lack of consistency and clarity across the Awarding Bodies of the depth and rigour of knowledge expected of the science of food, understanding of the functions of ingredients, impact of cooking on foods and depth of nutrition knowledge and understanding.

D Food technologies – existing, new and emerging
Both OCR and WJEC specifications require candidates to understand most aspects of the food technologies outlined in the framework, although WJEC provide more detail on this. Three of the specifications, not including Edexcel, make particular reference to nanotechnology and nanomaterials, with genetically modified (GM) foods mentioned in three specifications but not in WJEC. Manufacturing processes used in industry for AQA focus on awareness of commercial and industrial practices, producing a manufacturing
specification, producing a prototype in quantity and quality control practices. The OCR specification requires candidates to know about trends in food manufacture, industrial food production methods and CAD/CAM processes used in food manufacture with even more depth by Edexcel. For example, in production methods e.g. one off, batch and high volume production, the use of industrial equipment such as tunnel ovens; blast freezers, silos and vats and quality control and the legal requirements for quality assurance. The WJEC specification is also detailed, requiring candidates to know about designing to manufacture in quantity, producing work schedules, legislative issues in relation to British Standards Institute (BSI) and International Organization for Standardization (ISO) and detailed aspects of commercial manufacturing, including the use of just–in-time (JIT), scaling up quantities, parameters and tolerances, the use of pre-manufactured and standard components, manufacturing specifications and systems and processes.

AQA requires knowledge of different storage methods e.g. chilling, freezing, re-heating and their impact of the sensory, structural and aesthetic properties of products. OCR requires candidates to know about methods for extending shelf life, such as freezing, chilling, modified atmosphere packaging (MAP), canning and vacuum packaging. WJEC requires knowledge of microbial activity and the use of heat and cold to extend shelf life. Edexcel describes food preservation methods as heat, cold, drying, chemical and irradiation and food preservation techniques in the home are listed as freezing, drying and chemicals and in industry as hot, cold, dry, chemical and specialist packaging. This is all very confusing, repetitive and lacking in clarity for what should be taught.

There is considerable lack of clarity and consistency in this section of the framework on what candidates should know about the preservation of food, industrial manufacturing processes, emerging technologies and packaging leads to confusion. In some specifications its appropriateness for this age range could be questioned. There is no mention in any of the specifications of the impact of eating highly processed foods produced by the food industry except for one reference by WJEC to looking at the impact of a ‘snack food’ diet.

**E Sustainable development of food supplies**

The OCR and WJEC specifications require candidates to be aware of a range of sustainability and environmental issues, with specific reference to sustainability, recycle, reduce, reuse, refuse, repair and rethink (6Rs) and life cycle analysis. The OCR specification also requires candidates to know about food sources, food growing, transport of food, food waste and national and local sustainable food issues. AQA requires candidates to be aware of the use of scarce resources, transport costs religion, cultural preferences, organic and free range foods, Fair Trade, Farm Assured on food production and the environment.

Edexcel has an ‘issues’ section in product manufacture on moral, environmental and cultural issues within the food industry including factory farming, GM, Fair trade, organic. It also has a section in analysing products that includes a long list of terms including GM ingredients, Fair Trade, irradiated and food miles. The requirement for knowledge and understanding of GM foods is repeated in technological developments (modern, novel and smart materials) of product management. In none of these sections is it clarified what the candidate should actually know.

This aspect of the framework is well covered in the specifications and food
sustainability is now a popular topic. Generally it includes knowledge of food sources, how they are grown, transportation, ‘air miles’, food waste and national and global issues.

Roles of the consumer, food industry and government agencies

All the specifications require candidates to understand and practice health, safety and hygiene in relation to food, tools, equipment and the relevant legislation. OCR asks candidates to look at trends in consumer preferences and media influences on food choice. WJEC requires candidates to know about Electronic Point of Sale, (EPOS) technology and barcodes use in supermarkets. AQA requires knowledge of healthier cooking methods e.g. steaming for vegetables and microwaves for the retention of vitamins. Edexcel requires an awareness of how new technologies are used to produce new foods and ingredients and views of the European Union (EU). A main focus of the Edexcel specification is the nutritional properties of ingredients and food products and knowledge of government dietary recommendations e.g. eat less sugar, saturated fats and sugar and more fibre, nutritional labelling, the ‘Eat-well-plate’, ‘five a day’ and low glycaemic index (GI) foods and recommended fish intake. The last two are not mentioned by the other Award Bodies.

The last aspect of the framework related to pupils becoming informed consumers is important, yet dealt with inconsistently and inadequately in all of the specifications. The important issues are that pupils, as future consumers, should learn how to make informed decisions on the foods they eat and have an understanding the structure and role of the food industry and government agencies and their potential impact on their future lives.

Discussion

This analysis reveals quite a positive picture about the requirements of food technology at upper secondary examination level. There is the expectation that candidates will undertake research prior to food product design and development and that they will draw on a wide range of knowledge and skills when designing, developing and making. There is an emphasis on developing knowledge of food science and nutrition, although the depth required varies between the different Award Boards.

It is disappointing to see that the specifications still require candidates to ‘draw’ design ideas for food products, although the OCR specification does add ‘if appropriate’. The Edexcel specification emphasises techniques such as sketching and drawing that are annotated with no reference to other design strategies more suited to food technology. The WJEC marking system allocates marks for the ‘graphical presentation’ of design ideas, whilst the OCR scheme allocates marks for the use of ‘appropriate strategies’. The specifications also show that candidates are learning about food manufacturing, although again the depth to which this occurs is variable, with WJEC providing a great deal of detail about what candidates should know but OCR providing little. Edexcel divides parts of the specification into ‘home’ and ‘industry’ with the greater emphasis on industry. The required depth of knowledge and understanding is not clear in the specification as sections consist of lists of terms with no indication of actual content. In all the specifications there is an increase in the teaching of issues of sustainability and environmental issues in relation to food but much more needs to be done in teaching pupils about their roles as informed consumers, the implications of eating highly processed foods and the roles of the food
industry and government agencies in food availability and food choices.

The overall structure of the specifications does vary. Edexcel specification has two units, the creative design and make activities contains generic design and technology statements on designing and making with no guidance on how this is interpreted by food technology teachers. The second unit, knowledge and understanding of food technology has five topics broken down into twenty five parts where candidates are required to know about, for example fats (saturated and unsaturated fats) but there is no indication of the level of knowledge that is required. Also there is repetition of such terms as air miles and GM without clarity of what candidates need to know in a specific context. This is not the case with AQA specification where there are generic statements on designing and making but clarification in the materials and components section of the specification of how this should occur in food technology and the knowledge and understanding that is expected. OCR has three units, two of which are focused on designing and making and are assessed through controlled assignments (course work). These two units require candidates to follow a generic ‘design and make’ process with little exemplification of what this means in food technology, for example to ‘select and use appropriate tools and equipment’. In contrast, WJEC provides a long list of content which candidates are required to be taught and which is then assessed through one written examination paper, covering all aspects of the content, and one controlled assignment.

It is important that any teacher reading a specification can decide from the information given the topics that are to be taught, the level of detail needed and the understanding of that detail required by the student. This is not a simple matter in food technology, as within the community of practice at this point in time there is no general agreement as to these different features. This is not the case for, say, chemistry teachers. A statement indicating that at candidates aged from 16 years needed to know the properties and uses of the halogens would be universally understood at appropriate levels of detail by most if not all chemistry teachers. Consider the cryptic statement GM under the heading moral issues in the EdExcel specification. What is the teacher meant to make of this? Do candidates have to know how genetic modification is achieved in general terms and how this applies to organisms that are food for humans? Do candidates have to know about the issues surrounding the adoption and rejection of GM foods in this and other countries? Do they have to know about and understand the scientific view that GM poses no significant risk? Do they have to know about and understand the media campaigns that led to supermarkets removing GM products from their shelves despite little if any scientific evidence that they were harmful?

Similarly, the statements that candidates should know the dietary function and sources of saturated and unsaturated fats with unsaturated designated as polyunsaturated and essential fatty acids are insufficiently detailed. Do they have to know about and understand the difference in chemical structure that leads to the designation saturated and unsaturated? The dietary function of essential fatty acids is complex and depends on the relative amounts of the omega fatty acids. Do they have to know what these functions are? Do they have to know that the sources of polyunsaturated fats are in fact the essential fatty acids of which there are only two required by humans? Inspection of examination papers and course books published by Award Bodies may reveal the levels of detail
required but this should not be necessary. The information in the specification should be sufficient.

Whilst there is some positive evidence from this analysis that Award Boards, through their GCSE examination specifications, are contributing to the development of a modern food technology curriculum it is also clear that there is further work to be done. There are several aspects of the framework either missing or covered at only a minimal level, such as the role of government agencies and the food industry. The details required by different Award Boards is also an issue, if teachers are uncomfortable teaching about food manufacturing processes it is possible to select a specification which makes little reference to this. More consistency and greater clarity is needed in some of the examination specifications to ensure amplification and understanding of the nature of food technology and the value of pupils’ learning in a modern food technology curriculum.

Given these requirements at GCSE examination level, it is even more important that the lower secondary curriculum for food technology properly prepares pupils to meet these requirements and that there is progression across the year groups. Our evidence, from earlier research (Rutland & Owen-Jackson, 2012) is that this is not the situation.

References
Integrative Stem Education as “Best Practice”

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In accordance with the conference theme—“Exploring Best Practice in Technology Design & Engineering Education”—I make a case in this paper for investigating “integrative STEM education” as a prospective best practice in technology education. I begin with an embellished operational definition of integrative STEM education and follow that with an extensive rationale for investigating the integrative STEM education pedagogical model as a technology education best practice. In the latter part of the paper I discuss the “design experiment” research methodology (Brown, 1992; Collins, 1992) and make the case that technology education researchers employ this methodology in their investigations of integrative STEM education. Design experiment methods are ideally suited to investigating innovative pedagogies and would benefit technology education by concurrently improving the integrative STEM education pedagogical model while generating new theories of technological learning, S, T, E, & M learning, and integrative STEM learning.

In accordance with the conference theme—“Exploring Best Practice in Technology Design & Engineering Education”—I make a case in this paper for investigating “integrative STEM education” as a prospective best practice in “technology education” (a term used throughout this paper to refer collectively to the field by that name in the United States as well as parallel fields elsewhere in the world, such as “Design & Technology,” Technology & Engineering Education,” etc.). I begin with an embellished operational definition of “integrative STEM education” and follow that with an extensive rationale for investigating the integrative STEM education pedagogical model as a technology education best practice. In the latter part of the paper I suggest a research methodology for investigating integrative STEM education and discuss issues relating to the thesis of this paper.

The very notion of best practice presents a dilemma, as we really cannot know an educational practice to be a best practice until we have investigated it to make that determination. Moreover, the determination of best practice is socially constructed and thus subjective/political in nature. In America, best practice is usually justified by declaring it “standards-based.” But that, too, is a claim often made without evidence. Moreover, standards may be dated and relatively vague in their attention to both content and instructional method. For these reasons, it makes sense to go into further investigation of best practice candidates, as is suggested herein.

Why “Integrative STEM Education”?

Though the term “STEM Education” has been worn out in the United States, there has never been agreement regarding its meaning. Sanders (2008) labeled this phenomenon “STEMmania” and encouraged the field to abandon “STEM education” for “integrative STEM education.” In addition to the serious problems created by the hopeless ambiguity
of STEM education, I’m troubled that the use of that phrase has further marginalized Technology Education in the United States, as it has all too often been employed to generate new funding streams limited to science and mathematics education. The operational definition of integrative STEM education prevents that sleight of hand.

Throughout most of the 20th century, industrial arts educators in the United States focused on teaching industrial processes to boys and girls “for the values which such study affords in one’s everyday life, regardless of his occupation” (Bonser & Mossman, 1923). In the past few decades, the focus of technology education has shifted to “technological literacy for all,” as described in Standards for Technological Literacy (STL) (ITEA, 2000). The goal of technological literacy for all begs this question: Shouldn’t a technologically literate person in the 21st century be expected to possess the knowledge and ability to apply basic math, science, and engineering concepts and practices in designing, making, and evaluating solutions to authentic problems?

Consider that the Next Generation Science Standards (NGSS) call for:

> a commitment to fully integrate engineering and technology into the structure of science education by raising engineering design to the same level as scientific inquiry in classroom instruction…and by according core ideas of engineering and technology the same status as core ideas in the other major science disciplines” (NGSS, 2012, 1).

It seems to me that “integrative STEM literacy” would be a better name (for what’s described immediately above) than “science literacy” or “technological literacy.” But by whatever the name, technology educators should be playing a prominent role in delivering / investigating it.

**Integrative STEM Education Defined**

In September 2005, The Technology Education faculty at Virginia Tech launched an innovative STEM Education graduate program that recruits science, technology, engineering, mathematics, and elementary teachers/administrators who enroll to study teaching, learning and educational research at the intersections of these disciplines (Sanders & Wells, 2005). From the onset, the program philosophy was about intentionally situating the teaching/learning of science and mathematics concepts and practices in technological/engineering design-based instructional activities. When it became clear that “STEM education” had become hopelessly ambiguous, Sanders proposed alternative program names that might be more descriptive of the program’s philosophy than was “STEM education” as well as a number of carefully worded operational definitions that would capture the essence of the ideas on which the new graduate program had been founded. After numerous discussions, the faculty (Sanders and Wells) agreed upon “Integrative STEM Education” with the following definition:

Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts practices of technology and engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc. (Sanders & Wells, 2006).

The intent of this operational definition was to exclude pedagogical approaches that do not purposefully situate the teaching and learning of STEM concepts and practices in technological/engineering design-based pedagogy. Moreover, only technologies that are integral to designing, making, and engineering were to “pass” for the “T” in this definition.
That is, using one or more instructional technologies to teach science and/or math concepts and practices would not constitute “integrative STEM instruction” because it wasn’t consistent with the operational definition. Table 1 provides a list of selected characteristics of integrative STEM that further describe its nature.

Table 1 Selected Characteristics of Integrative STEM Education

<table>
<thead>
<tr>
<th>Learning outcomes: As a result of one or more semesters of K-12 integrative STEM education, students will be able to:</th>
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<tr>
<td>▪ demonstrate integrative STEM knowledge and practices;</td>
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<tr>
<td>▪ effectively use grade-appropriate S, T, E, &amp; M concepts and practices in designing, making, and evaluating solutions to authentic problems; and</td>
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<td>▪ demonstrate STEM-related attitudes and dispositions.</td>
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<th>Scope: Integrative STEM education…</th>
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<tr>
<td>▪ is appropriate for all K-PhD grades / students;</td>
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<tr>
<td>▪ is not intended to supplant S, T, E, &amp; M instruction that is more effectively taught non-integratively;</td>
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<td>▪ may be implemented by one or more S, T, E, or M teachers in one or more classrooms / class periods;</td>
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<tr>
<td>▪ may be implemented during and/or after the normal school day; and</td>
</tr>
<tr>
<td>▪ should be thoughtfully and effectively articulated across multiple school grades/bands.</td>
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<th>Pedagogy: Integrative STEM education pedagogy:</th>
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<tr>
<td>▪ is consistent with accepted learning principles (e.g., Bransford, et al., 2000; Bruning, et al., 2004; Ormrod, 2012; Eberly Center for Teaching Excellence (2012))</td>
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<tr>
<td>▪ may be interdisciplinary, transdisciplinary, or multidisciplinary in nature (Drake, 2007);</td>
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<td>▪ purposefully engages students in integrative thinking that ranges from simple to complex;</td>
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<tr>
<td>▪ purposefully engages and assesses students in the application of grade-appropriate S, T, E, &amp; M concepts and practices in designing, making, and evaluating solutions to authentic problems;</td>
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<tr>
<td>▪ provides a robust context for integrative STEM-related learning associated with all levels of the cognitive and affective taxonomies (Bloom, et al., 1956)</td>
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Antecedents to Integrative STEM Education

In the late 1870s, Calvin Woodward, who had earned a PhD in mathematics from Harvard University, established a lab at Washington University (St. Louis) in which he required his mathematics students to construct geometric models from drawings, so they might better understand the mathematics concepts he was teaching (Bennett, 1937). In 1880 he founded the “St. Louis Manual Training School” and has since been thought of as the founder of the field that became known as Technology Education in the United States By situating the learning of mathematics concepts and practices in the context of wooden
model exercises, Woodward was arguably the first to promote and investigate an integrative approach to STEM instruction as best practice.

Eighty years later, the USSR’s “Sputnik” mission triggered new funding for educational reform in Science, Mathematics, and Industrial Arts education (the latter being the field now known as Technology Education in the U.S.). Donald Maley, the leading voice in Industrial Arts Education at the time, put out this call for integrative STEM education:

“It is at this point as never before in the history of education that Industrial Arts can enter into its own with one of its true values recognized. “Where else in the school is there the possibility for the interaction and application of mathematical, scientific, creative, and manipulative abilities of youngsters to be applied in an atmosphere of references, resources, materials, tools, and equipment so closely resembling society outside the school?” (Maley, 1959, 258-259).

While Maley’s response to his own rhetorical question was to develop his secondary level Research and Experimentation course, which purposefully situated mathematics and science in the context of technological activity, most others in the field continued to focus their energies on instructional content rather than method. A half-century later, his “R&E” class might still be considered a best practice in technology education.

S, T, E, & M Education Communities Validate Integrative STEM Education as Best Practice

Best practices are validated by the communities in which they are implemented. This process begins with the introduction of new instructional materials and practices, typically through curriculum development, publication of supporting materials, and professional development. Early adopters within the community begin to implement the new instructional materials and scholars in the community begin to investigate their efficacy. Through these processes, each of the S, T, E, & M education communities have begun to validate integrative STEM education over the past two decades.

Science Education Community Validates Integrative STEM Education as Best Practice

Nation at Risk (National Commission on Excellence in Education, 1983) a national report highly critical of the disconnected subject area “silos” and other shortcomings in K-12 American education triggered the current wave of education reform in the United States. In response, Science for All Americans (American Association for the Advancement of Science, 1989) set the tone for STEM education reform with the following theme, which runs throughout Science for All Americans: “It is the union of science, mathematics, and technology that forms the scientific endeavor.” (p. 25). They followed with this core idea of integrative STEM education: “The ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others.” (AAAS, 1993, pp. 321-322).

Given that the AAAS represents ten million individuals in 261 AAAS-affiliated societies, it’s fair to say the science education community validated integrative STEM education as best practice more than 20 years ago.

The emergence, this past year of the publication titled Next Generation Science Standards (NGSS, 2012) from a powerful political partnership involving the AAAS,
National Academy of Sciences, National Science Teachers Association, National Academy of Engineering, and the Achieve organization re-validates the integrative STEM in through statements such as:

What is different in the Next Generation Science Standards (NGSS) is a commitment to fully integrating engineering and technology into the structure of science education by raising engineering design to the same level as scientific inquiry in classroom instruction when teaching science disciplines at all levels, and by according core ideas of engineering and technology the same status as core ideas in the other major science disciplines. (NGSS, 2012, 1).

The NGSS includes the following (integrative STEM-validating) rationale for promoting this turn toward engineering; “From a practical standpoint the Framework notes that engineering and technology provide opportunities for students to deepen their understanding of science by applying their developing scientific knowledge in different contexts.”

Further validation for integrative approaches to STEM education comes from science education scholars, who have been investigating integrative STEM instructional approaches for the past two decades. (See, for example, Cajas, 2001; Crismond, 2001; Edelson, 2001; Fortus, Dershimer, Kračik, Marx, Mamluk-Naaman, 2004; Fortus, Kračik, Dershimer, & Mamluk-Naaman, 2005; Kolodner, 2002; Roth, 1991; Roth, 1992; Roth, 2001; Schaub, Klof, & Raghavan, 1991; Seiler, Tobin, & Sokolic, 2001, 2009).

Technology Education Community Validates Integrative STEM Education as Best Practice

Standard #3 of the national Standards for Technological Literacy (STL*, ITEA, 2000) emphasizes the integration of technology education with science, mathematics, and other school subjects. Connections between technology and engineering are made explicit in Standard 9—“Students will develop an understanding of engineering design” (p. 99)—and implicitly throughout most of the other standards.”

Scholars from the technology education community began to get involved in the development and investigation of integrative STEM instructional materials and practices in the early 1990s and have continued those investigations to the present (See, for example, Barak, & Zadok, 2009; Brusic, 1991; Brusic & Barnes, 1992; Childress, 1996; Dearing & Daugherty, 2004; Engstrom, 2012; Hutchinson, 2002; LaPorte & Sanders, 1996; 2008; Satchwell & Loepp, 2002; Merrill, 2001; Rossouw, Hacker, & de Vries (2010); Scarborough & White, 1994; and Todd, 1999).

Technology Education units within State Departments of education began developing new state-wide integrated mathematics, science, and Technology frameworks and standards (e.g., New York State Education Department, 1990; Massachusetts Department of Education, 2001) as well as new “Engineering” courses that sought to integrate content and practices across the STEM continuum (e.g., New York State Education Department, 1995; Virginia Department of Education, 1992). Similarly, Project Lead the Way (founded in 1996 by a Technology Education teacher) widely disseminated its middle and high school engineering curriculum that integrates STEM content and practices (Blais, 2004). And over the past decade the International Technology and Engineering Educators Association (ITEEA) has been developing/disseminating nationally its “integrative” K-12 Engineering by Design
(EbD) curriculum.

In addition, over the past two decades, the technology education literature has been heavily populated with articles describing instructional materials designed to integrate technology, science, and mathematics (Sanders and Binderup, 2000) and articles addressing issues associated with the integration of STEM concepts and practices (e.g., Bunsen & Bensen, 1990; Kipperman & Sanders, 2007; Loepp, 2004; Merrill, 2001; Sanders, 2004, 2006, 2008, 2011; Williams, 2011).

**Engineering Education Community Validates Integrative STEM Education as Best Practice**

The National Academy of Engineering (NAE) has overseen several projects that have resulted in books promoting integrated approaches to STEM education as a means of introducing engineering content into K-12 schools (see, Committee on Standards for K-12 Engineering Education, 2010; Katehi, Pearson, & Feder, 2009). Currently, the NAE’s project titled *Toward Integrated STEM Education: Developing a Research Agenda* “aims to develop a strategic research agenda for determining the approaches and conditions most likely to lead to positive outcomes of iSTEM.”

**Mathematics Education Community Validates Integrative STEM Education as Best Practice**

The national mathematics standards (NCTM, 2000) have been less explicit in their support for integrative STEM instructional approaches than have the other national STEM standards documents. They do, however, note the importance of connecting mathematics instruction to “real world problems” and of situating mathematics in contexts other than mathematics classrooms. The new *Common Core State Standards for Mathematics* opens the door for integrative approaches through their emphasis on “cross-cutting initiatives.”

A growing number of scholars have begun to investigate the teaching and learning of mathematics in K-12 technology and engineering design contexts (see, for example, Burghardt, Hecht, Lauckhardt, & Hacker, 2010; Lehrer & Schauble, 2012; Moore, 2012; Nathan, Phelps, & Atwood, 2011; Nathan & Wagner, 2011; Norton, 2007; Stone, 2008).

**Research on integrated teaching validates integrative approaches to STEM education**

The research on integrated / interdisciplinary approaches to instruction has been mixed and perhaps smaller in volume than one might expect, signaling a need for further, well-designed research in this area. A number of researchers have identified benefits of integrated instruction. For example, Beane (1995) found that students in integrated curricula did as well or better on “traditional measures of school achievement” than those in separate-subject curricula. Greene (1991) found increased student interest and increased achievement scores on the *National Assessment of Educational Progress* for California students enrolled in year-long thematic units. Vars (1991) reported higher standardized achievement scores associated with integrated instruction. A number of studies have concluded that increased student interest resulted from interdisciplinary instruction.

Hartzler (2000) conducted a meta-analysis of 30 quantitative studies of the effects of
integrated instruction on student achievement. Among her conclusions were the following: 1) students in various types of integrative/interdisciplinary programs performed as well or better on standardized achievement tests than students enrolled in the usual separate subjects; 2) students in integrated curricular programs consistently out-performed students in traditional classes on national standardized tests, in-state-wide testing programs and on program developed assessments; 3) integrated curriculum is a viable alternative to traditional subject-centered programs without fear of student failure or declining standardized test scores; 4) integrated curricular programs were successful in all four of the major academic areas: Language Arts, Math, Social Studies, and Science and at all grade levels showed the most promise; 5) Students from all socio-economic levels benefited from integrated curricular programs (159-160)

**Learning Sciences and Integrative STEM Education**

With the publication of *How People Learn*, (Bransford, Brown, & Cocking, 2000) the learning sciences community came together to organize and synthesize the collective body of knowledge relating to how people learn. They, and others who continue this important work organize the findings of the learning sciences into: 1) a set of factors that are known to be important for influence learning—generally referred to as “principles of learning”—and 2) a much larger set of learning theories—statements that provide explanations of the underlying mechanisms that contribute to learning (Ormrod, 2012).

In Table 2 below, I have juxtaposed a set of principles of learning synthesized from the learning sciences research by the Eberly Center for Teaching Excellence at Carnegie Mellon University with brief and somewhat parallel statements I have drawn from the integrative STEM education literature. I present this table for two reasons. First, I think it provides further support for the idea of integrative STEM education as best practice. Secondly, the statements in the right column—drawn from the literature—strike me as kernels of ideas that could/should be further investigated. So, for example, the first learning principle in Table 2 deals with prior knowledge, and the column to the right indicates “integrative STEM education provides timely opportunities for students to activate prior knowledge.” I think technology education researchers should investigate that idea and others like it (e.g., others listed in the right-hand column of Table 2 and/or other ideas drawn from the literature) as I think doing so would lead to further “conjectures” and “humble theories” (as described later in this paper) about technological practice-related learning and learning in the integrative STEM education context. Moreover I think it behooves technology education to be at the forefront of that research activity.

**Table 2. Principles of Learning and Associated Integrative STEM Education Pedagogy**

<table>
<thead>
<tr>
<th>Theory &amp; Research-based Principles of Learning (Eberly Center for Teaching Excellence, 2012)</th>
<th>Integrative STEM Education…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students’ prior knowledge can help or hinder learning. Students come into their courses with knowledge, beliefs, and attitudes gained in other courses and through daily life. As students bring this knowledge to bear in our classrooms, it influences how they filter and interpret what they are learning. If students’ prior knowledge is robust and accurate and activated at the appropriate time, it provides a strong foundation for building new knowledge. However, when knowledge is inert, insufficient for the task, activated provides timely opportunities for students to activate prior knowledge.</td>
<td></td>
</tr>
</tbody>
</table>
Inappropriately, or inaccurately, it can interfere with or impede new learning.

<table>
<thead>
<tr>
<th>How students organize knowledge influences how they learn and apply what they know. Students naturally make connections between pieces of knowledge. When those connections form knowledge structures that are accurately and meaningfully organized, students are better able to retrieve and apply their knowledge effectively and efficiently. In contrast, when knowledge is connected in inaccurate or random ways, students can fail to retrieve or apply it appropriately.</th>
<th>Provides a unique and powerful context for meaningfully organizing STEM knowledge for future retrieval/ use.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students’ motivation determines, directs, and sustains what they do to learn. As students gain greater autonomy over what, when, and how they study and learn, motivation plays a critical role in guiding the direction, intensity, persistence, and quality of the learning behaviors in which they engage. When students find positive value in a learning goal or activity, expect to successfully achieve a desired learning outcome, and perceive support from their environment, they are likely to be strongly motivated to learn.</td>
<td>Generates high levels of interest and motivation among a wide range of students of all ages and abilities.</td>
</tr>
<tr>
<td>To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned. Students must develop not only the component skills and knowledge necessary to perform complex tasks, they must also practice combining and integrating them to develop greater fluency and automaticity. Finally, students must learn when and how to apply the skills and knowledge they learn. As instructors, it is important that we develop conscious awareness of these elements of mastery so as to help our students learn more effectively.</td>
<td>Immerses students in the application and integration of S, T, E, &amp; M knowledge, skills, and practices over extended periods of time.</td>
</tr>
<tr>
<td>Goal-directed practice coupled with targeted feedback enhances the quality of students’ learning. Learning and performance are best fostered when students engage in practice that focuses on a specific goal or criterion, targets an appropriate level of challenge, and is of sufficient quantity and frequency to meet the performance criteria. Practice must be coupled with feedback that explicitly communicates about some aspect(s) of students’ performance relative to specific target criteria, provides information to help students progress in meeting those criteria, and is given at a time and frequency that allows it to be useful.</td>
<td>Provides students with a specific goal (a design challenge) and ongoing feedback from peers, teachers, and from their self-evaluations of their designed/made solutions.</td>
</tr>
<tr>
<td>Students’ current level of development interacts with the social, emotional, and intellectual climate of the course to impact learning. Students are not only intellectual but also social and emotional beings, and they are still developing the full range of intellectual, social, and emotional skills. While we cannot control the developmental process, we can shape the intellectual, social, emotional, and physical aspects of classroom climate in developmentally appropriate ways. In fact, many studies have shown that the climate we create has implications for our students. A negative climate may impede learning and performance, but a positive climate can energize students’ learning.</td>
<td>Creates conditions for students to engage in ongoing positive, non-threatening, and reflective social interaction with their teachers, teammates, and classmates.</td>
</tr>
<tr>
<td>To become self-directed learners, students must learn to monitor and adjust their approaches to learning. Learners may engage in a variety of metacognitive processes to monitor and control their learning—assessing the task at hand, evaluating their own strengths and weaknesses, planning their approach, applying and monitoring various strategies, and reflecting on the degree to which their current approach is working. Unfortunately, students tend not to engage in these processes naturally. When students develop the skills to engage these processes, they gain intellectual habits that not only improve their performance but also their effectiveness as learners.</td>
<td>Engages students in a group design challenge that encourages them to take responsibility for their planning, self-assessing, self-monitoring and reflection.</td>
</tr>
</tbody>
</table>
Content & Method for Best Practice
Teaching of any subject requires attention to both the content to be taught and the instructional methods employed. The STL (ITEA, 2000) sought to identify “content for the study of technology,” and for the past dozen years, the STL have provided guidance for technology educators in the United States and beyond with respect to what to teach. Though I am proposing integrative STEM education pedagogy in this best practice model, I envision the technological content identified in STL as the primary content to be delivered by technology educators via the integrative STEM pedagogy. Historically, the field used the “project method” to address the how to teach question. For more than two decades, technology educators around the world have increasingly turned to design-based instructional methods for teaching content for the study of technology. I think it’s safe to say that the technology education community has long considered design-based instruction a best practice. Integrative STEM education is a design-based pedagogy that builds upon all that technology educators have learned about design-based instruction over the past two decades. In addition, integrative STEM pedagogy purposefully seeks to engage students in using/apply intoo math, science, and engineering concepts and practices in designing, making, and evaluating solutions to authentic problems. One might, therefore, think of integrative STEM education as design-based technology education that authentically integrates the doing of mathematics and/or science into the design-based activity.

Investigating Integrative STEM Education
The design/make/evaluate pedagogical paradigm offers a robust learning ecology for the integration/application of engineering, science, and mathematics concepts and practices into the study of technology. And, although the science education community is now ramping up to “fully integrate engineering and technology into the structure of science education by raising engineering design to the same level as scientific inquiry” (NGSS, 2012), technology teachers are uniquely qualified to implement and investigate integrative approaches to STEM education. The unique perspective technology education researchers bring to this activity will result in unique and important findings that those from other fields with differing perspectives (e.g., science education, mathematics education, and learning sciences) are not likely to discover.

While relatively few in technology education have formally employed the “design experiment” research methodology (Brown, 1992, Collins, 1992), in many ways, it is ideally suited to investigating innovative teaching practices in technology education. For that reason, among others, Janet Kolodner (1999) made this same recommendation to Technology Education researchers more than a decade ago. Ann Brown (1992) the first to describe design experiment methods 20 years ago, summarized it this way: “I attempt to engineer innovative educational environments and simultaneously conduct experimental studies of those innovations” (1992, p. 141). Trained to study human learning by observing lab rats and children in research labs rather than classrooms, Brown’s goal was to “transform classrooms from work sites where students perform assigned tasks under the management of teachers into communities of learning” (p.141).

The point of the design experiment was twofold. On the one hand, Brown wanted to
“orchestrate all aspects” of the classroom environment, based upon previous research findings, to create a designed learning ecology that would facilitate the development and testing of learning theories: “It is essential that we assess the aspects that our learning environment was set up to foster” (p. 143). Toward that end, the research team describes its assumptions about “the intellectual and social starting points for the envisioned forms of learning.” These starting points and “conjectures” drawn from the literature become kernels of the theories to be tried and tested in the design experiment. On the other hand, Brown thought of the design experiment method as “intervention research designed to inform practice.” (p. 143). In other words, data collected in a design experiment for the purpose of testing one’s theories is also used to revise any and all details of the pedagogy. For this reason, technology education researchers and practitioners would both benefit from design experiments in the field. The likely result would be improved instruction—e.g., from good” practice” to “better” or “best” practice—and a new set of theories of technological learning.

Design experiments typically draw data from an array of sources; Brown listed 1) standard measures of content knowledge; 2) observations (audio / video recordings) of teacher planning, direct instruction, individualized coaching and responsive teaching, social interactions among teachers and students; 3) student work artifacts and student portfolios; 4) email or audio/video recordings of teacher and/or student discourse; 5) interviews with teachers and students; etc.

Documenting the “learning ecology” is an important component of design experiments (Kelly & Lesh, 2000). Studies of technology education practice would generally benefit from careful documentation of the learning ecology being investigated. In his review of Analyzing Best Practices in Technology Education Householder (2008) wrote: “It would be highly valuable to have more detailed, thicker descriptions of highly effective classroom practices. Richer images of outstanding instruction could withstand penetrating analyses and lead to the development of a stronger theoretical base for innovation in technology education.”

Though Brown’s tenets of design experiments remain relatively unaltered, the methods she outlined and methodological issues she addressed were revisited in special issues of Educational Researcher (2003) and the Journal of Learning Sciences (2004). Readers interested in design experiment methods will find both of these special issues helpful. For example, Cobb, Confrey, diSessa, Lehrer & Schauble, (2003) outlined five crosscutting features of design experiments:

1. The purpose of design experiments is to develop a class of theories about both the process of learning and about the means that are designed to support that learning.
2. Design studies are test-beds for innovation. The intent is to investigate the possibilities for educational improvement by bringing about new forms of learning in order to study them.
3. Design experiments create the conditions for developing theories yet must place these theories in harm’s way [by testing and revising them based upon the data collected].
4. As conjectures are generated and perhaps refuted, new conjectures are developed and subjected to test. The result is an iterative design process featuring cycles of invention and revision.
5. Theories developed during the process of experiment are humble, not merely in the sense that they are concerned with domain-specific learning processes… but also because… the theory must do real work…. The critical question that must be asked is whether the theory informs prospective design, and if so, in precisely what way? (Cobb, et al., 2003)

Discussion
The final point from Cobb, et al., (above) speaks to a gap in technology education research. Technology education researchers have not made the development of learning theory the hallmark of their work. They have more generally been concerned with the broad issues of curriculum and instruction rather than with formulating and systematically investigating conjectures and “humble learning theories” regarding the nature of technological learning. Thus, the field has been prone to making broad claims with relatively little evidence to substantiate those claims. For example, technology educators in the United States are fond of saying, in effect, “Students who take Technology Education courses become technologically literate.” Although Technology Education in the United States is grounded in that idea, there has never been a measure of technological literacy that has really been used beyond its development phase. (Garmire & Pearson, 2006) and theories relating to technological and/or integrative STEM learning are exceedingly scarce.

And yet, there is now unprecedented interest from science, technology, and engineering educators in the idea of situating the teaching and learning of mathematics and science in the context of engineering design activity. Moreover, there have been countless unsubstantiated claims regarding the benefits of doing so. We need new theories that help to explain the mechanisms involved in technological learning, and technology education researchers should be deeply involved in that work. Integrative STEM design experiments would provide an exceptional environment in which technology educators might begin to test their humble theories and conjectures relating to technological learning. Certainly science and engineering educators will be taking on that work in the decades ahead. But technology educators will continue to approach the study of technology from a unique perspective; a perspective that would give rise to unique theories of learning that perhaps will not come from the work of those in other fields.

Integrative STEM education is, therefore, an innovative pedagogy that presents enormous opportunity for technology education researchers. The opportunity has to do with establishing integrative STEM design experiments that may be used to investigate a wide range of conjectures and humble theories regarding STEM and integrative STEM learning in a learning ecology that situates that STEM learning in the context of authentic technological/engineering design-based problem-solving.

Some Technology educators contest the idea of integrating science, mathematics, and even engineering concepts and practices into curricula designed for the study of technology. Yet, technology educators (and technologists) have always used mathematical tools and have always applied scientific concepts and practices, in their work. Moreover, it is ludicrous to think the field that now calls itself (in the United States) “Technology & Engineering Education” would not seek to step up its game with respect to the integration of mathematics, science, and engineering into the Technology Education curriculum. To
wit, one of the stated goals of the ITEEA’s *Engineering by Design* curriculum is to “provide clear standards and expectations for increasing student achievement in math, science, and technology” (ITEEA, 2012).

To be sure, I’m not advocating design experiments as the only method for investigating best practice candidates. Because different research designs/methods each have their strengths and weaknesses, I think the field should employ the full continuum of research methods to investigate technology education teaching and learning. Nor am I advocating integrative STEM education as the only form of technology education best practice. Rather, I’m suggesting the field would benefit from investigating new pedagogical approaches with the *design experiment* method and I’m advocating integrative STEM education as a candidate for technology education best practice consideration.

**Conclusion**

Nearly a decade ago, in her paper titled “Improving Technology Education Research on Cognition” (2004), Karen Zuga wrote:

Technology educators and researchers in the United States do have a history of trying to research cognition as it relates to technology education. However, the efforts have been criticized from within the profession as having too much breadth and not enough depth. There are several reasons for this state of affairs that are related to the size of the profession, as well as to the topic, technology, and the culture of the professionals. In order of priority, changing this state of affairs may best be done by: 1) creating theory for technology education; 2) identifying the constructs and concepts that students learn through technology education activities; 3) adopting a theoretical framework for research design and problems; 4) assessing the effectiveness of technology education in addressing those key concepts; 5) including teachers in research; and 6) using qualitative methods.

I confess I re-discovered Zuga’s paper after completing the draft of this paper… and now can’t help but close with it. The idea of investigating integrative STEM pedagogy with the design experiment methodology *nails* each of Zuga’s six recommendations. Moreover, choosing “integrative STEM pedagogy as the focus of the design experiment will allow researchers to deeply interrogate the not-so-humble-theory that teaching science and mathematics in the context of technological/engineering design improves students’ interest, understanding, and abilities in each of the STEM disciplines.

**References**


Technology Teachers as Researchers: The Tuff Experience

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In this paper, experiences from graduate school TUFF (Technology Education for the Future, in Swedish TUFF), where twelve practicing technology teachers (primary, secondary and upper secondary school teachers) was given the opportunity to do research up to the licentiate level ('half a PhD') for 2.5 years, is presented. Ten of the participating teachers have answered a survey and six have been further interviewed to get a deeper understanding of their experiences regarding two selected questions namely (1) why it was difficult for the participants to finish their theses in time and (2) their views on their contacts/collaboration with between school, municipal and university. In the discussion it is concluded that the graduate school has added new knowledge in technology didactics to the Swedish society. Findings also show that the planning, organization and implementation of teacher graduate schools must be coordinated carefully with all concerned parties (municipalities, schools, universities and the teacher-graduate students) and span over a longer period than previous initiatives and projects in order to achieve sustainable effects from the teacher graduate research schools.

Introduction

In 2008, a governmental initiative (the so called Boost for Teachers Initiative) made it possible for ten universities in Sweden to start graduate schools in selected subject areas. In-service teachers were offered two and a half years of study leading to licentiate level ('half a PhD'). The conditions of this initiative were very favourable for both participants and organizers (universities). For teachers, the arrangement meant four days of studies and one day of teaching in school each week with full payment during the entire period of study. The universities were awarded full funding for the operation of the training.

One of these doctoral programs is Graduate School Technology Education for the Future (Swedish acronym: TUFF). Graduate School TUFF is specially designed for technology teachers wanting to do research about teaching and learning technology. At the 6th Biennial Technology Education Conference 2010, we presented the background of the governmental initiative and our experiences from the first two years of working with TUFF (Skogh, 2010). In June 2012, the TUFF project was formally concluded and we are now in the position to evaluate the program.

The main purpose of this text is to describe and discuss some of our experiences from TUFF. What was gained and what might have been lost? And not least important—what can be learned from the TUFF experience?

Background

Teachers as researchers

Since the early 2000s, efforts have been made to promote and support practice oriented
educational research in Sweden. The need for a dialogue between research, training and the educational sectors, and the need to make research results available to interest groups, has been emphasized by both researchers and politicians (Andræ Thelin, 2009, Prop. 1999/2000:81).

In 2001, the idea of so-called teaching-graduate students was introduced in a governmental proposal (Prop. 2000/2001:3). The example given by authorities has since been followed by a number of PhD programs. These similar, successive PhD programs have however been initiated by municipalities and/or universities wanting to collaborate. On a national level the 2001 initiative to promote teachers to do practice-based research was followed up in 2008 within the frames of a professional development program called the Boost for Teachers Initiative.

**The Boost for Teachers Initiative**

The Boost for Teachers Initiative was launched in the beginning of 2008 and focused on continuing professional development for teachers. The program aimed to “…strengthen teacher’s competence, both in the theory of their subject and pedagogical approaches to teaching” (NAE, 2009). Teachers’ participation in the program should, according to regulations, be governed by the needs and priorities of the local schools/municipalities. Demands were obviously put on participating teachers. To be eligible a number of requirements were set. Participating teachers must have a teaching qualification in higher education, be practicing teachers and be qualified for research studies by concerned universities (Skogh, 2010). In the autumn of 2007, universities in Sweden were invited to develop specially designed graduate school programs. In March 2008, ten programs were selected by the government (via the National Research Council). One of the selected programs was TUFF.

**About TUFF**

TUFF was launched in March of 2008 and has been run in cooperation between Stockholm University, the Royal Institute of Technology and the University of Gävle. During the spring of 2008, the recruitment of applicants started in parallel with the designing of the program, sorting out economic procedures and issues of practical and logistic nature. There were demands for a speedy process as studies, according to the governmental decision, had to start in August of 2008 (Skogh, 2010). In order to guide research into issues of particular concern to the graduate school, a list of research questions was presented to the applicants. It was also decided that all theses should be written in English. Between thirty and forty applications were submitted to the program. The following criteria were decisive in selecting who to admit to the program:

In addition to the formal requirements stated by the government and the participating universities we were looking for persons having the ability to verbally and in writing present their research interest and their choice of research question/ research area with precision and in a credible manner. We also wanted our future students to demonstrate a number of subtle personal properties that are difficult to capture in words but still are well known to all researchers; purposefulness, a clear sense of reality, good reflectivity, openness to opinions and arguments and, not least, accuracy. Research work means both solo work and group work. We were therefore keen to find individuals with self-discipline and with good interpersonal skills (Ibid.).
An overview of the basic facts about TUFF is presented in Figure 1 (below)

**Figure 1 FAQ about TUFF**

- Started March 15, 2008 and was formally closed June 30, 2012.
- Run in cooperation between by Stockholm University (SU), Royal Institute of Technology (KTH) and the University of Gävle (HiG).
- Two postgraduate education subject areas: Education in Arts and Professions (SU) or Philosophy (KTH).
- Three aims were set up:
  - to strengthen the status of technology and the efficiency in compulsory school technology education
  - to strengthen the recruitment to technical studies in high school and college and
  - to promote gender-neutral education and gender balance in recruitment.
- From these aims three objectives were extracted. Research should address the following areas:
  1. (1) explore factors affecting recruitment to technology training and develop methods to promote recruitment,
  2. (2) develop practical methods for teaching technology education in primary and secondary education and
  3. (3) explore how gender equality can be increased in recruitment and in the teaching of technology subjects.
- The result of study for each student should continuously be fed back to their schools in order to certify a practice-related research situation as well as to inject the outcome of research in school practice.
- Twelve (12) teacher graduate students (six women, six men).

**Related research**

There is a considerable amount of national and international research concerning different aspects of teacher education and teachers training and/or teacher socialization. In addition to the studies mentioned by Skogh (2010) as e.g. Cochran-Smith & Zeichner (2005) and Carlgren, Handal & Vaage (1994) there are a number of international (e.g. Enthoven & de Bruijna, 2010 and Zeichner & Noffke, 2001; Goodson, 2008) and national (e.g. Eklund, 2012; Carlgen, 2009) studies focusing practitioner research. In the context of this paper – experiences made from working with teacher graduate students within TUFF – research about teacher-graduate school programs in Sweden are of particular interest. Below three such studies are presented.

In a pilot study (Proitz, 2005) the first 'generation' of teaching-graduate students (the 2001 NAE-initiated teaching-graduate program) was studied. Interviews with the students indicate that most municipalities (school owners) appeared to be 'silent' partners in the follow-up of the candidates and also regarding the matter of planning for the teachers’ future, after graduation (Ibid, p. 114). Andre-Thelin (2009) performed a study of the same project/students. Several of the students mention positive experiences regarding their contacts with representatives from their municipalities. Unfortunately, according to the students, holders of key positions in the municipal administration were often replaced, thus risking continuity in personal contacts. At the time of the study (2009) 56 % of all
students in the program had completed their PhD-studies. Since a majority of the teachers started their PhD studies in 2002 the average time spent on PhD studies in many cases exceeds the stipulated 5 years of studies (80% studies, 20% institutional assignments). The vision of a future job where their acquired knowledge would be acknowledged and used was shared by most students. To return to their prior work as teachers was, according to the students, not an option.

In 2012 the government initiated an evaluation study of the ten teacher graduate schools within the 2008 Boost for Teachers Initiative (including TUFF). The study (HSV, 2012) shows that the work process and implementation of education has largely functioned as intended, although a relatively high proportion of the participants needed more time than planned to finish. At time of the survey (December 2011) 44% percent of 160 participants were in need of additional time to complete their studies. The main reason for this is reportedly, the demanding combination of research studies and work in schools. Few of the concerned school principals have a plan regarding how to utilize the teachers’ skills in school activities. Moreover, only 50% of the participating teachers are planning to continue to work as teachers.

**Aim and research question**

In this paper we are in particular interested in identifying factors of importance to the organization and content of the graduate school program. The contribution aims at increasing our knowledge about how future programs should be designed to be as effective as possible. The following two research questions are addressed:

- What experiences do TUFF students express regarding their studies in general and their own personal goal fulfillment in particular?
- What perception of interest from the municipal/school regarding their research and future career?
- What lessons could be learned from this?

**Theoretical framework**

The TUFF students studied have made an active choice to continue their education after several years of teaching in schools, well aware of the clearly stated aim and goal of the graduate programs that they, after completing their studies, should return to school and contribute to the school development in their schools/municipalities. The intermediate process – the question of how the teaching in the academy is organized, planned and implemented – needs to be studied in order to understand the outcome of their graduate studies, i.e. how and if they complete their studies and if they return to school and develop it.

In this study, Frame factor theory thinking (Sv. Ramfaktorteoretiskt tänkande) is used as a tool for understanding how the TUFF graduate students in diverse work and life situations has/can benefit from the opportunities created within the Boost for Teachers Initiative and TUFF. This conceptual model was introduced by Dahllöf (1967, 1999) in the 1960s and was initially referred to as Frame factor theory thinking (FFTT) by Gustafsson & Selander (1994). FFTT provides a model for thinking about management training and education not as an effect of interventions, but as opportunities within established limits.
This model of thinking is, according to Dahllöf, of particular help when studying problems as throughput, availability, recruiting and student behavior. It clarifies that guidance towards a certain goal or outcome requires different conditions, i.e. control of what comes out of training.

**Methods**

**A survey**
A survey was sent (by e-mail) to the twelve teachers in late May of 2012. The teachers were instructed to fill in the answers directly in the word-document, print it out and thereafter send it in an envelope to us. They were instructed to tick a box indicating gender identity but not to write their names. The two-part survey consists of open-ended questions. In Part 1 questions are posed about the application/admittance procedures, working/studying conditions, the perception of goal fulfillment etc.). Part 2 consists of questions about their attitudes towards graduate studies in general and to TUFF in particular (their own personal goal fulfillment, their contacts with their schools/municipalities and their future career plans). Ten of the twelve teachers answered the survey.

**Interviews**
After analyzing the survey data a need for additional comments was identified. Supplementary interviews were therefore conducted with selected teachers from the three participating universities (two students from each university). The aim of the interviews was to get a deeper understanding of statements regarding the teachers’ views on their own personal goal fulfillment (having or not having completed the studies) and about their perception of interest from the municipal/school regarding their research and future career

The semi-structured interviews were made in early July of 2012 via telephone. The interview questions were the same as in the survey however this time the teachers were given the opportunity to express their thoughts more thoroughly. Each interview lasted between one to two hours. The interviews were documented instantly on a laptop.

Collected data has been systemized and thereafter analyzed through repeated readings of statements.

**Results**

**A summary of the survey**
All students find their graduate studies very valuable for their own personal evolvement. They all found their working tasks during their studies very stimulating, mainly because of a change in working conditions. As a researcher they got time for reflection on teaching methods and subject development, which has not been the case when working in school.

Six out of ten students would like to continue their graduate studies to doctoral level for several reasons; 1.) They find it stimulating and wish to get an even deeper understanding of the subject technology. 2.) It would improve their status in the world of academia, which in turn could open up new carrier possibilities. 3.) A PhD degree is e.g. a requirement when applying for funding from the Swedish research council. 4.) The last reason mentioned is that they do not think that their acquired competence will be put to
use in the school environment and therefore the desire to enter another carrier path is frequently expressed.

The time allowed for completing the studies (2.5 years) was perceived as too short by the students. Since they all had to go back to a full-time job after the scheduled period had expired, it has, according to the teachers, been difficult to complete their theses even though they were workwise close to graduation. The reasons for not being finished in time are further scrutinized in the interview study.

Only two out of ten students feel they have had a good relationship with their school management or with the responsible persons at the municipality during their graduation studies. One reason for this might be that only one student has decided to participate in the TUFF research school as a result of a discussion and in collaboration with the municipality. The opportunity to join this research school was a personal choice, which opened up the possibility for a new career. Several students point out that this was the only way to do it as the time from when the positions were given notice until time for application was very limited. Municipality and school management simply had no time to learn about this project in advance.

Most students say that the quality of their own teaching has improved after the study period, but only four students think that the teaching quality will be better in their school or municipality because of their education. Six students cannot see that their knowledge and competence will be used at all when/if they go back to their position as schoolteacher. This has caused a lot of frustration for the students as they themselves see great possibilities to make a difference in school. The four students who do feel that they are supported by school management or by their municipality have a much more positive attitude towards going back to school after finishing their thesis and they also think that their knowledge will be put to good use.

A summary of the interviews

None of the interviewed students have fulfilled the goals for a licentiate thesis at the time of the interview. However, all are very dedicated to their studies and they plan to finish in the near future, in the next six-month period. When the question of not being finished was discussed, different personal reasons (referred to as being ‘difficult to influence’) came up, such as e.g. change of resident, sickness, parental leave and similar. As mentioned previously, the focus of this study lies in identifying factors of importance to the organization and content of the research school. Therefore, these and other comments of a personal nature will not be addressed in this paper.

All students mentioned that it was time consuming to get into the academic working process, as they were not used to this way of working. Students with no previous experience of academic work at all estimated that this process took up to a year. During the interviews, several ideas came up that could speed up this process, such as:

- Direct the presentation of research problem. It could have been helpful if the supervisor or/and municipality had a clearer picture of what could be done. Of course this can just be done to a certain limit, as it will otherwise trespass on the freedom of the researcher.
Let the students work more together in the beginning. Also in this case the research problem has to be more directed from the start and some students can work together around the first problem.

Establish a course about scientific writing where all students have to write a fictitious article in order to learn how this is disposed. None of the students think the requirements are set too high, but they admit that the high requirements has been one reason why they have not fulfilled the goals on time. (The students have all published articles in international journals, they have taken 45 units of courses, and they have participated in conferences and contributed to a Swedish anthology.) Several students feel that the requirements for this research school have been higher than for other similar research schools. On the other hand they appreciate this and are proud of this ambitious research school. They also feel that the step to reach the doctorate level is not so big.

A third factor that is often mentioned in the interviews is that it has been disrupting to stay 20% of the time in school during these 2.5 years. Some felt that it was difficult to restrict the working time to 20%. It seems like the students who are most satisfied with this combination are the ones who has done their school duties in periods where they have spent more than 20% in school (in other words concentrated to fewer but longer periods of time). As mentioned before most students think it would have been even better to take a doctorate degree at once as this degree is more accepted in the academic world, but the students also see the difficulties in this arrangement for the school/municipality as 2.5 years are already seen as a long time period to be away from the position in school.

During the interviews another concept was discussed, namely the possibility to create a licentiate degree that could be even more practical and developed in closer collaboration with school and municipality. Several students saw this as a good possibility to make a more efficient research school, but, on the other hand, some were afraid that research would be too directed and leave too little creativity to the research student. The students were also afraid that it would be more difficult to reach the doctorate level afterwards. This is seen as a problem as many see as an alternative carrier path.

The students were also asked to discuss the collaboration with the school and municipality. Of the six teachers interviewed, three expressed that the collaboration was ‘not so good’ or even ‘bad’, two students found the collaboration ‘partly good’ and one student found the collaboration ‘very good’. All students except one (who thinks the collaboration worked very well) expressed that they lacked a plan for how their acquired knowledge should be used after graduation. All students agreed that there is no structure in the existing system at any level that supports the collaboration between university and school/municipality.

The students who reported a poor-working collaboration think there is no or little interest in how their knowledge can be used from the school or municipality. At some schools the principal has even expressed dissatisfaction about the obtained knowledge. In these cases the problem seem to be that there is no consensus among the schools and the municipalities on how this obtained knowledge can be used for the school or municipality. There is no signed agreement between the student and the school/municipality, which in some cases has led to misunderstanding when persons in leading positions are replaced.
Commonly, according to the students, persons at leading positions in school or/and municipalities lack knowledge about what it means to pass a research education.

In the one case where the collaboration was found to work very well, the student and the municipality had set up a plan in the beginning of the research study period. In this special case a position had been established at the municipal level for development in technology at all schools in the municipality.

The two cases where the collaboration worked partly well are interesting. Here the students can see/feel a will from the management in school or at municipality to create a structure for this kind of collaboration. In one municipality a part time position had been established for technology education development. In the other case, the school and municipality together looked into an idea of developing a model school where the students with research degrees can work as supervisors for university students or as experts in school development projects.

**Discussion and conclusion**

It is indeed striking how well the results of this study coincide with the experiences made in the first round of teacher-graduate students in the early 2000s (Prøitz, 2005; André Thelin, 2009). The findings are, not unexpectedly, equally similar to the findings in the recently published HSV report (2012). All concerned parties value the idea of researching teachers. This way of enhancing and promoting the implementation of educational research findings in schools is seen as an important initiative. There are however problems that has to be solved. The low pass rate is a disturbing problem to all concerned parts. In analogy with the study made by HSV (2012) few students have managed to fulfill their goals in the stated time. TUFF show an even lower graduation rate than other similar Swedish research schools, as none of the students finished in the stated time (one student has finished at the point when this article is written). The pressure put on the individual teachers is heavy, resulting in stress and sometimes feelings of failure (c.f. André Thelin (2009), HSV, 2012). To municipals and schools each delayed examination leads to consequences of both economical and personnel nature. For concerned universities each prolongation of studies means increased costs and, by extension decreasing academic reliability.

Regarding the cooperation between municipalities and universities stated in the instructions given by the NAE (2009), both this and previous studies (Prøitz, 2005, André Thelin, 2009) reveal obvious shortcomings. The introduction of the TUFF program was not preceded by discussions between the graduate school and school principals/municipalities (c.f. HSV 2012). The perceived and in fact also manifested gap between academy and school must be considered and dealt with in future ventures.

Looking at the reported results from a Frame factor theory thinking perspective (Dahllöf, 1967, 1999), the findings are both logical and understandable. What opportunities have been opened up – and for whom? Teachers have been able to do research. Municipalities and schools have gained additional didactic and research competence that they can use in the development of schools. Universities have gained extended research resources (academically and economically). The hypothetical possibilities are undoubtedly good. The problem is that the needs of the different parties
(individual, municipality, university) are not compatible. It is rather the opposite. It seems like the needs for one of the actors’ risks becoming a restriction for one or both of the others. When a teacher is given the opportunity to do research, the demands from her/his municipality, school, university and from the teacher her/himself, are tangible and obvious (c.f. Andræ Thelin, 2009). However the benefit of successful studies (or the burden to having failed) primarily concern the teacher her/himself. From the municipalities’ point of view successful research studies leads to a probable risk of losing a competent teacher to the university. The universities are in most cases the winners as they gain economic resources as well as access to qualified researchers. There are however limitations regarding the amount of available positions also at universities.

The lesson learned for future investments in teacher graduate schools could be formulated in the following way: the opportunities of the individual teacher must be accommodated within the same constraints that surround municipalities and universities. This means that the planning, organization and implementation of teacher graduate schools must be coordinated carefully with all concerned parties and span over a longer period than previous initiatives and projects.

Implications for future graduate research programs
Findings suggest that future teacher graduate research programs should be organized in a different way. Future investments need to be based on agreements where the needs and requirements of all parties concerned, as far as possible, are met. Discussions between the universities and the school/municipalities regarding how to reach such an agreement should start immediately. A similar debate regarding graduate research programs for employees in industry is in fact going on in Sweden today. As a result of these discussions a new Industrial licentiate program will be introduced and tested this fall at the Royal Institute of Technology. In this new research program the projects will be much more focused on the need from industry than in previous programs.

Finally, there may be reasons to reconsider the strategy of offering teachers graduate programs leading to the licentiate level (‘half a PhD’). A full PhD does require four years of studies but it gives full access to the academy, which a licentiate degree does not give.

The phenomenon of licentiate graduate schools is fairly new and the effects from the programs (c.f. future career paths chosen by the graduated teachers) will be interesting to follow.

References


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Teacher’s professional growth in planning and teaching technological systems

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Teachers and researchers in the field of technology education stress the importance of addressing what is necessary to offer good learning opportunities. This paper focuses on teacher’s professional growth in a teacher-researcher collaboration process concerned with planning and teaching technological systems. In modern society, technological systems facilitate the needs humans have relating technical and human components in networks. Understanding systems in everyday life, (e.g. water supply system, various transport systems) requires capabilities to understand the complexity of such systems and their constituent parts without having the possibility to come into contact with the entire system; systems are not tangible in the same way as individual artefacts. In this study we use data from a research project (Klasander, 2010) where two groups of technology teachers plan teaching about technological systems in lower secondary school, convened by a researcher for ten meetings during one and a half years. Using Clarke and Hollingsworth’s (2002) model for professional growth, the analysis identified shifts in teachers’ knowledge and beliefs, professional experimentation and external source of information. This also provided exemplars of how teacher professional knowledge may develop in the area of technological systems.

Introduction

In the newly revised Swedish national curriculum technological systems are identified as an important part of the compulsory school subject Technology, both in the strand describing Technological solutions and in the strand describing Technology, man, society and the environment. Technological systems embrace a broad definition of technology related to human endeavours. The syllabus for technology in the lower secondary school includes such items as:

- How components and subsystems work together in larger systems, such as the production and distribution of electricity… The Internet and other global technical systems. … Systems – their advantages, risks and vulnerabilities. (Skolverket, 2011)

The revised national curriculum specifies teaching in a way that impose new demands on teacher’s knowledge and teaching. To teach a particular subject area requires that the teachers’ have pedagogical content knowledge, PCK. That is unique and multifaceted knowledge – content specific, curriculum related, using teaching strategies and theories of learning and knowledge as well as recognising pupil’s preconditions to learn (e.g. Shulman, 1987; Zetterqvist, 2003). PCK describes what knowledge a teacher needs to provide good learning opportunities for pupils’, but does not require an understanding of how such knowledge can be obtained, which is an important and relevant issue, especially for teacher trainers. To identify and describe how teachers’ knowledge in technology develops Clark and Hollingsworth’s (2002) model for teacher’s professional growth is a useful tool.

Consequently, the overall aim of this study was to investigate how teachers develop
their professional knowledge about technological systems. The research question was:

- How does professional growth develop in a process of teacher-researcher collaboration concerning planning and teaching technological systems in lower secondary school?

**Background**

The government, the researchers in the field of technology education and the teachers themselves have expressed concern about the teaching of technology in compulsory school (Teknikdeligationen, 2010). These concerns have centred on things such as pupil’s attitudes, interest and knowledge but an essential part has been the limitations in teacher knowledge of subject-specific content relating to e.g. technological systems (Klasander, 2010).

The standards in the Swedish national curriculum are rather generally formulated. Even if some key learning areas are described, it is often the teachers themselves who decide what technology content is taught in the classroom and how. However, a majority of Swedish teachers lack relevant education in teaching technology. Their knowledge is limited and sometimes undeveloped. High quality teaching in technology requires teachers who have developed an understanding of how to teach the content. The question is what is needed to become a high quality technology teacher? (Rohaan, Taconis, & Jochems, 2010)

The present study focused on how teachers’ professional growth developed with technological systems as the specific subject content in focus, during engagement with a researcher interested in this specific content.

**Pedagogical content knowledge - PCK**

The concept of PCK as a construct and a model has proven to be fruitful for explaining what knowledge teachers need to possess. Shulman (1987) described PCK as the knowledge that focuses on the teaching of the subject, including content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, knowledge of educational ends, purposes, and values and their philosophical and historical grounds. This list of knowledge areas has been further developed by other researchers (see e.g. van Driel, Verloop & de Vos, 1998; Zetterqvist, 2003) to construct representations of specialist knowledge of practice.

There are today some studies in technology with connections to PCK (see e.g. Banks, Barlex, Jarvinen, O'Sullivan, Owen-Jackson, & Rutland, 2004; Rohaan et.al., 2010; Williams & Gumbo, 2012) but there are still many subject-specific areas to explore, such as technological systems. There are also some studies about professional development in technology in general (Bybee & Loucks-Horsley, 2000; Compton & Jones, 1998). Compton and Jones’ (1998) concluded that the focus should be on teachers’ conceptualizations of technology education, pedagogy, and technological practice. Bybee and Loucks-Horsley (2000) described technology teachers professional development in four key components that technology teachers need: 1) to develop technology skills; 2) to learn about how to teach technology; 3) tools and motivation to continue their own learning; and 4) long-term professional development to support standards-based reform.
In this study we drew attention to some parts of the PCK by focusing on teachers’ knowledge of technological systems when developing the teaching, teachers professional development concerning a specific area of the subject technology.

**Teachers’ professional development**

To describe the complex contextualization of teacher professional learning Clark and Hollingsworth (2002) presented an empirically tested model of how teachers’ professional growth evolves. The model includes four analytic domains

1) the personal domain - knowledge, beliefs and attitudes,
2) the domain of practice - professional experimentation,
3) the domain of consequence - salient outcomes,
4) the external domain - external source of information or stimulus

Between the domains there is a mediating process of enactment and reflection. The main idea with the model is to describe teacher’s professional growth as a complex and continuous process. When a change is accomplished in one domain reflection and enactment trigger change in another and in this process there are activities that work as mediators of change for both practice and cognition. This process isn’t linear but rather a cyclic process of change going on when teachers develop their professional growth. Opfer and Pedder (2011) believe that teacher learning must be conceptualized as a complex system rather than an event. By this they assume that there are various dynamic factors at work at the same time during the process of teachers’ professional growth.

**Design**

Empirical data in this study was derived from an interactive project between a researcher and two groups of technology teachers in lower secondary. The teachers come from two different schools; one group consists of three teachers and the other group of six teachers. During one and a half year, each group of teachers’ had nine and eleven meetings respectively together with the researcher. All meetings were audio taped and transcribed. The aim with the interactive project was to change the classroom practice towards more use of a system approach, taking the existing teaching projects as a starting point. More detailed reports of the interactive project can be found in Klasander (2010). During the interactive meetings the researcher participated, interacted and communicated with the teachers about technological systems. This action research method is done by teachers with teachers to bring about a change in teaching (e.g. Carr & Kemmis, 1986; McTaggart, 1997). In this study it is teachers’ process of developing knowledge from the first meeting to the last one that is focused.

In the analysis the provided data of chronologically ordered transcribed meetings is repeatedly read to get to know the process as whole. The analysis continued with a focus on units of the meetings that described teacher-researcher discussions about technological systems. The units from the meetings in the beginning and the end was then compared and contrasted to identify emerging professional growth among the teachers during the process. To describe the process the units from the meetings were related to changes in the personal domain, the domain of practice, the domain of consequence and the external domain. The change in one domain was linked to a change in one other domain and the links are described in relation to enactment and reflection. This resulted in a tentative
model of teachers’ professional growth concerning technological system and a starting point for further investigations about how teachers’ knowledge in a specific content evolves.

Results
The analysis of the almost two years of teacher meetings indicated an increasing awareness of systems in general and on the teaching of technological systems in particular in the two teacher groups.

We choose here to emphasize the considerations and the dilemmas associated with technological systems that emerged during the meetings and put these in relation to what may be important to develop professional pedagogical knowledge about technological systems.

Practical elements in teaching
In discussions between the teacher colleagues and the researcher a practical/theoretical dualism became clear where they put great importance to the practical elements of the technology subject. In the teachers’ opinion practical elements are when pupils mainly manually design, construct, are creative and solve practical problems. These practical-manual elements are clearly linked to the construction materials used. With theoretical elements the teachers mean tasks that involve reflection on historical, social and environmental perspectives in relation to technology, with an emphasis on reading, thinking, discussing, writing, and possibly sketching.

- ... You work with the practical and then have theory. The two halves, so to speak (teacher group A, session 4)

It is clear that the teachers care about the practical elements of the technology subject and are concerned that technological systems might contribute to a growing number of theoretical aspects of teaching. This is despite the fact that practical and manual elements in a very marked manner almost totally dominate their teaching up to now.

- But it’s easy to get stuck in just doing theory and forget that technology is practical. Some children are very practical and certainly not theoretical. And they must also have an opportunity to show his sense of technology (teacher group B, session 3)

- It cannot just be theory. They need to get something built. (teachers group A, session 4)

This can be described as a discourse concerned with the construction of a school subject identity. Teachers motivate the practical-manual features with the argument to be an oasis in an increasingly theoretical school. Especially in relation to pupil groups they categorize in terms of practitioners or theorists. This duality characterizes not only the technology subject, but is an approach to pupil’s skills and abilities that permeate the school debate in general.

The teachers’ discussions of practical work with technical systems results in a sort of compromise - they let the pupils make a model, primarily aiming to visualize the components in the system. The teachers want the model to make the systemic visible, while they want to keep a practical-manual feature.

- ... But then the question is, what construction tasks do we have ... Because there’s a benefit for them to build their own stuff without having a finished drawing. What are the opportunities? Yes, one could build models of different systems, for example. (teachers group A, session 4).
- So the function is not that important ... but it's more of a model building. To show how it looks ... (teachers group A, session 6)

Obviously the teachers were teetering between the artifact-focused education they are confident in and the new systems-oriented education. The system model transforms into an artefact. While the intention is for it to show the systemic aspects of a technological solution the statement that the function is not important signals that systemic aspects are sacrificed in favour of modelling artefacts. As we will see in the next section, the teachers’ balancing act is neither unreasonable nor easily resolved.

**Teaching for understanding wholes**

According to the teachers the inclusion of technological systems in the technology subject has the aim to get pupils to see connections and create a whole. The teachers are concerned with the question of how to design their teaching so that pupils can perceive a whole. They are aware that they often fail to illuminate the relationships that can enable pupils to perceive wholes.

- But the whole is our weak point, right now. That's the way it is, we teach only different parts. (teacher group B, session 3)

In relation to the qualities that a model of a system displays, it became clear that visualizing a system and its component dependencies requires other insights and methods, than to build a model of a designed product. Teachers face a dilemma in which they do not feel they have strong support in previous teaching or learning materials.

During the meetings, the teachers discussed different options for how various formats of teaching could create an understanding of the whole. One way that emerged in the discussions was to start with single, well-known artefacts such as a washing machine or a mobile telephone and move “upwards” in the system hierarchies. Even if the two artefacts can be regarded as physically delimited systems in their own, they are both components of systems (water supply system and telecom system) where their insertion is necessary for them to function as intended. Another way is by starting at a system level, and studies of these systems function(s). What parts are they made out of? What are the key components needed for such a system or network to work? What is moved between different components and what connects them to each other?

The teachers did not come to any consensus on what is the best way to teach for understanding of the whole. Their different personal experiences and knowledge determined which way they prefer. The teachers highlighted some problems they perceived both to start on a component and on a system level. They think it requires much more detailed knowledge of them, such as electronics in order to explain the context and functions of the appliances around us, or to make the invisible visible, such as the wires and pipes that are buried in the ground. A further obstacle is finding the time for interaction with the world outside the classroom, such as visits to production plants.

**Teachers’ understanding**

During the meetings the teachers initially did not use system-specific terms when discussing technological systems. It was primarily the researcher who introduced concepts and thoughts about systems. In the final meetings between teachers and researcher, the teachers used concepts such as input and output when they described tasks presented to their classes.
At the end of the research period the teachers expressed uncertainty about which technological systems they should include and what aspects of systems should be in focus. In that they became more aware of the system. They also gained a greater understanding of technological systems expertise and could, in a more precise manner, express the uncertainty they felt about how they should develop their teaching. The fundamental question they faced is whether they should teach pupils ways of thinking about technology as systemic, or if they are to teach pupils some specific technological systems. Are certain technological systems better examples than others to get pupils to see and understand the complex technical environment they grow up in? Emerging in the next quotation, is an exemplification of the problems they were experiencing. They were seeking support in the curriculum and textbooks, but did not feel that they found something that was sufficiently concrete. This also linked to how they expressed their own lack of knowledge of systems concepts.

- If you want to do it, if you want to highlight the system more clearly for example in the curriculum, by talking about energy systems, traffic systems, systems for environmental management and recycling systems. Are you constantly aware of the system, the curriculum must be more... it is not specific enough. It has to exemplify in any way. But it's as generally written, so you can enter how much the system you want ... or less if you want. (teacher group A, session 11)

- (...) In this teaching book, system concept ... is barely there. It is nowhere written what a technological system is. It defines components (...) and there is an example of a car somewhere and components are described, the brake system and subsystems and ... then systems are not mentioned more in the book. (teacher group A, session 11)

**Pupils' understanding**

During the meetings teachers exemplified pupils’ understanding of technological systems based on their own experiences and pupils’ reactions to teaching.

Teachers found that there were pupils who spontaneously talked about the system on an artefact level, how the components interact in an artefact. This finding may be related to the fact that teachers recognized technological systems since they have started with the teacher-research meetings and therefore were more aware of when pupils mention systems in their descriptions. There is also the fact that pupils brought with them the concept of systems from other contexts than the school context.

- I had one pupil who said it, actually. System. I had not even mentioned the word. He said that, the pupil! (...) He would describe how a lock works. (...) A lock of a door, and then he said, it's a technological system, he said, in the lock. He had a systemic approach. The lock was a system. It is the first time it has happened! (teacher group A, session 2)

The teachers also discuss that there were some major problems getting the pupils to understand the system concepts of components and subsystems, on a more developed
level. They did understand it at a superficial level but when faced with a new context, they could not see systemic aspects and use concepts in a relevant way in relation to the technology subject.

- I do not feel that this (technological) system is particularly difficult for pupils to understand. The term "system" and "components", "subsystem" and this (...) At one level, they understand it. (...) But, to understand it a little deeper…, to put a bridge in a system, they do not understand that it is part of a system until you tell them that it is all about communication, or that it is roads and everything .. well, how to move a round in the city. They cannot really understand it themselves. (teacher group A, session 4)

It is clear that the teachers were aware that their own understanding of technological systems was of great importance for pupils understanding of systems. Several times the teachers also expressed that, although participation in the research project has been an opportunity for professional development, they would need even more.

- The problem is that systems you find in everyday life, for us teachers, is far too difficult to understand. When I was studying at university, the teacher talked a lot about MP3-players and that type of systems. (...) The subsystems and components. And, at least I have still not understood it all. I believe that we teachers must be much more educated, so to speak, in modern electronics if we give examples there. But I think that many pupils in my group think it would be fun to know what a MP3-player looks like inside, because it is something close to them. Then they might not really be interested in how it looks inside, only they can use it. (teacher group A, session 4)

The teachers have somewhat settled in their ways of thinking about systems and they voiced a need for additional knowledge to create a deeper understanding and hence improve education.

Conclusions

By identifying teachers' dilemmas in planning for the teaching of technological systems we have found two aspects that are of crucial importance: practical elements and to understand the whole. Both these aspects are related to subject specific content knowledge (e.g. Shulman, 1987; Zetterqvist, 2003). In order to give concrete example of how to bridge these dilemmas more external examinations in close collaboration with teachers as they teach is needed.

The teacher-researcher collaboration has been a useful external stimuli and the teachers believe that they need training and are keen to continue to have the opportunity to discuss the teaching of technology and technological systems. They also stress that other external sources such as textbooks and the curriculum needs to be developed to improve teaching about technological systems.

Looking at this in relation to professional growth, the recognition of the lack of knowledge is one step forward towards a possible change in the personal domain as well as in the domain of practice. The study shows that the teachers require a better understanding of which systems may be relevant. More knowledge about the similarities and differences between various technological systems could be helpful to be able to select systems. A better understanding of the system's components and different layers could also contribute to a more developed understanding.

There are indications that the teacher-researcher collaboration project has worked out well. Through this external stimulus a change in teachers' personal domain may be
discerned. However, it is not yet possible to see any major changes in the domain of practice but the teachers have begun to reflect on what and how to deal with teaching technological system. They have identified the problems, opportunities and deficiencies that may mark the beginning of a change in teaching for learning about systems.

This study is a small sample and does not provide a complete picture of teachers’ professional growth, but the results point to some important aspects that are valuable to build further study dealing with teachers' content-specific knowledge of technological systems.

References


“The Technologies” curriculum area as is manifested within Australian curriculum, assessment and reporting authority

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This paper will critically examine the Australian states position during the development and implementation of an Australian national curriculum within “The Technologies” learning area. An overview of the background, where political forces, provided a rationale for and agreed to the introduction of a national is provided. An academically-informed knowledge of the tensions involved including the status of Technology based subjects in schools, keeping the Technology subjects contemporary and relevant in the 21st century, funding its introduction nationally, resourcing the Technologies learning areas with facilities, tools, equipment and consumables and training teachers to teach a problem based curriculum that uses critical thinking to promote lifelong learning is discussed. Concrete examples are included to illustrate how a particular tension may impact upon policy and practice within “The Technologies” area of the national curriculum.

Introduction

The idea of a national curriculum was presented by the Hawke Labour government in the 1980’s and was later broached by Prime Minister John Howard. In 2008, the development of a national curriculum was recognised by former Labour Prime Minister Kevin Rudd and the then education minister Julia Gillard. This resulted in the establishment of the temporary National Curriculum Board, which in turn resulted in the establishment of ACARA; the Australian Curriculum, Assessment and Reporting Authority.

ACARA was given the role of developing the national curriculum. ACARA is directed by Professor Barry McGaw, an education specialist, and involves representatives from each territory and state and three representatives from the non-government (Catholic and independent schools) sector.

At the time, Julia Gillard, the Minister for Education said a national curriculum was an important stage in providing a quality education for all young Australians.

The new national curriculum will draw together the best programs from each state and territory to ensure every child has access to a world class curriculum, it will lift achievement and drive up school retention rates, (Brown, 2010) It’s a good thing for those students who move interstate each year who have to confront a new curriculum as well as a new school,’ Gillard said. (Brown, 2010) It will also allow teachers the flexibility to shape their classes around the curriculum in a way that is meaningful and engaging for students, (Brown, 2010) The national curriculum will also bring benefits to parents, Gillard said. It will give them clear and explicit agreement about what it is that young people should know and be able to do.(Brown, 2010)

The national curriculum conveys that every student should or will be taught under the one syllabus. From ACARA’s data it says it will help shape the lives of the nation’s future citizens, and ACARA also states that our future citizens will work for the common good, in particular sustaining
and improving natural and social environments (acara.edu.au), as well as ensuring they are responsible global and local citizens.

After recent studies by the Australian Council for Educational Research (ACER) supporting the national curriculum has shown that although the content of many High School Certificate (HSC) courses is common to all states and territories, the states maintain seven different ways of assessing and examining competency of this content and seven different formats for recording student grades, making it almost difficult to compare subject results from one state to another. (Masters, 2007) ACARA states that Australia should have one curriculum for school students, rather than the different arrangements that exist at the moment (acara.edu.au).

Whilst the rationale for a national curriculum is clear and convincing there exist a complex set of tensions that must be fully considered during its development and introduction. Curriculum development involves a complex set of tensions and contradictions that is shaped by ideological, historical and educational forces. (Adamson & Morris, 2008) There is a history of tension between the State and National Governments in regards to curriculum and what curriculum means to each of these bureaucratic groups. This power struggle, according Ewing (2010) has been evident since the Commonwealth was formed, which gave each of the state governments educational control in their own jurisdictions. This freedom has generated a network of individualized curriculums and governing bodies throughout Australia and according to Ewing (2010) it is not the most efficient way to educate our Nation.

In 2007, Ministers from each State joined together in developing a National Curriculum with the view that it would improve education for all students (Ewing, 2010). Even though the States have given their support, there are uncertainties in regards to implementation and development of Technology Education at the State and National level. Some of the underlying issues at the National level pertain to the development and implementation of Technology subjects and the status of Technology subjects within the curriculum context. At the State level, issues such as keeping the Technology subjects contemporary and relevant in the 21st century, resourcing restrictions, funding and the added effect of staffing shortages are just some of the issues to be addressed.

Donohoe (2008) has identified, what he believes is, the type of curriculum that Australia should be looking at to ensure every child has access to a world class curriculum, to lift achievement and drive up school retention rates, (Gillard: in Brown, 2010) Donohoe’s research is built around a number of worldwide benchmarking projects and identified the type of curriculum that has been developed by stronger-performing education systems overseas.

Some of the characteristic of these systems are:

- they should be related to specific year levels instead of covering a range of years,
- they are compared against world’s-best equivalent documents,
- they incorporate regular testing and consequences for failure,
- they are concise and manageable,
- they adopt a core/elective approach, and
- they use evidence-based methods to determine what is effective in raising standards and best supporting teachers.

(Donohoe, 2008)

Whilst Technology and Applied Studies has been a prominent and firmly resourced faculty
in states such as New South Wales, Western Australia and Queensland, Design and Technology has been a virtually non-existent subject choice for students in South Australia, Tasmania and the Northern Territory, meaning that its inclusion in the national curriculum is in itself a contentious issue.

The Technology and Applied Studies key learning area, is now known as The Technologies in the new national curriculum. It is of interest to see how the policy determined will impact upon the practice within The Technologies key learning area.

ACARA has been charged with the responsibility of developing a consistent curriculum for Australia and assist the States and Territories in the implementation process. This agency is guided by two reports: the Melbourne Declaration on Education Goals for Young Australians (MCEECDYA); and the Shape of the Australian Curriculum. It has been outlined by ACARA that it is the States and Territories which will be responsible for incorporating the Australian Curriculum into their jurisdictions. In New South Wales, for example the Board of Studies is responsible for implementing the National Curriculum throughout the State. According to the NSW Board of Studies they will adapt the National Curriculum into a format which is still familiar to NSW teachers.

The new national Technologies curriculum will ensure that all students benefit from learning about and working with the traditional, contemporary and emerging technologies that shape the world in which we live.

The rationale for teaching Technologies is that they enrich and impact on the lives of people, cultures and societies globally. The link between technologies and enterprise as a catalyst for twenty-first century innovation and the development of creativity cannot be underestimated. This supports the comments made by Sir Ken Robinson, in 2010, when addressing a TED: Ideas worth spreading conference that creativity should be considered just as important as numeracy and literacy in schools.

The ACARA document states that Australia needs enterprising individuals who can make discerning and ethical decisions about the use of technologies, independently and collaboratively develop innovative solutions to complex problems and contribute to sustainable patterns of living. The Australian Curriculum: Technologies has the potential to develop Australia’s capacity to creatively respond to our national research priorities, many of which focus on sustainability; and participate in and contribute to a knowledge-based economy. (acara.edu.au)

The decision to include Design and Technology as a mandatory subject for all children in Australia has some resulting tensions that require resolution. Recent research demonstrates that creativity and a problem solving approach to Design and Technology education is central to today’s global society. Furthermore, D & T is becoming based less upon manufacturing and more upon problem solving, creative thinking and design principles.

Creativity is acknowledged to be important for economic growth and as an everyday life-skill, however several influential reports have suggested that education could do more to harness creative talent. (McLellan, R. Nicholl, B. 2009).

In 2008 the ministers for education of each state contributed to the publication of The Melbourne Declaration. It was this report that outlined Australia’s educational goals for the future and is the basis for the draft of the new national Curriculum by ACARA. Heeding research on the design process, The Melbourne Declaration cited the need for compulsory Design and Technology education, specifically in the area of creative thinking,
problem solving, and design principals, along with a strong focus on computing and information technology. It is to be implemented as a foundation for further learning and adult life the curriculum. It will include practical knowledge and skill development in areas such as ICT and Design and Technology, which are central to Australia’s skilled economy and provide crucial pathways to post-school success. (Barr, A., et al., 2008) With Design and Technology confirmed as a mandatory subject in the national curriculum, the issue for states that have never previously offered the Design and Technology subject becomes implementing it in their school systems.

Design and Technology education provides the learning needed for students to engage in a ‘rapidly changing, knowledge economy’ (DATTA, 2008). Australians all face lifestyle changes and challenges and opportunities in the environment and economy. There is also the request to deliver an education that encourages new experience and abilities. Thinking in new ways that cross traditional boundaries like culture or subject discipline, developing critical awareness, embracing technological understanding and imaging many futures. (DATTA, 2008).

The tensions in The Technologies learning area are many, and some may never be resolved, because it is perhaps one of the most costly and difficult to implement study areas. Technology is ever changing and what we learn in the 2010 decade may be completely different or even obsolete by the 2020’s, by which time the curriculum more than likely will have gone through another change, to better suit the students’ current needs.

The status of “The Technologies” in the National Curriculum and its implications for the Technology subjects must be carefully considered. The Melbourne Declaration has taken the teaching of Technology subjects into consideration and has stated that it is important to teach Computing and Design and Technology Australia-wide because of the ever-changing 21st century lifestyles. The Melbourne declaration believes that the future is important when it comes down to teaching technologies...changing the ways people share, use, develop and process information and technology. In this digital age, young people need to be highly skilled in the use of ICT (MCEECDYA).

The status of the Technology subjects in the National Curriculum is currently in development and is still under the State jurisdictions as per stipulated by ACARA. Ewing (2010) criticizes the approach to the National Curriculum development stating that it is imperative to consider the broad spectrum of subjects for students of the 21st century and that this absorption with only some of these areas may reduce the effectiveness of the Australian Curriculum.

The current status of the Technology subjects may be linked to decisions made by politicians. This can be seen in the New South Wales Education Reform Act 1990 under the title ‘Division 2 Secondary Education’ under point (9) the Act outlines the key learning areas for Secondary Education years 7-10 and Technology and Applied Sciences is one of these listed subjects. The Act goes on to disclose the subjects of Math’s, English and Science and Human Society (HSIE) should be taught throughout the year but Technology subjects do not have to be taught throughout the year. This contributes to the perception by parents and students that Technology subjects are not as important as English, Maths, Science and HSIE.

The effects of this Education Reform act can be seen in the ACARA Technologies
draft paper (2012) whereby only years 7-8 will have mandatory subjects to study under the two strands of Design and Technology and Digital Technology subjects. This broad umbrella is stretched to accommodate all the Technology subjects in a tight fitted framework. With the added disadvantage of a significant reduction in the time allocations for these two Technology strands.

The lack of importance placed on technology subjects in the National Curriculum is a major concern for the status of Technology throughout Australia. An example of this concern is echoed by Larry Spry the President of the Design and Technology Association of South Australia, in his response to the Draft paper: National Declaration on Educational Goals for Young Australians. He expressed a deep concern and absolute astonishment at the diminished position of Design and Technology. It is Spry’s belief that Technology Education has not been accurately understood and it is the ideology of Science, Math’s and literacy that are the more important subjects in enriching the future of Australia. This can be further supported by the NSW Teachers Federation which state NSW places a great deal of emphasis on the importance of key subjects such as English, History, Maths and Science. Furthermore, not enough attention has been given to Design and Technology and the possibilities of making the other subjects more relevant to the students of today.

The follow on effects of this position paper can be currently witnessed in the ACARA Technologies Draft paper in which Digital Technologies stands not within the umbrella of Design and Technology but as a separate entity. One could ask why the same consideration was not applied to the other Technology subjects.

The Home Economics Institute of Australia (HEIA) has also outlined their position with a statement to ACARA in which HEIA is asking ACARA to make home economics a subject in its own right. It is a further tension within this subject that for the last 15 years this learning area has been connected to Health and Physical Education and Technology subjects which lead to the subject being “splintered and fragmented.” A further issue for the Institute is that ever since National approaches were adopted in the mid-1990s the States and Territories have used different curriculums in Home Economics faculties. It would appear from HEIA’s point of view a National Curriculum with a consistent scope would provide common ground for professional conversations. Like most political solutions, the curriculum comes about by compromise, bargaining, and other forms of accommodation. This may in fact, be the case for determining the future of Technology subjects throughout Australia.

Resourcing costs are another underlying issue for the States, for example; the NSW Minister for Education Adrian Piccoli stated in a 2011 media press release that NSW will delay implementing the National Curriculum due to Federal funding. This lack of funding was witnessed at the MCEECDYA meeting whereby, the Federal Government did not allocate any funds for the professional development of teachers so they would be equipped to implement the National Curriculum. This is a critical issue according to Ewing (2010) who claims adequate Federal funding is needed not just for teacher development but for resources used in schools. Furthermore, in the ‘Shape of the Australian Curriculum’ it is stated that the major benefit of a National Curriculum is that resources can be amalgamated and shared amongst the states. This can be seen as an underlying tension between the State and National curriculum agendas which appear
contradictory in this matter.

A direct result of Commonwealth resource decisions can be seen in a decrease in teacher supply according to the Australian Secondary Principal Association (ASPA). This funding has resulted in universities reducing the number of students they can take in and the subjects most affected by this are “The Technologies” subjects. ASPA believe the quality of learning is under threat by the apathy of the Governments in regards to resourcing decisions made.

Another tension to consider is how much it will cost to resource, staff and fund the commitment to cover the requirements of the curriculum. This issue will affect rural and isolated communities most severely. Rural, regional and remote schools, particularly those with small enrolments, multi-grade level classes and often significant numbers of relatively inexperienced staff, typically face many challenges when major changes in education have to be implemented. (Anderson, et al., 2010). We may see some schools and areas forced to offer Design and Technology as a course, and students forced to study it, without offering experienced teaching, comprehensive resources and funding to ensure students can excel.

The ACARA statement that all students will receive equal opportunity in all areas of the new curriculum is a strong promise to uphold. Raising all areas and schools to the level of the most advanced and established schools may not be possible, so the option of augmenting the focus of the curriculum may render some resources in more established schools less relevant.

Change is often met with resistance when it is not seen as beneficial. Lack of information feeds into both the perceived difficulty of the technologies, and views about the importance of implementing a national curriculum. As well, lack of information appears to be exacerbated when principals report being very satisfied with their present curriculum framework. (Halsey, 2010).

Initiation of a design and problem solving based Technologies curriculum aims to enable remote and inexperienced Design and Technology states and schools to achieve the outcomes of the curriculum for their students, without expensive resources. However, some states and schools have committed large amounts of funding and years of effort to developing their current curriculums, especially in the area of manufacturing, as opposed to problem based learning, will see the new curriculum as an attempt at rendering all of those expensive resources and as redundant.

Staffing the new national curriculum poses another complication, An issue that has been prominent in the Design and Technology sector over recent years has been a lack of accredited staff.” (Ritz, 1999). With this issue being relevant in the current Design and Technology curriculum in states that already offer the technology subjects, it is obvious that this problem will only be amplified when the whole nation begins studying Design and Technology. The old world view of hands on manufacturing-based learning in the Technology sector attracted practically skilled teachers who taught subjects from a manufacturing standpoint, however, the current curriculum focus has shifted to a design or problem solving approach promoting lifelong learning.

When Technology Teacher shortages did arise, state governments began funding and initiating schemes to train tradespeople and industry workers to be teachers, an almost back door into a technology teaching career. In consultation with the Victorian Department of
Education and Training, the Institute designed and implemented a Graduate Diploma in Technology Education to re-train people with trade qualifications to teach design and technology studies in secondary schools, especially in VET in VCE programs (University, L. t. Website, 2002).

As the focus of Design and technology has shifted from manufacture to a problem solving and critical thinking basis, not to mention a high degree of computing and information technology becoming prominent in the course, many long term teachers, uncomfortable with the reforms, resisted the change and continued teaching in a manufacturing vein. As ACARA introduces the national curriculum surely this teacher shortage will become a major issue.

When an incumbent national curriculum became a certainty, Technology’s inclusion in it was far from guaranteed. After all, it was a resource heavy subject that wasn’t offered in many states, the likelihood it would be dropped altogether was a relevant concern. Universities started dropping training programs, current teachers neglected to update their qualifications, many of whom were set to retire, and a gap started to form in terms of supply of qualified Design and Technology teachers for the jobs they needed to fill.

With the introduction of the new national curriculum we see a convergence of many of these problems. Technology teaching, now based in a problem solving approach rather than manufacturing, requires a qualification which now has a different identity and focus from what it was once originally known for.

Issues such as the need for high degrees of computing skills, a gap of up to three years of graduate training caused by the cancellation of some programs at university level, a resistance from current teachers to upgrade their qualifications and baby boomers reaching retirement age have all led to a shortage of teachers that will now need to cover the whole country. This is especially true of staffing in rural areas. Offering incentives to attract teachers to these areas will be a challenge linked with the national curriculum.

Design and Technology is a subject in modern education that will always attract tension, from the individual classrooms of any school, to the implementation of a national curriculum. The incumbent national curriculum will include the implementation of mandatory Technology courses. The quality of the implementation, funding, teacher training and resourcing will be some of the major factors that will contribute to its success. These questions will only be answered slowly as the curriculum for Technology subjects at the National level is currently a work in progress.

In light of the literature and what Adamson and Morris (2008) have stated about curriculum. It is evident that curriculum in Australia is a multifarious system which is affected by past histories, the many and varied ideologies of policy makers and that of society which continues to direct and shape the education policies and practices throughout Australia.

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Using an iPad-presented social story to increase on-task behaviours of a young child with Autism

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Wendi Beamish
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Social stories have been widely used to help children with autism understand how to act in a particular situation. A single subject design was used to investigate the effectiveness of presenting a social story on an iPad to increase the on-task behaviours of a high functioning five-year-old girl with autism. The intervention was undertaken in a one-on-one situation within an autism-specific preparatory classroom. Analysis of video data collected over six weeks indicated that this intervention was successful in increasing the subject’s rate of attention to teacher and materials. Improvements in affect around time-with-teacher were also noted. This study adds to the efficacy of using social stories with young children with autism. Additional research is warranted to explore the viability of the iPad as an intervention tool to promote early learning for young children with and without exceptionalities.

Introduction

Autism is a pervasive developmental disorder characterised by impairments in social interaction and communication, and by restricted and repetitive behaviours and interests (American Psychiatric Association, 2000). It is one of three recognised disorders in the autism spectrum; the other two being Asperger Syndrome and Pervasive Developmental Disorder. All disorders impact not only on learning and achievement from an early age but also on many aspects of everyday functioning at home, school, and in the community.

With the movement in education towards full inclusion for increasing numbers of students with autism, there is a growing need to find research-validated interventions that teachers can integrate into their classroom. One such intervention that has been used with this student population is social stories. Social stories are literally accurate, individualised stories which contain text and illustrations to support clarity and meaning (Gray, 2010). These stories describe social situations, provide relevant cues, and define appropriate responses (Gray & Garand, 1993). They are commonly used to help understand reality, communicate information, and give assistance on how to behave or act in particular situations (Dodd, 2005). For example, a social story can be used to present social concepts and rules related to participating in a game or how to undertake a difficult task such as initiating social interactions in the playground (Boutot & Myles, 2011). The goal of a social story is to share accurate social information in a patient and reassuring manner that is easily understood by the child.

Information and Communication Technology (ICT) is also of growing interest within
the area of education. Within the last decade, the Australian government has focused attention on how ICT can make teaching and learning more effective. Blackmore, Harcecastle, Bamblett, and Owens (2003) report that ICT is best used in the classroom when integrated into general teaching and learning and suggest a number of areas for improvement, including the integration of ICT into subject content and teaching practices and access to ICT for disadvantaged students. From these perspectives, ICT offers a potential avenue for the delivery of social stories for children with autism. For example, Litras, Moore, and Anderson (2010) combined video modelling with social stories to remedy social deficits faced by young children with autism.

This exploratory study investigated the effectiveness of presenting a social story on an iPad to increase the on-task behaviours of a high functioning five-year-old girl with autism. It was predicted that the iPad-presented social story would improve the child’s attention during table-top activities with a teacher.

Method
Participant and setting
The participant (pseudonym Sarah) was aged 4 years 10 months and attended an early intervention centre for young children with autism spectrum disorder (referred to subsequently as “the centre”). The centre was operated by AEIOU Foundation, a state-wide service provider for children with autism (2 to 6 years of age) and their families throughout Queensland. Sarah was in the pre-preparatory classroom for 4-5 year olds with 13 other children, one teacher, four teaching assistants, and therapy support.

At the time of this study Sarah attended a 5-hour program 5 days a week at the centre. She had daily access to a speech therapist and occupational therapist through a transdisciplinary model of service provision. Sarah’s expressive language was limited to labelling familiar objects and people. Her cognitive ability was reported by the teacher to be developing well. However, it was noted that she was easily distracted by environmental factors if her requests were not met immediately. Sarah had emergent reading skills and she required support with some fine motor activities such as scissor use.

The focus behaviour
The behaviour of focus (dependent measure) was identified as appropriate and typical classroom seated behaviour exhibited by a kindergarten or preparatory age child. The behaviour was defined as attention to task, materials or teacher while seated. In this study, a social story to prompt this attending behaviour was presented on an iPad to Sarah prior to her engaging in table-top activities with the teacher.

Research design
A single baseline A-B-A design was employed to assess the effectiveness of the intervention. This design builds upon the basic A-B design by adding a withdrawal of the intervention (the second A). This second baseline is referred to as the verification phase as a second return to baseline increases our confidence that the original predication made from the baseline was accurate (Riley-Tilman & Burns, 2009). The study therefore comprised three phases: baseline (pre-intervention); intervention via iPAD presented social story; and withdrawal from intervention (post-intervention). The first two phases (i.e., baseline and intervention) were executed consecutively. However, the last phase – due to external
demands – occurred a week after the intervention was concluded.

Procedure
Prior to the commencement of this study and any data collection, approval was obtained from AEIOU Foundation, Sarah's family, and Human Ethics in Research at Griffith University. All data collection sessions were conducted in the corner of the classroom and at a kidney shaped table where Sarah faced the other children in the class who were engaged at other learning centres. All sessions were conducted by the first author and were approximately 7 minutes in duration. Eighteen sessions were conducted across a 4 week period (baseline and intervention) and then 3 additional sessions (withdrawal of intervention) in the 6th week of the study. All sessions took place in the morning (9:30 - 10:30) and activities typically included puzzles, colouring in, building, cutting and pasting, and threading. Preparation for the session involved setting up the teaching space at a table and setting up the Flip Video on a tripod for digital video recording of the session. During the intervention phase, an additional 2 ½ minutes was required to present the social story via an iPad to Sarah prior to engaging her in the scheduled table-top activities.

Inter-observer reliability
The first and second authors coded and scored all session recording. In addition, members of the research team independently scored 20% of the sessions across all phases. The point-by-point agreement for this study was 90%.

Materials
iPad
An Apple iPad tablet was used to deliver a social story using an autism specific application designed for teaching social messages and learning purposes. A personalised social story was developed using the Stories2Learn application which incorporated photographs of Sarah and the first author in the classroom, the social story text, and a corresponding audio message that was provided by the first author.

Social story
The social story was generated according to criteria recommended by Gray (2010) and adhered to the social story formula. Initial information about the participant's behaviour during tabletop activities was gathered through direct observations and interviews with teaching staff in efforts to assess a baseline of the specific behaviour (Howley & Arnold, 2005). This data was used to identify the specific topic and text for developing the social story. Table 1 presents the text used in the social story, together with sentence type according to Gray (2010).
Table 1 Sentence Types used in Sarah’s Social Story according to Gray’s Guidelines (2010)

<table>
<thead>
<tr>
<th>Text</th>
<th>Sentence Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>My name is Sarah.</td>
<td>Descriptive</td>
</tr>
<tr>
<td>At the learning centre Julie is here to help me.</td>
<td>Descriptive</td>
</tr>
<tr>
<td>When I’m at the table I will sit on my chair with my feet on the floor.</td>
<td>Coaching</td>
</tr>
<tr>
<td>Sitting like this helps me learn.</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Sometimes when I learn new things I want to shout.</td>
<td>Perspective</td>
</tr>
<tr>
<td>I will use my quiet voice in learning centres.</td>
<td>Descriptive</td>
</tr>
<tr>
<td>This will help me listen to what I have to do.</td>
<td>Descriptive</td>
</tr>
<tr>
<td>When I’m learning I will keep everything on the table in front of me.</td>
<td>Coaching</td>
</tr>
<tr>
<td>It is important to keep everything on the table.</td>
<td>Affirmative</td>
</tr>
<tr>
<td>This helps me learn.</td>
<td>Descriptive</td>
</tr>
<tr>
<td>I learn when I sit on my chair, use my quiet voice, and keep everything on the table.</td>
<td>Coaching</td>
</tr>
</tbody>
</table>

The iPad was used to photograph Sarah in a variety of scenarios that represented the targeted behaviour and focus for the social story. The social story, photographs and audio commentary were loaded onto the Stories2Learn application by the first author. Each screen shot on the application depicted one sentence incorporating both written text and audio message, together with a corresponding photograph to match its meaning (see Figure 1). To access the story, Sarah needed to tap on the photograph of each screen shot to listen to a sentence. To advance to the next sentence and screen shot, Sarah needed to tap the arrow on the right side of the screen. At the conclusion of the social story the screen shot identified that the social story had ended.

Figure 1 Screenshot from iPad of 3rd sentence in Sarah’s social story.

Results and Analysis
The data for the target behaviours was graphed, visually inspected, and then numerically analysed. First, the data for the target behaviour was plotted and is further displayed in Figure 2. Figure 2 displays the frequency of the target behaviour, expressed in terms of the number of 10 second periods Sarah was on-task over the five minute observational period.
Thus, the ceiling number of on-task behaviours was 30 for each session.

Figure 2 Frequency of on-task behaviour during baseline, intervention and verification.

Second, the data for the target behaviour was visually inspected to determine if a functional relationship existed between the delivery of a social story via an iPad and any observed behaviour change. Based upon a visual inspection of the data, Sarah appeared to make gains in the frequency of her on-task behaviours during the intervention phase of the study.

Because single case design relies heavily upon the visual inspection of data for interpretations of results (Riley-Tilman & Burns, 2009), the data collected was also explored from a variety of approaches (viz., change in trend, variability, and change of Median level). Table 2 presents the analysis using these approaches. A comparison of graphed data between the baseline and intervention phases indicates a movement of observed behaviour towards a more stable trend, reduced variability in attending, and an increased level of attending. Although it is difficult to draw conclusions from a comparison of graphed data between intervention and withdrawal of intervention phases due to the limited number of data points in the later phase, there appeared to be maintenance of level of attending. That is, gains made in attending during intervention using the social story were maintained for at least a week following the withdrawal of the intervention.
Table 2 Analysis of Sarah’s Graphed Data across Phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>• Stable, slightly upward trend</td>
</tr>
<tr>
<td></td>
<td>• Relatively large variability (value of 9)</td>
</tr>
<tr>
<td></td>
<td>• Median* level 22.75</td>
</tr>
<tr>
<td>Intervention</td>
<td>• Stable trend (close to zero)</td>
</tr>
<tr>
<td></td>
<td>• Smaller variability (value of 5.2)</td>
</tr>
<tr>
<td></td>
<td>• Median level 27.75</td>
</tr>
<tr>
<td>Withdrawal of Intervention</td>
<td>• Upward trend</td>
</tr>
<tr>
<td></td>
<td>• Smaller variability (value of 5)</td>
</tr>
<tr>
<td></td>
<td>• Median level 27</td>
</tr>
</tbody>
</table>

*Median – as opposed to Mean – was selected here due to the limited number of data points (particularly in the verification phase) and the potential impact of extremes in the data set.

In addition, we looked at data overlap between the baseline and intervention phases in order to obtain an indication of effect size. For this calculation, the most extreme baseline data point (i.e., the value of 26) was compared to the number of intervention data points that are above this line divided by the total number of data points within the intervention phase. This result offered a percentage of nonoverlap. In this case, there was 70% non-overlapping data. Scruggs and Mastropieri (1998) suggest at least 80% for a large effect size; thus, the result was what Cohen (1988) would classify as a medium effect. Taken together, visual analysis and interpretation of the graphed data lent support to the intervention being successful at increasing Sarah’s attending or on-task behaviours during tabletop activities within her classroom environment.

Discussion

This study was exploratory in nature and investigated the effects of presenting a social story on an iPad to increase the on-task behaviour of a young child with autism. As hypothesised, the result revealed the intervention was successful in increasing Sarah’s rate of attention to teacher and materials. The observed increased level of attending (as shown by the change in Median level between baseline and intervention phases), together with the finding of effect size, supported the effectiveness of the intervention in this study.

The combination of the social story together with the iPad proved to be an effective intervention with a girl not quite 5 years of age. The result confirms previous findings that social stories can be effective with children with autism during the early years of learning (see Crozier & Tincani, 2007; Gray & Garand, 1993; Ivey, Heflin, & Alberto, 2004; Kuocho & Mirenda, 2003; Litras, Moore, & Anderson, 2010). Moreover, the result aligns with previous findings that social stories, combined with ICT, are beneficial, and increase the learning of individuals with autism (Hagiwara & Smith Myles, 1999; More, 2008; Sansosti & Powell-Smith, 2008).

This positive result from using an iPad-presented social story to increase attending behaviours may be attributed to the enhanced meaning Sarah gained from the visual
representation of information on the iPad together with the motivational aspects of ICT. This technology has been associated with increased student motivation, attention, reinforcement, and self-direction (Chen & McGrath, 2003; Davies, Stock, & Wehmeyer, 2004; Laffey, Espinosa, Moore, & Lodree, 2003). In addition, ICT has been found to offer individuals with autism a non-threatening, protected, and dependable environment (Keay-Bright & Howarth, 2011; Konstantinidis et al., 2009; Wall, 2004). All these benefits were brought together in the iPad-presented social story for Sarah.

The data collected during the study did not allow judgements to be made about the extent to which either the iPad or the social story contributed to the change in Sarah’s behaviour. However, the combined effects of the iPad and social story have a number of practical implications for teachers working with children with autism. Sarah responded well to the audio-visual media and easily navigated the application using the touch screen display. The Stories2Learn application was cost effective and easy to use. The built-in tools provided a structure in which the personalised social story was easily created using photographs, text, and audio messages. The portable nature of the iPad allowed the teacher to collect the necessary photographic data to construct the social story in the actual setting.

**Limitations**

Although this study contributes to existing data on social stories and provides initial evidence for using iPads with young children, several limitations should be noted. First, findings are based on a sample of one. Further research needs to be undertaken to investigate the effects of iPad-presented social stories with children of varying ages, abilities, and learning styles, with and without autism. Second, this study was conducted under the restricted time conditions of 21 brief sessions at the same time in the morning program. Similar research needs to be conducted for longer periods and at different times of the day. Third, intervention focused only on table-top learning by an individual within the classroom. Additional research into iPad-presented social stories needs to be conducted in other curriculum areas and in a variety of group situations within and outside the classroom. Fourth, the social story was aimed only to increase attending behaviour. There is an urgent need to expand the research across a range of prosocial behaviours.

**Conclusion**

This study adds to the efficacy of using social stories with young children with autism. It also provides insight into the viability of the iPad as an intervention tool. At this point in time, the integration of the iPad into learning and teaching is in its infancy. Because of the rapid uptake of these devices in schools, there is an urgent need to know more about the iPad as an educational tool and the ways it can be used by teachers to promote the learning of all students in Australian classrooms.
References


Supporting student learning in relation to entrepreneurial innovation in self-initiated industrial design major projects

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Often Industrial Design students at the tertiary level, and Design & Technology students at the secondary level, complete a major project in their final year. These projects may be framed as being self-initiated design projects. Due to socio-cultural and technological changes these student projects, are becoming more complex, with greater emphasis on formally conducted research to set justifiable directions in development of innovative solutions that are entrepreneurial in nature. As design educators we are charged with the task of shaping the educational experiences of our students so as to move them closer to those paralleling professional designers. Consequently, we need to draw from models of self-initiated design that occur in professional practice to help develop appropriate strategies for supporting students in the completion of these challenging design projects. A background study investigated self-initiated projects developed by professional industrial designers, identifying particular links between aspects of background knowledge and a set of predominate project factors common in self-initiated design. This paper presents the results of this study suggesting that major projects (that are self-initiated) by university design students in their final year and indeed high school D&T students can be supported by research conducted into self-initiated design processes, as they exist in professional practice.

Introduction

This paper will present a model for self-initiated design projects and discuss its potential to support the education and training of tertiary and secondary design students who are typically required to self-initiate designs as part of projects coordinated in the later stages of their course. The Industrial Design Major Project subjects offered by the University of Technology, Sydney's Design Program will be used to provide the example. A detailed account of the background study that produced this model will be covered in separate publications. The focus in this paper will be to describe the model, provide a supporting rationale for its application in transitioning students from novice to expert designers and then suggest ways of applying the model in design education. The concept of major projects that require students to self-initiate a design, by first openly researching a topic area that they select has been in place for many years. They are formally set in the later stages of study, allowing students to reflect on design and design methods and to encourage the development of their own way of working (Dorst, 2003), though this may not have always been the purpose behind them. Self-initiated design projects conducted in industry seem to represent a recognition of the importance of transitioning from 'manufacturing know-how' toward what Giard (1990) describes as 'the knowledge of designing' at the same time as design education has been argued to be a 'passive condition' in that it maintains the notion of a designer who's actions are determined by causes...
external to their will (Findeli, 2001). Major projects that require students to self-initiate designs represent opportunities to prepare students for contemporary design dilemmas: to be leaders, entrepreneurial and strategic managers (Teixeira, 2010). Self-initiated design, in professional practice, sets these objectives, presenting a case for the application of the Typologies of Self-initiated Design Model in design major projects that are similarly, self-initiated and framed by a similar focus.

**Entrepreneurial Design and Technological Change**

There is a need to prepare students for entrepreneurial innovation in design practice.

Rapid manufacturing may supersede the current use of traditional mould and die production technology (Hague et al., 2003) though, as Ball (2012) states, changes in the way we digitally transfer data together with the rate of manufacturing advancement in East Asia has rendered production methods that were once expensive and complex to now be cheap and accessible. Beyond the direct connections between design and production, technological change is leading to the capability of smart autonomous machines (Norman, 2007) that require designers to focus on the interactions, social implications and design for experience as a priority. The stricture that once bound industrial design to operate in the service of manufacturing industry is fading, opening up opportunities for entrepreneurial, self-initiated product design. There is recognition of the potential for design thinking to best guide the now critical, exploratory pursuits toward innovation in business (Martin, 2009) and to effect radical innovation, even beyond the technological paradigm toward what Vergianti and Norman (2012) describe as 'meaning change' in solutions through design-driven innovation. Designers as leaders in business both large and small - as in the case of the development of micro brands that can be started and operated with tiny start-up costs (Ball, 2012) - are now recognised and exemplify the ways designer's self-initiate entrepreneurial action. Typologies of Self-initiated Product Design are useful in understanding the principle components of these projects and the best arrangement for utilising knowledge and resources for implementation and practice.

**Self-initiated Product Design: Describing the Background Study**

It is necessary to put forward an explanation of the primary research into self-initiated product design in order to present the Typologies of Self-initiated Design that resulted. The study involved interviewing nine practicing industrial design consultants who had individually self-initiated designs for products, achieving varying levels of completion. The aim of the project was to define self-initiated product design and propose avenues for implementation and practice for projects of this type. It found that self-initiated product design is a process by which a product or artefact is designed and where the principle concept comes from the designers own background knowledge and not by way of an external requirement (i.e. from a Client). Self-initiated Design by professional designers are projects for which there is resource allocation and an intention to commercialise finished outcomes. This means that in cases where the project is conducted "in lieu of a Client" (Parsons, 2009) - one of few alternative descriptions offered in literature - there are many managerial obstacles to negotiate. The background study set the following research questions:
1. What is the nature of self-initiated product design process?
2. What factors internally or externally motivate and define self-initiated design projects in industrial design practice, including consultancy firms?
3. What leads to successful outcomes in self-initiated product design?

The broader intention of the study is to propose that professional design conducted in the absence of a client request and of formally prepared design briefs (that schedule tasks, define deliverables and remuneration contractually) follows a process motivated by the designers own aspirations and background knowledge. It was therefore rationalised that very limited documentation or established routines exist for self-initiated design projects and by drawing on the principle of primary generators in product designs (Darke, 1979; Roy 1993) that it was likely they would differ between designers. Hence, an intervention measure was included to assist designers in their explanation of self-initiated design process.

**Self-initiated Product Design: Diagrams**

During the interview designers were required to prepare two diagrams (Fig 1.). The first, drawn early in the interview is of their design process for clients, normally produced quickly and efficiently. The second, produced at the end of the interview is of their self-initiated design process, in all cases, prepared slowly and by trying to recall the procedure undertaken. This strongly suggested that the process was not formally documented, reported on or practiced routinely. The diagrams produced by the interviewees were modified according to the style shown below in order to compare the processes and convey the differences clearly as shown:

**Figure 1 Comparing design for client and self-initiated product design process.**

Comparing design for client and self-initiated product design process.
The process diagrams above are by the same designer. The lower diagram contains very distinctive and important variances when compared with the upper diagram:

- The engineering detailing phase in self-initiated design is much more integrated into the design process suggesting active development of technical aspects.
- Self-initiated design is much more iterative, indicating greater project control.
- Self-assessment of concepts happens before the Brief in self-initiated design.
- The Self-initiated design process ends with a selling function: indicating an intention to commercialise the design and requirement for strategic measures.

These principles were evident in either diagrams prepared or interview responses by other designers, lending support to the description of overarching themes established.

**Self-initiated Product Design: Background Study Results**

The interview data and diagrams were analysed using thematic analysis (King & Horricks, 2010) producing a series of four overarching themes: Novelty; Control; Support network; Background Knowledge. These overarching themes represent common aspects of self-initiated design projects that seem to be requisite factors for moving the project beyond an idea. The evidence also suggests that they combine in particular ways during the course of a project in formats described here as typologies of self-initiated design. Descriptions are provided below and are formatted into typological connections later in the paper.

**Novelty**

It is important in self-initiated design that the concept is novel. Roy (1993) also identified this feature in case studies of innovative products, going further to link the innovation or novelty to primary generators - very early, self-imposed, subjective ideas (Darke, 1979) and domain specific knowledge. In some cases the designer certified novelty by conducting a patent search but in other cases novelty relied on background knowledge. There were also cases where members of the designers support network were able to confirm novelty hence the connection between the nature of the novelty, the make up of the support network and a common technical understanding of domain specific knowledge related to the design in successful projects.

**Control**

Analysis of the interview data further indicates that self-initiated design projects proceed due to the degree of control the designer has over the project (the process and the result of the process). The precise nature of this control over the project and its parameters evolve as the project becomes more intense, so initially, the perception of how much control the design maintains or assigns to others may be different from the required reality. In any case, the control factor relates to the designers preferred way of working. This may be a reaction to the constraints and difficulty of meeting aspirations in organisational structures (Lawson, Bassanino, et al. 2003), as working for clients can require. Ultimately, for commercial success, the project control influenced by the designer must coordinate with strategic goals and by what the support network can deliver.

**Support Network**

The interview data also indicates that for self-initiated design projects a requirement both for setting up the project and proceeding through it, is some form of support network. Members are selected and arranged, initially by the designer. The support network may be
very small. It may be one or two fellow designers or a technician that the designer has worked with for many years. They may be from various fields but if the project is to be successful, they must coordinate with the project in the right way.

**Background Knowledge**

Design process is informed by the application of the designer’s own background knowledge. Dorst (2008) uses the work of Hubert Dreyfus to describe the expert practitioner as one who will respond to the problem intuitively within their established field but who is also vulnerable to contextual changes in their profession. Self-initiated design proceeds through experiential learning best described by Lawson and Dorst (2009) in their appropriation of Kolbs Learning Cycle for design practice. Additionally, knowledge gained and applied through design can be divided into different forms of knowledge: Domain Specific Knowledge, Strategic Knowledge and Experiential Knowledge all connected and drawn upon in the development of designs as demonstrated in the knowledge connection models by Popovic (2004).

**Typologies of Self-initiated Design: An applicable model**

Analysis of the interview data suggests that decisions regarding the novelty, support and control priorities associated with the development of self-initiated designs were informed by particular areas of background knowledge. In referring to Figure 2 below these particular areas of background knowledge may be framed as being Technical knowledge, Personal knowledge, and Industry knowledge. More accurately, the decisions were effected by a combination of background knowledge areas, however, it can be demonstrated that particular types of background knowledge were the primary influence in making the decision. Therefore, connections between background knowledge and the predominant factors for self-initiated design (novelty, support network and control) can be combined to form typologies as in Figure 3 below. Representing background knowledge in this way enables various diagrammatic formations to be developed.

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**Figure 2** Background knowledge divided into three types of knowledge.
The typologies indicate the three variations for self-initiated designs selected on the basis of their degree of commercial potential. Typology 1 represents the successful arrangement of elements in association with both each other and the designers own background knowledge. Typology 2 and 3 represent arrangements that, according to the study, may prevent the project from progressing toward a viable outcome - where viability refers to the potential of the design to activate or be a candidate for a sustainable business model (Brown 2009). Hence the most desirable model for entrepreneurial innovation is Typology 1. Projects investigated as part of this study that adopted this typology, were projects that led to the commercialisation of the product solution. We acknowledge that broadly, the measure for success in a project may be in relation to meeting other goals, but this study focuses on achieving commercial viability as part of an entrepreneurial initiative. A key finding is that a design based on experiential knowledge must evolve concurrently with the building of other knowledge areas related to the broader design context in order to detail the design more appropriately for commercial application. This will mean managing fixation on design concepts as technical knowledge builds and the nature of what aspects of the product development can actually be controlled. Issues of confidentiality must also be considered when exposing the design to a support network.

**Expert vs. Novice Designers**

Typologies of Self-initiated Design have been established through an analysis of design process and design outcomes by experienced professional industrial designers. Before making a case for the application of these findings in design education, we must first acknowledge some of the differences between an expert designer and a novice. A novice in general terms is one who will consider a problem as it is given to them and follow strict rules in solving that problem (Dorst, 2008). More specifically in design, this translates to an approach where the focus is on understanding the problem before generating solutions (Cross, 2007), leading to design fixation and making assumptions due to a lack of applied domain-specific knowledge and limited experiential knowledge (Popovic, 2004). Design fixation in novice design also leads to a "depth-first" (Cross, 2007) approach to solving the design problem and can manifest in premature concept embodiment before 'stepping back from the brief' in order to reflect widely as discussed by Kokotovich (2008) on both the design problem and possible solution concepts collectively. Cross (2007) describes that expert designers take a broad systems approach to design problems and are able to strategically develop new design goals through a process of rapid-exploration and solution-
conjecture drawing on first principles, which may be argued as being aspects of domain specific background knowledge. This design thinking process represents knowledge connections (Popovic, 2004) in concept development enabling the experienced designer to reflect upon and frame the problem space in the co-evolution of a problem-solution pair (Dorst and Cross, 2001). To support the development of the design student from novice to expert industrial designers, education at secondary and tertiary level has sought to build curricula based upon a learning-by-doing approach (Dorst, 2003), to mirror the issues encountered in practice. Today, due to the development of academic research in design practice, rather than simply setting projects for students to complete and hoping that upon reflection of their performance, they develop some understanding of how to 'design better', within the structure of the projects set, we can guide students more effectively by setting tasks where they mimic the strategies of expert designers to enhance creative output (Kokotovich, 2008). The Typologies of Self-initiated Design is intended to provide a strategic guide to formulating and managing self-initiated design, enabling broad application of the knowledge gained including application in design education.

**Industrial Design Major Project at UTS**

It is considered that the integration of The Typologies of Self-initiated Design applies most directly to design education in cases where students are required to self-initiate their own design project. In both tertiary and secondary design education programs both locally and around the world, students normally in the final stages of their course, are required to self-initiate their own design project. That is, they are not issued a design brief that outlines the problem to be addressed. They are required to develop a design solution to a problem that they identify both through the acquisition of knowledge through research and a personal interest or motivation. The challenge of "where to begin" at the start is matched by the expectation of a highly resolved outcome at the end. At the University of Technology, Sydney, final year Industrial Design students engage in such a project across two subjects: Industrial Design Major Project - Research and Conceptualisation (1st Semester) and Industrial Design Major Project - Realisation (2nd Semester). The Subject Outline (2012) clearly states that the project "context is through a self-determined, research driven design brief" with an objective to "create a feasible, economic and sustainable design solution". The level of expectation is high as the project requirements are designed to "reflect professional practice" and "demonstrate the students' knowledge and skills gained through the course". Design outcomes need to be justified for real-world application and this is assessed through the students demonstration of a market need, the technical explanation of the solution concept and the rationale for its embodiment according to the issues of design and manufacture against commercial constraints. Students are required to work with an external advisor that they source in the early stages of the project. The table below aims to highlight the striking similarities between Industrial Design Major Project at UTS and Self-initiated Product Design Projects by experienced industrial designers.
Table 1: Similarities between Professionally conducted SI(P)D and ID Major Project.

<table>
<thead>
<tr>
<th>SI(P)D Themes</th>
<th>Industrial Design Major Project at UTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>The requirement to address a market need means introducing a product / system or service, currently unavailable. All well developed industrial design major projects include some degree of demonstrable novelty.</td>
</tr>
<tr>
<td>Support Network</td>
<td>All students are required to source their own External Advisor. The External Advisor should be a person with a level of technical experience in the field of the design problem. This person sits on the assessment panel and although they do not provide grades, they contribute to discussion with other panel assessors both pre and post presentation by the student.</td>
</tr>
<tr>
<td>Control</td>
<td>Students are required to identify an area and frame the problem or market gap discovered in a distinctive and personal manner (Cross, 2003) as expert designers do. They must also manage their own design process and make decisions on how to best develop content within the project.</td>
</tr>
<tr>
<td>Background Knowledge</td>
<td>In the first semester the subject: Industrial Design Major Project - Research and Conceptualisation requires students to build their knowledge within a field that they select. This selection may be motivated by a number of factors, but what is of importance here, is that knowledge is gained through research in order to support their product design development in the second semester.</td>
</tr>
</tbody>
</table>

Implications in the Reported Research

The Typologies of Self-initiated Design model can be used in a way that supports student learning in tertiary and secondary design projects that require self-initiation, on the basis that a relationship has been identified between the expert model (Fig. 3) established and the subject criteria and requirements typical in the UTS Major Project outline. The successful model (Type 1) is the version to promote with a proposed adjustment to the expert model for educational purposes (Fig. 4). The Typologies may provide a way to visualise the components of the project, shift their emphasis and coordinate their relationship to the other objectives offering clearer directions for the student, focussing their effort and building efficiency into the process. A proposed adjustment to the expert model, for education, is shown in figure 4. The way in which elements of the model connect with one another has been supported by the development of a mapping method, identified in some of the interviews conducted where it was possible to discuss a project in more detail. At the start of the project, the connection between the elements may be more representative of Typology 3 (fig. 3) where the perceived novelty behind the design idea and the aspects of the design or the way of working on the design that the designer would
like to control are all based on previous background experience exclusively. This is a safe place to be because a result can be produced even if untested. What must happen is that the designers control over the project, if it is to be rationally maintained, needs to be adjusted in accordance with both a developed understanding of both strategic goals and the way's in which the selected support network can service the project. The aspect of novelty needs to be adjusted to match the support network service and be also tied to developed domain specific knowledge to facilitate appropriate exchange with the support network that in turn is capable of servicing the project according to the controls put in place by the designer, informed by clear and appropriate strategic goals as in Typology 1 (Fig 3).

Figure 4 Typologies of Self-initiated Design in Industrial Design Tertiary and Secondary Projects.

Further Research
The model (Fig. 4) must be tested through analysis of completed student major design projects. These must be rated as successful, semi-successful or unsuccessful according to appropriate criteria and mapped against the Typologies of Self-initiated Product Design diagrams from the primary study, to ensure compatibility. Explanations of the connections between typology themes need to be developed through case study analysis to appropriate the Typologies of Self-initiated Product Design as a diagramming method suitable for guiding design students conducting self-initiated design projects at Tertiary and Secondary levels.

References
Technology Teachers PCK: The need for a conceptual revision

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Research has shown that one of the factors that enables effective teachers is their rich pedagogical content knowledge (PCK), a special blend of content knowledge and pedagogical knowledge that is built up over time and experience. This form of professional knowledge, first theorized by Shulman (1987), is topic-specific, unique to each teacher, and can only be gained through teaching practice. The academic construct of PCK is recognition that teaching is not simply the transmission of concepts and skills from teacher to students but rather a complex and problematic activity that requires many and varied “on the spot” decisions and responses to students’ ongoing learning needs. Much has been written about the nature of PCK since Shulman first introduced the concept in 1987, and most of the research application has been in the area of Science. This presentation will discuss recent application to Technology which has revealed possible inadequacies in some PCK conceptions, and clarification of the nature of effective technology teaching.

Introduction

We all know that a good teacher understands their students well, and is able to respond to them with a unique combination of content knowledge and teaching skills which results in learning. Historically, these areas of content knowledge and pedagogical knowledge were treated in a dichotomized way (Ball & McDiarmid, 1990; Shulman, 1986a; Veal & MaKinster, 1999). In technology, a parallel dichotomy is often characterized as between theory and practice (Williams, 2002) where the pressures of timetables, classrooms, and examinations encourage teachers to separate theory and practice, each accompanied by a suite of different conventions related to pedagogy and content.

Having realized that a gap exists between content knowledge and pedagogical knowledge, Shulman (1986a) developed a framework for teacher education by introducing the concept of Pedagogical Content Knowledge (PCK), such that teacher training programs should combine content and pedagogy to effectively prepare teachers. Shulman’s concern lies at the foundation of transformation in the context of teaching – teachers transforming content into meaningful understanding by learners.

Research has since shown that effective teachers have rich pedagogical content knowledge (PCK), this special blend of content knowledge and pedagogical knowledge that is built up over time and experience, and is topic-specific, unique to each teacher, and is essentially gained through teaching practice.

The construct of PCK is recognition that teaching is not simply the transmission of concepts and skills from teacher to students but rather a complex and problematic activity that requires many and varied “on the spot” decisions and responses to students’ dynamic learning needs. According to Shulman (1987), PCK includes special attributes that a teacher possesses, which help him/her to guide a student to understand content in a manner that is personally meaningful. Shulman (1987), having identified teacher
knowledge as central to teacher quality, developed a seven-part classification of teacher knowledge built on elements that include knowledge of subject matter; pedagogical content knowledge; general pedagogical knowledge; knowledge of curriculum; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational aims, purposes, and values. Cochran, King, and de Ruiter (1991) distilled these to four key elements:

- Knowledge of the subject matter
- Knowledge of learners
- Knowledge of environmental contexts, and
- Knowledge of pedagogy.

In recent reviews of PCK (Kind, 2009; Rohaan, Taconis, & Jochems, 2010), the point is made that expert teachers are not ‘born’ with PCK, and it is a lengthy process for student teachers to acquire the bank of skills and new knowledge needed to become a professional and expert teacher.

Research in science also indicates that many graduate student teachers lack a deep conceptual understanding of their subject matter, with disjointed and muddled ideas about particular topics (Loughran et al., 2008). These struggles with content knowledge are significant hurdles for teachers to overcome as they embark on their teaching careers. As science knowledge and technological development grow apace, creating strategies to enable teachers to develop PCK around novel topics and pedagogical challenges should support success for learners in the 21st century.

Research in technology education reveals a less well-developed understanding of the role of PCK, though an international discourse does exist with studies being reported in both general design and in technology education (De Miranda, 2008; Jones & Moreland, 2004; Rohaan et al., 2010; Rohaan, Taconis, & Jochems, 2009), as well as in different disciplines of technology such as Information and Communication Technology (Koehler & Mishra, 2005). While researchers like McCormack (1997, 2004) identified the inter-related nature of procedural and technical knowledge in technology education, international diversity remains a characteristic of the content of the technology domain, which is an impediment to the development of research into the PCK of technology teachers.

Kind (2009) identified three common factors that appear to contribute to the growth of PCK. First, is the possession of good subject matter knowledge (SMK); second, is classroom experience, with studies pointing to significant changes occurring in the early months and years of working as a teacher; and third, the possession of emotional attributes like high levels of personal self-confidence, and provision of supportive working atmospheres in which collaboration is encouraged.

There is a strong research history in the Technology Education community about pupils’ attitudes toward technology (PATT) (Ankiewicz, Van Rensburg, & Myburgh, 2001; Burns, 1992; Rennie & Treagust, 1989; Van Rensburg & Ankiewicz, 1999; Volk & Wai Ming, 1999), but less related to PCK, which therefore presents an opportunity for research in technology education. The findings of a study by Rohaan, Taconis, and Jochems (2008, 2009) revealed that a link exists between teachers’ knowledge and learners’ concept of and attitude toward technology. Jones and Moreland (2005) suggested that
teachers require a clear understanding of the nature of technology and the conceptual and procedural aspects of the different technological areas. Reddy, Ankiewicz, De Swart, and Gross (2003) contended that technology teachers’ inability to make technological experiences cumulative, purposeful, and empowering resides in their inability, for example, to see the inter-relationship between technological content knowledge, skills, attitudes, and values and technological capability.

**Content Representations (CoRes)**

Recently a number of researchers in science teacher education have begun investigating and devising pedagogical approaches that help teachers to conceptualise their professional learning and their PCK development (e.g., Abell, 2008; Loughran, Berry, & Mulhall, 2006; Loughran, Mulhall & Berry. 2004; Nilsson 2008). While there is still debate over the very nature of PCK (Kind, 2009), this new field of research offers much potential for improved teacher education, but it is problematic. For example, a key issue emerging for developers of such approaches in science and technology education has been the virtual absence of concrete examples of expert teachers’ PCK, since this highly specialized form of professional knowledge is embedded in individual teachers’ classroom practice (Padilla et al., 2008) and rarely articulated within the teaching community of practice.

To address the paucity of PCK exemplars in science teaching, Loughran et al. (2006) explored the PCK of highly regarded science teachers for particular topics in junior secondary science, to see if they could tease out some common threads in their pedagogy that could be considered as comprising the knowledge base of science teachers and which might be helpful to share within the profession. Loughran et al. developed conceptual tools known as Content Representations (CoRes) to encapsulate the collective PCK of expert teachers in ways that make explicit the different dimensions of, and links between, their knowledge of content, teaching and learning about a particular topic. CoRes, as represented in Table 1, attempt to portray holistic overviews of expert teachers’ PCK related to the teaching of a particular topic. They contain a set of key ideas about a particular topic at the head of the columns, and a set of pedagogical questions/prompts for each row.

**Table 1. Sample CoRe matrix**

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>Key idea 1</th>
<th>Key idea 2</th>
<th>Key idea 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>What you intend the students to learn about this idea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Why is it important for the students to know this?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulties/limitations connected with teaching this idea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge about student thinking which influences teaching about this idea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other factors that influence your teaching of this idea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching procedures, and reasons to use these procedures to teach this idea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific ways of ascertaining student understanding or confusion about the idea</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This developing body of literature related to making experienced and expert teacher PCK
explicit, and concerns over the nature of technology prompted research projects in this area.

**Project 1 Early career teachers PCK**

**Research Design and Methodology**

This research addressed the key area of early career teacher education in science and technology. The study aimed to research the use of a CoRe as a pre-planning tool to develop early career secondary teachers' PCK and was designed to examine whether such a tool, co-designed by an early career teacher with expert content and pedagogy specialists, can enhance the PCK of early career science and technology secondary teachers. A research design was therefore developed that incorporated a unique partnership between an expert classroom teacher, an expert in subject matter knowledge (e.g. scientist or technologist), two early career teachers and experienced researchers who had previously conducted research in each subject. Two four-member partnerships were formed, one in science and one in technology. These partnerships were located in the central north island of New Zealand.

This study then researched how the development of PCK in the early career secondary teachers might be influenced, firstly through their involvement in co-construction of CoRes in specific topics with the experts in the partnership; secondly, by trialling these CoRes as planning tools for teaching their science and technology programmes; and thirdly, how this CoRe-informed planning might then impact upon teaching and learning in their classrooms.

**Research questions**

The following research questions were addressed:

- How can experts in content and pedagogy work together with early career teachers to develop one science topic CoRe and one technology topic CoRe to support the development of PCK for early career secondary teachers?
- How does the use of a collaboratively-designed CoRe affect the planning of an early career secondary teacher in science or technology?
- How has engagement in the development and use of an expert-informed CoRe developed an early career teacher's PCK?

**Research design and data collection methods**

This study employed an interpretivist-based methodology (Guba & Lincoln, 1989) and an action research approach (Creswell, 2005) within a multiple-case study design (Yin, 2009). Data was gathered using qualitative research methods focused on semi-structured interviews, observations and document analysis. The case study approach was used in order to facilitate a holistic, interpretive investigation of events in context, with the potential to provide a more complete picture of how expert-informed CoRe design might impact on early career teachers' classroom practice.

The four case studies each featured an early career science or technology teacher, acting as a practitioner-researcher during their second or third year of teaching, working alongside a researcher from the project team. This cohort of teachers was chosen for the study because they were beginning to establish themselves in their profession, they were known to the researchers as teachers who were seeking professional development
opportunities and had some teaching experience to draw upon in planning and delivery.

The content experts were active university researchers and lecturers in their fields. They were identified for this research because of the recognition of their subject expertise within their community, as well as their reputations as effective communicators of their subjects. The pedagogy experts were experienced teachers involved in providing professional development in their own school as well as being recognised nationally in the teaching community through participation in professional teacher associations.

As each teacher planned, and then taught a unit based on the CoRe, a thematic analysis approach (Braun & Clarke, 2006) proved to be most useful for data analysis. This analysis was structured around the research questions using both inductive (drawing themes from the raw data) and deductive analyses (drawing themes from the theoretical framework of the study i.e., the five components of PCK, as identified by Magnusson et al., 1999). Analysis of the workshop data, the interview and journal data and the observation and interview data was carried out by the researchers. Findings were collated and presented to the whole research team for interpretation and discussion in a second one-day workshop.

Project 2: Technology teachers in NZ and SA

Research Design and Methodology

This research enquired into Technology teachers’ PCK in New Zealand and South Africa, using a comparative perspective and a methodology derived from the philosophy of PCK. The rationale for the selection of these two countries is the similar timeframe of implementations and review of Technology Education curriculum which has occurred in each country.

The research design followed a case study approach to explore secondary school Technology teachers’ PCK (Boyce & Neale, 2006) to address the research problem: What is secondary school Technology teachers’ PCK? A convenience sample of eight schools was selected to become case studies, four in cities, two in small towns, and two in the countryside. All the schools were mixed gender, they varied in size from 600 to 1800 students, and all the classes observed were at the lower secondary level.

A convenient time was negotiated with each teacher; during which they would be teaching lessons that could be observed. An observation schedule based on the elements of PCK derived from the literature was used concurrently by two researcher-observers. Observation was deemed important to counter possibilities of bias that could emerge during interviews (Kelly, 2006). Generally the observation was followed by an interview, and documents and resources used by the teachers were analyzed.

In order to validate the data, all classes were observed by both researchers and the interviewees were asked to confirm what they had said once the data had been transcribed. The findings from the interviews, observations and document analysis were triangulated.

The interview data was coded first, adopting a variation of the coding strategy used by Marshall and Rossmann (1999). This involved a stepped process moving from a general approach to develop themes and codes and then detailing the themes. The variation on this coding strategy was the use of analyst-constructed typologies, which were based on the principles of PCK developed from the literature. The analyst-constructed themes were: subject matter, curriculum, assessment, learners, pedagogy, educational context,
educational aims, purposes and values, and indigenous dimensions, which also formed the basis of the interview questions. Once the interview data was analyzed, it was integrated with the teaching observation notes, the document analyses and incidental personal memos that the researchers had been keeping (Marshall & Rossman, 1999). The outcome was eight integrated narratives about each of the cases.

This research question was elaborated through the following sub-questions which were derived from the literature:

- What do technology teachers understand as the nature and purpose of technology education?
- What constitutes the technology teachers’ knowledge of the technology education curriculum?
- What are the pedagogies that teachers believe are suitable to teaching technology?
- What types of assessment activities do the technology teachers utilize and how are these related to the content?
- What technological teaching and learning resources do the technology teachers use?
- How do the technology teachers integrate indigenous technology in their teaching?

**Findings**

An implication of this study arose from the unsurprising finding that the nature of the science and technology learning areas is different. These differences were manifest in the historical conceptual thinking underlying the learning area, the way that the subject is taught, and the traditional backgrounds of the teachers in those subjects. These differences raise implications for the design of CoRes in different learning areas. The original CoRe structure was designed in science, and whilst the technology teachers were able to work with the CoRe structure, there was some debate at the end of the project as to whether the set of eight pedagogical questions might be the most appropriate ones for all learning areas.

**Epistemology**

The concept of the content area or topic that a CoRe refers to is relatively unproblematic in Science. Science has a well-established epistemology leading to an established organisation of knowledge into accepted topics of inquiry. Technology on the other hand has a shorter history of study as a philosophical enterprise and no commonly agreed upon epistemology. Robust debate still exists about the nature of knowledge in technology and the way knowledge empowers technological practice. The results of this research indicate that as the concept of CoRe design is widened to incorporate teaching and learning in areas other than Science, what is considered to be a “content area” or topic within that learning area may need to be considered carefully.

**Enduring Ideas**

There was a marked difference between the way the Science teachers and the Technology teachers approached the task of developing the conceptual "Enduring Ideas" for the CoRe topics of Organic Chemistry and Materials Technology respectively. The science teachers much more quickly developed a consensus about the Enduring Ideas, because they already had in mind a common idea of what was important for this topic, developed from textbook and curriculum agreement, and so the discussion involved simply deducing from this
agreed list which ones they wanted to include in the CoRe. In the technology group, there was a sense of developing the list of potential enduring ideas from first principals, consequently there was far more negotiation and justification in the workshop leading to the development of agreed enduring ideas. There was no schema that was familiar to all the workshop participants which could provide a common starting point. Consequently a lot more of the workshop time was spent by the technology group coming to agreement on the enduring ideas.

In the case of Science, the process of choosing the topic was relatively unproblematic. An initial choice was made to move from Science to the subset of Chemistry, and then within that, the area of Organic Chemistry was selected as the topic for the CoRe. In the less structured epistemology of Technology, Materials Technology was selected as the topic, a second tier level of knowledge organization. It may be the case, that had a third tier area been selected as the topic (for example Composite Materials), as was done in Science, the more narrow subset may have resulted in less discussion and debate and a faster resolution in agreeing to the ‘enduring ideas’ of, say, Composite Materials Technology.

Usefulness of the CoRe
The immediate usefulness of the CoRe seemed to lie in different areas for Technology and Science. The science ECTs seemed to get the most benefit from seeing the need for and developing with confidence, examples of organic chemistry in authentic contexts to support the theoretical understandings they were focussing on developing with their students. In Technology the ECTs saw the immediate benefit in quite the opposite way. For them the opportunity to see the big picture of Materials Technology, to articulate its theoretical underpinnings and consequently development of a philosophy that was conducive to a rational epistemology was perceived to be the main benefit. What followed from this was a more thoughtful approach to developing lesson content by the ECT’s as evidenced by the introduction of a range of different pedagogies and teaching resources. Whereas in the absence of the CoRe, the technology teachers would just teach those aspects of materials technology that the students needed to complete their current project.

Application of the CoRe
The application of the CoRe to a teaching unit was different in Science and Technology. In Science, the chemistry CoRe was truly a content representation, dealing with a discrete and contained unit of work which was treated as such by textbooks and was aligned with the curriculum for this year level. In Technology, the Materials CoRe had to be contextualized within a project which permitted the application of the content. So it was not a self contained content representation, but rather a topic that could be applied within a project context.

Practical-Theory Dichotomy
The practical/theoretical dichotomy was an aspect of both the science and technology teacher’s implementation of the CoRe, but in opposing ways. The science teachers noted that after an examination and discussion of, in particular, the pedagogical questions related to the content ideas, they had a deeper understanding of the importance of engaging in practical activities in order to assist students understanding of the relevance of the topic.
The reverse outcome was the case for the technology teachers. After the realization of the need for a conceptual framework prior to determining the enduring ideas for the topic during the first workshop, the teachers felt that students also needed a broader framework of understanding than their immediate and felt needs related to the completion of their current project. Consequently, during the implementation of the CoRe, the teachers planned for more classroom activity than they normally would in order to provide this framework for the students, and to spend time generalizing from the specifics of their current project to broader principles that could be applied elsewhere. A number of students indicated that they did not appreciate this provision, reflecting their belief that the main reason for their being in class was to get on with building something.

In both SA and NZ, teachers made reference to this practical – theory dichotomy in technology. Although it was more difficult for SA teachers to have their students engage in practical work because of equipment and facilities limitations, they recognized that practical engagement was important, and felt that students learnt and retained more after doing practical activities. NZ teachers seemed to recognize to a greater degree the expectation from students to do practical work, but emphasized the need for complementary theory. So because of expectations and facilities, NZ teachers seemed to find the implementation of practical activities easy and had to work harder to integrate written work and theory, while in SA it seemed easier to focus on theory and more effort was required to incorporate practical activities.

**The Nature of Knowledge**

In the context of a CoRe, the differences between that nature of technological and scientific knowledge have not been considered by research. Relevant technological knowledge is defined by its usefulness to the task at hand. If it does not help to achieve a specific goal then it is neither useful nor relevant and so can be discarded. Consequently it is difficult to predetermine what technological knowledge is relevant because problems that may arise in the pursuit of a technological goal cannot be anticipated. So the notion of designing a CoRe in the current format and using that as the basis for the design and implementation of a unit of work in technology is fraught.

However, in the more structured style of teaching technology in SA, the rationale for introducing new knowledge was based on the curriculum and textbook sequencing of topics in a context where classroom organization prevented practical tasks from being the main organizer of technology. In NZ, the technology teachers explicitly mentioned the importance of linking theory to current practice. They only taught new knowledge (conceptual and procedural) when the students had a practical application for the knowledge, so they needed to know it and consequently saw it as relevant.

**Conceptual and Procedural Knowledge**

This importance of both conceptual and procedural knowledge is an issue in the implementation of a CoRe in technology education as a means of enhancing a teacher's PCK. Vincenti (1984) describes conceptual knowledge as explicit, the theory of technology. Procedural knowledge is the often tacit driver of decision making and relates to appropriate decisions made through designing, problem solving, modelling, testing and planning. Parayil (1991) interestingly characterizes this tacit knowledge as papyrophobic in nature, admittedly less so as time goes on, but maybe still recognizable in many technology
classrooms.

The early career technology teachers in this research highly valued procedural knowledge, but this was not really elaborated in the CoRe, which is why they felt they had to re-contextualize what had been developed in the first workshop. However, the CoRe encouraged them to weave more conceptual thinking into their lessons, something which the students found a little difficult, as they were more used to focussing on practical skill development. However, the teachers felt that the additional conceptual thinking would help the students understand more of the fundamental ideas behind materials technology, which they would be able to transfer to future projects.

The assumption has been, in the application of CoRes to the area of Science, that the ‘enduring ideas’ relate mainly to conceptual knowledge. In an application to Technology, the enduring ideas need to be reflective of both procedural and conceptual knowledge. The integration of this knowledge in a Technology CoRe could also assist in overcoming the common dichotomy between theory and practice in Technology, by having questions which consider both in an integrated way.

**Vocational-General Education**

There was little evidence of any vocational - general divide in the provision of technology education in SA. As technology is not a significant component of the senior secondary curriculum, there is no opportunity for the provision of specialized vocational pathways, and as all students study technology at the lower secondary levels, they all follow the same curriculum. However, in NZ it is not uncommon for technology departments in schools to specialize in a vocational approach to the subject. Such departments offer vocational units of competency at the upper secondary levels, and in some instances the lower secondary provision also has a vocational bias.

**Assessment**

The teachers reflected a broad range of assessment strategies based on projects, weekly tests, end of year examinations, portfolios, case studies and homework. Types of assessment included teacher assessment, self assessment, peer assessment and group assessment. Assessment criteria were derived from the teachers own ideas, assessment matrices, curricular levels of attainment. The combination of all these elements painted a complex and inconsistent picture of assessment. In neither country was there a consistency of assessment practice, each teacher seemed to have a preferred method of assessment.

**Discussion**

These analyses of technology teachers PCK have assisted in clarifying elements of good technology teaching, and the comparison with science teachers has also highlighted differences between technology and science teachers PCK. The appropriateness of the CoRe matrix as a measure of technology teachers PCK was consequently brought into question. The feeling from both the technology teachers and from the researchers is that the CoRe structure, which was developed for a science teacher context, may not be the best way of representing or measuring good technology teaching, in the form of the PCK construct.

The use of the following questions in the NZ-SA research seemed to paint an adequate
picture of technology teachers PCK, when multiple sources of data were used: in this case classroom observations; interviews; and document analysis.

- What is the nature and purpose of technology education?
- What is the teachers' knowledge of the curriculum?
- What are the pedagogies that the teacher uses?
- What types of assessment activities are used?
- What resources do the teachers use?
- How do the technology teachers integrate indigenous technology in their teaching?

But the use of the CoRe, either as a tool for planning teaching or as a way to illustrate expert technology teachers PCK, doesn’t seem to be appropriate. This is quite explicable, given the differences between science and technology educational activities and the fact that the existing CoRe was designed for science teachers. The CoRe questions are:

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<tr>
<th>What you intend the students to learn about this idea</th>
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<tr>
<td>Why is it important for the students to know this?</td>
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<tr>
<td>Difficulties/limitations connected with teaching this idea</td>
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<tr>
<td>Knowledge about student thinking which influences teaching about this idea</td>
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<tr>
<td>Other factors that influence your teaching of this idea</td>
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<tr>
<td>Teaching procedures, and reasons to use these procedures to teach this idea</td>
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<tr>
<td>Specific ways of ascertaining student understanding or confusion about the idea</td>
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Apart from the research outcomes cited above related to these CoRe questions, a group of experienced technology teachers from Australia, New Zealand, USA, Egypt, South Africa and the UK were asked to evaluate these prompts and comment on their appropriateness for technology education. The following discussion summarises their responses.

A number of general comments were received about the overall impression conveyed by the CoRE in its application to Technology. The first was that the CoRe approach seems to imply a teacher centric approach to planning for learning, assuming that the teacher is the centre of things, and decides what knowledge is important rather than the situation which commonly occurs in Technology Education classrooms where both the teacher and the student are co-constructing learning as it develops in the context of a real project.

A number of comments related to the practical nature of Technology Education contrasted with the conceptual focus of much learning in Science, which provides the context for the CoRe. In Technology Education, where the value of knowledge and understanding lies in its applicability to solving a problem or progressing a design, the CoRe seems inadequate in addressing this application of knowledge. Consequently, it was suggested that maybe a better question to ask, rather than ‘What you intend the students to learn?’ is ‘What you intend the students to do with this idea?’

This examination led to a critique of the overall design of the CoRe, asking the question, for Technology Education, are ‘Big Ideas’ the best organizer? Maybe a better organizer is ‘Project’, or ‘Application’. So the big ideas in Technology might have a less
conceptual focus such as ‘using tools to manipulate materials’ or ‘developing divergent design ideas’ or ‘critiquing’.

Or maybe the epistemology of Technology Education is not adequately advanced enough to be able to generalize on the important ‘Big Ideas’. In Science, this is not a difficult task, because in general terms, science educators, textbooks and curriculum all generally agree on the important Big Ideas, and understanding these ideas is the rationale for Science Education.

The following table summarises the respondents comments of the appropriateness of the CoRe questions to Technology Education.

<table>
<thead>
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<th>What you intend the students to learn about this idea</th>
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<tr>
<td>• Content in technology is often seen as quite specific and technical, and so often fails to consider the broader nature of technology and the socio-technical systems through which technology exists.</td>
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<td>• If the content is student driven, then it is likely that students will require and reach different levels of knowledge around each big idea.</td>
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<tr>
<td>• In technology, learning may be reflected in what the students do with the knowledge, how they apply it, so a more appropriate questions may be What do you intend the students to do with this knowledge?</td>
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<th>Why is it important for the students to know this?</th>
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<td>• In terms of the big picture, this often varies in technology between a vocational or a general goal.</td>
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<tr>
<td>• In science, knowledge and understanding of a big idea is often sufficient, whereas in technology, we want students to take some form of action as a result of their knowledge. Often the objective is the application of knowledge that encourages an innovative and diverse response.</td>
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<tr>
<td>• The implication of the question is that teachers can answer it, but the reality of technology and the active experimentation and reflection that is developed through practical project work, is that it may not be able to be answered. This is a strength of technology, so maybe the questions can be posed in a less definitive way.</td>
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<th>Difficulties/limitations connected with teaching this idea</th>
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<tr>
<td>• These could be related to students, or as is commonly the case in technology, to the facilities, resources and learning area.</td>
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<th>Knowledge about student thinking which influences teaching about this idea</th>
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<tbody>
<tr>
<td>• What previous experience do students have?</td>
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<td>• What about existing skills and knowledge?</td>
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<tr>
<th>Other factors that influence your teaching of this idea</th>
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<tr>
<td>• The pedagogy of technology is the holistic integration, application and then innovation of technology skills and knowledge.</td>
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<tr>
<td>• In technology, students need a pedagogy that supports them as they tackle open ended design and making tasks. This type of support is different from most other classes as students are required to show considerable autonomy.</td>
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<tr>
<td>• This seems more aligned with cognitive decision making.</td>
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<th>Specific ways of ascertaining student understanding or confusion about the idea</th>
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<tr>
<td>• What about skills and knowledge?</td>
</tr>
<tr>
<td>• What method will you use and how will you know that a student has achieved an acceptable</td>
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</table>
Conclusion
This examination of science and technology teacher’s PCK has served to highlight some of the differences between these two curriculum areas, and to reinforce some of the unique characteristics of Technology Education. The usefulness of a CoRe either as a tool for teacher planning or an elaboration of expert teachers PCK seems limited in Technology. However, the notion of a schema which represents the concept of PCK (ie, a CoRe) has been useful in the area of Science Education, and parallel logic would apply to Technology Education to help answer the question: What does good technology teaching look like?

Bibliography


