

THE NATURE OF TECHNOLOGY: TEACHERS UNDERSTANDING OF DESIGN AND KNOWLEDGE IN EMPOWERING TECHNOLOGICAL PRACTICE IN EDUCATION

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Abstract

Technology education in New Zealand has as undergone a series of developments over the last years, the latest being the review of the curriculum in 2007 and subsequent realignment of national qualifications. These changes in curriculum and assessment have implications on classroom practice and teacher's concepts of what being a successful teacher in the learning area of technology means. This paper examines three areas of understanding that are fundamental for teachers to acknowledge, to address effective teaching and learning in technology in the 21st century; the difference between education and training, design and design education, and the roles of knowledge's in empowering technological practice.

Introduction

In the beginning, before Pacey that is (Pacey, 1983), Edwin Layton described technology in this way. "*We may view Technology as a spectrum with ideas at one end and techniques and things at the other, with design as a middle term. Technological ideas must be translated into designs. These in turn must be implemented by techniques and tools to produce things.*" (Layton, 1974, pp. 37-38). In the quickly changing world of the 21st century this definition may seem somewhat simplistic and imperfect but it serves this discussion well as he paints a metaphorical picture of technology as a spectrum with ideas at one end and at the other, the implementation of techniques and tools to produce things. This spectrum is perhaps, mirrored in the current dichotomy of teacher views on technology education in New Zealand. Some see and practice technology education as the development of practical skills for students, often linked to industry training standards while others embrace the design and knowledge components of technological practice in a more holistic approach to technology education.

This dichotomy is perhaps not surprising given the history of technology education and curriculum development in New Zealand. The progression of technology curricula is well documented (Burns, 1992) (Ewington, 2002) (Jones, 2003). A national school system was introduced in 1877 with technical education being introduced for the last 2 years of primary schooling (10–12 years) in 1890. This consisted of metal and woodwork for boys and cooking, needlework and/or laundry for girls. At the same time separate technical high schools were developed and channelled working class children into manual and trade employment. This primary function of technology education continued unchanged (and unchallenged) for nearly 70 years (2 – 3 generations) until it was widened in 1945 to all high schools offering subjects such as metal and woodwork

and cooking and sewing for junior students (13–15 years). The curriculum and pedagogy however continued to focus on developing student's manual skills, whether that is for life skills or employment, with an emphasis on training for life. In Layton's spectrum, the emphasis was well and truly to the right hand end with students developing knowledge of techniques and tools to produce things.

It was not until the 1970's that the curriculum began to change significantly to have a greater focus on design. It is interesting to note that the technology curriculum in New Zealand had remained relatively unchanged for the better part of 100 years. The change of emphasis in curriculum was signalled with the development and implementation of subjects such as workshop technology and graphics and design. In the metaphor of Layton's spectrum the balance of focus on technology made a shift to the left to acknowledge design as an integral part of technology and important in technological practice.

This shift of emphasis within technology education has continued giving more emphasis to design and the ideas part of technology. In 1995 the Technology Curriculum (Ministry of Education, 1995) established technology education as a learning area in it's own right and moved it from being an optional subject for interested students, or interpreted historically as a subject suitable for the working classes to give life skills and employment opportunities, to a compulsory part of everyone's education sharing in a balanced curriculum for the 21st century.

This move in curriculum signals a fundamental change in the role of technology teachers. The role of developing student's technical skills is widened considerably to that of an educator. The domain of the technology teacher now becomes the education of the student developing technological literacy through experiences of technological practice. The implications of this for teacher practice are not to be underestimated. Importantly, teachers need to understand that the role of developing students' technological skills has not been taken away, but added to.

In 2007 the national curriculum was revised (Ministry of Education, 2007) and the structure of technology education underwent another subtle but significant change to include even more emphasis on the ideas end of Layton's spectrum within technology with strands now focussing on knowledge in technology as well as the nature of technology itself alongside technological practice.

Teachers entering the profession as initial teacher education students for technology education at the secondary level typically come with industry background, intuitively understanding the techniques and tools end of Layton's spectrum. To become effective technology educators for the 21st century they also need to develop understandings of; education - the differences between this and training, design and design education, as well as the roles of knowledge's in technology and how these empower technological practice.

Teachers understanding of education versus training

The 2007 curriculum makes a clear call for a holistic education for New Zealand students. One of the fundamental roles of education is to empower individuals to make choices in their lives and give them the skills and knowledge to succeed, in whatever

path they choose. Furthermore, education can be seen as a means to emancipation and social equity. The history of technology education in New Zealand can be interpreted as a means to train the working class for a role in industry. A question in the 21st century however is whether that role of the curriculum is still valid and should technology education be positioned in this way? Should an essential learning area of the curriculum be positioned as a means to supply social capital to industry?

A view often heard about the students that take technology subjects in secondary school, is that these are the students that are not academic, they are more practical in nature and learn by doing. The argument follows that it is better for them to take these practical subjects and gain success here. If this argument is accepted then a number of implications arise. If these students are less academic, and they are sidelined (another word for marginalised) into practical classes and therefore have less exposure to core curriculum experiences in general literacy and numeracy, what effect does this have on their development of functionally language literacy and numeracy, which many would argue are essential life skills? If literacy and numeracy are fundamental for a person to be successful in their life and future learning, by shifting these students to a course of study that is practical, does this not potentially make the problem worse for them? If New Zealand has an issue of low adult literacy, then perhaps the history of marginalising technology education students into practical courses, and in many instances pre-trades training, is part of the bigger problem.

Technology teachers need to understand their role in developing general language literacy and numeracy for their students. In saying this, technology teachers need to understand their role as an educator as well as trainer. One of the ways to account for the need for education within technology education is to acknowledge the critical role of general language literacy and numeracy as a part of successful technological practice. The ability to communicate and understand others and to negotiate meaning by all people involved in technology, is essential. A feature of technology in the 21st century is the team nature of technological practice and general language literacy particularly is fundamental. Any time one employs someone else to do a technical job for them this becomes oh so clear, and sometimes costly when it does not happen well.

Technology teachers educate students in language, literacy, numeracy and technology. They teach them to think and make valued judgements. Within the curriculum (Ministry of Education, 2007, p. 12) all teachers are called to address a set of key competencies which define these meta concepts of education. These competencies include; thinking, using language and text and symbols, managing self, relating to others and participating and contributing. These competencies link easily with technology education.

In the key competency of *thinking*, within technology students will need to be creative in their design and development of the intended outcome. This can be encouraged through activities such as getting students to examine and redesign products familiar products e.g. cell phones, can openers, i pods, bicycles. Because most students have a large amount of knowledge about how these products work and how they can be improved, it bypasses the information gathering stage and allows students to be creative and use their imaginations about an area in which they have expertise. Students will also need to think creatively about designing and using strategies to solve the problems

they are going to encounter during the project and evaluate their ideas and processes. This will also get students thinking critically and using metacognitive processes.

The key competency of *using language, symbols, and text* links easily as each area of technology has its own specialised language. The knowledge within a subject is expressed through language be it spoken, written or drawn. Furthermore for students to have access to the knowledge described above, it is crucial they understand the language used in technology and learn over time how to interpret and communicate using a variety of technological languages including drawing. Therefore students need to be exposed to the correct use of the language used in the area of technology they are in, and this needs to be modelled by the teacher using the languages available to the subject area. Additionally students will need to be supported through difficult words and the concepts behind them, and understanding the importance of drawing, both as a communication tool and as a thought process.

Within the key competency of *managing self and relating to others*, technology education offers the opportunity to work in a context that is real to the students. Because the students can see they are helping to solve a real problem that exists within their school and community, that it affects people around them, this in turn helps to motivate the students enabling them to set goals, make plans and manage projects. Additionally they learn how to relate to others in group work, interviewing stakeholders and listening to what they have to say and evaluating their feedback, talking to people in authority such as the principal and members of the board of trustees and sharing ideas with these people.

The key competency of *participating and contributing* is fundamental to technology education. The New Zealand Curriculum (Ministry of Education, 2007, p. 12) states that “This competency is about being actively involved in communities. Technology is all about students being actively involved in their community. The backboard project will see students actively involved and participating within the school and wider community and have the community involved with the students during the process of developing an outcome. Therefore as the Curriculum points out, students will gain a sense of belonging and build the confidence to participate within new contexts.

A further consideration for technology teachers is the role of values as stated in the curriculum. The Values of Excellence; Innovation, Inquiry, and Curiosity; Diversity; Equity; Community and Participation; Ecological Sustainability; Integrity; Respect all inform the learning that students should be doing and can be driven by the technology teacher.

The challenge for technology teachers therefore is to present units of work for students that address the necessities of the technology curriculum, developing students increasing technological competence while at the same time seizing opportunities to educate them in the wider sense for success in the world of the 21st century.

Teachers understanding of design and design education

Design within technology education is an active area of research (Johnsey, 1995), (Ewington, 2002), (Mitcham, 2001) and has its own developing literature base and research agenda. As a relatively new component of technology education for many

teachers, this research is important to inform developing classroom practice to address the changes in curriculum. There are some further challenges it seems, for teachers to consider when understanding the role of design in technology education.

A common apparent misconception seems to be that by addressing design as part of technology education, the opportunity to develop quality technological outcomes, to make stuff to a high standard of skills and craft, disappears. Some see that by adding design as part of technology the outcomes are only models. An understanding of the role of modelling and testing as part of technological practice is fundamental. Modelling and testing needs to be understood as the precursor to construction as a means of risk management and failure prevention.

A philosophical difference is raised here with the aims and forms of technology education. When technology education is positioned as it has been historically, the development of known skills and techniques and knowledge then technological outcomes are predictable. The pedagogy used for this classroom practice can be teacher led and teacher centred and in many ways didactic in approach, the teacher determines the outcome and students work hard to reach that outcome. If however, design becomes a central part of technology education then the technological outcomes are not predictable. Here, features such as modelling and communication of ideas becomes far more important and the ability to analyse, critique, make and justify valued judgements as part of technological practice becomes far more important. Risk management and failure analysis become important skills to apply and the pedagogy of the classroom demands far more educational roles of the teacher. The outcome of technological practice for students however can remain the same; the development of a quality technological outcomes. Design as a part of technology does not take away the opportunity to make quality technological outcomes.

Teachers understanding of design and design education is important for technology education in the 21st century. Design has evolved as technology has grown. “Prior to the rise of modern technology, design was hidden or embedded in the craft of making. Artisans, as it were, ‘designed’ artefacts in the course of constructing them, so that making seldom involved anything like a separate moment of thinking out or planning beforehand, but proceeded as intuitive trial and error fabrication, letting oneself be guided by materials and tradition, and even by personal relationships in the community” (Mitcham, 2001, p. 30). Of interest here is the word intuitive. Today we would call it tacit knowledge, something that we just know, unaware of how. But where did this knowledge come from? Trial and error fabrication suggests less time constraints than perhaps we operate with today. It also suggests learning and refining from mistakes. This approach requires understandings of the role of modelling within technological practice.

Mitcham’s ideas of letting oneself be guided by the materials suggests an intimate knowledge and understanding that is necessary of the characteristics of the materials used and likewise knowledge of the history of traditions within the community. It speaks of a relationship, which has been built over time, perhaps through the generations, between the craftsman, their materials and the people they are making for. “People today design their lives -that is they try to think out in advance how to go about doing something. In what are now the most characteristic design activities they use computers to assemble and organise this information, to render it in graphic form, and

in this way to test out alternative courses of action before actually undertaking them.” (Mitcham, 2001, pp. 29-30). This approach suggests more time using existing technology to plan and design, which in itself is perhaps a better use of our available time, but it may explain our loss of affinity the craftsmen of past used in design.

Layton places design in his spectrum as a middle part. We have already seen that the placement of design in the process of making something has changed over time as technology has developed. There is no doubt that ideas must be translated into designs, for until that point they are, but the beginning of a concept in someone’s mind, with no pattern to be followed for making.

Design in the 21st century is also developing as an area of knowledge and practice in it’s own right and technology teachers need to be aware and understand these developments and how they affect technological practice and how different areas of technology employ different approaches and thinking in design. Functional design and aesthetic design are important starting points for technology and in the 21st century are being built upon by systems thinking in design. A systems approach to design embraces the practice of designing products, processes, services, events, and environments with the focus placed on the quality of the end users experience of culturally relevant design solutions. This is sometimes referred to as Design for Experience. Here less emphasis is placed on increasing and improving functionality and more on the holistic experience of the user (Aarts & Marzano, 2003). Other areas of design development in the 21st century include environmental design, hazard analysis, product design, information design, information architecture, brand management, interaction design, and service design.

Environmental design is a particularly relevant area for technology teachers to engage with. Carl Mitcham stated over ten years ago that “it seems we undertake technological actions less and less for the good of our descendents and more for the benefit they bring us.....and that these actions often hold others, including our own progeny, hostage to the risks of our technical deeds”(Mitcham, 1994, p. 108). This statement would suggest that immediate gratification is more important to us than our future. Technology is making our lives easier and exciting but at what cost. According to Layton’s statement, the fault would lie with the idea, the design or the technique used in the making. I don’t find fault with life being made easier or more exciting on the most part and since technique is largely employed by the design, the fault must lie with design. Is their insufficient responsibility placed within the design of technology?

As noted by Kimbell (Kimbell, Stables, & Green, 1996) “industrialised societies have increasingly sought to build a ‘better’ world, *and* we have repeatedly been brought up short by the manifest failings in our efforts. Eco design is an interesting response to the problem, not just because it seeks to illuminate the grand scale of ecological matters but because of the tools it has spawned. Environmental audit (EA) and Life Cycle Analysis (LCA) are complex tools that have been developed – quite literally- to account for each decision that contributed to the design of a product”.

Already we are seeing more complexity to design than Layton suggested. Within design it has become apparent that it is more than creating a pattern, plan or recipe from which skill and equipment can be used to make something. There is becoming and needs to be more so, a responsibility in design to consider why we are designing, is there another

aspect to this design that could be used in another situation? Can the design be altered to assist in another area? Can the outcome be developed using someone else's waste using the 'cradle to cradle' philosophy (McDonough & Braungart, 2002)?

Teachers understanding of the role knowledges play in empowering technological practice

As has been argued, at the turn of the century technology education was focussed on teaching life and employment skills. The learning outcomes and styles of teaching focused upon developing those skills and competencies within students. Although skills are still an important aspect of Technology Education, there is a whole realm of knowledge and learning that is available to students that can be accessed through their participation in technological activities. By focusing only on teaching students the skills they need, there is a missed opportunity for them to gain a deeper level of learning. This could be accessed through the same or similar project but with a focus on the deeper learning that is taking place. Therefore an understanding of the levels of knowing in technology and the relationships between these knowledges is greatly important for teachers. One way of describing these knowledge interactions for understanding, is by identifying technical, procedural and conceptual knowledge in technology.

Technical knowledge can be defined as the knowledge required to operate at the level that Layton refers to as employing techniques and tools. This is knowledge of *doing* things in technology. Technical knowledge is sometimes known as personal skills, the ability to perform certain tasks, the practical knowledge of skills and techniques, tools, machines, chemical use, resource manipulation, products and wastes. In other words, it is the knowledge of materials and resources specific to a technological product and process. In our historical analysis of curriculum in New Zealand this sort of knowledge has been the focus of much of technology education.

The next level of knowledge can be called Procedural Knowledge. This knowledge can be described as the knowledge of *how* to do things in technology. Often it is the knowledge associated with problem solving (McCormick, 1997) and importantly occurs within a context. The attributes and functioning of procedural knowledge is debated in the literature (Gott, 1988), (Stevenson, 1994) but for teachers, the idea that knowledge of when to apply different techniques and solutions is important to support technological practice. McCormick for example, sees less importance in the specifics of the levels, than the idea that they exist "and that, when it comes to learning procedural knowledge, a balance is struck between detailed procedures that support learners in specific contexts and abstract ones that are impossible to use" (McCormick, 1997). So to make sense of these, if procedural knowledge is the recipe then technical knowledge is the knife skills.

Conceptual knowledge is the knowledge *about* things in technology. It is knowledge rich in relationships and understanding and it can be described as "know that" knowledge. It is this knowledge that allows us to explain things through our own understandings. Within a classroom situation it can be seen as an understanding which forms links with student's existing knowledge. Importantly conceptual knowledge is not simply factual knowledge, but consists of ideas that give some power to thinking about technological activity. Conceptual knowledge ...is concerned with relationships

among 'items' of knowledge, such that when students can identify these links, we talk of them having 'conceptual understanding' (McCormick, 1997, p. 143).

Conceptual knowledge allows students to form mental abstraction of things that are real in the world. In technology an understanding of materials or ingredients could be classed as conceptual knowledge as we do not actually use materials or ingredients we use steel or timber or flour for example. Therefore concepts could be seen as the parents that give birth to other concepts and things in the world. This is the power of conceptual knowledge as in understanding the wider concept enables creativity and the ability to give birth to other ideas and things.

The change from teaching predetermined skills and outcomes in technology to developing creativity through design, requires teachers to adopt an understanding of design. Moreover it requires teachers to develop an understanding of the different levels of knowledge in technology and how they interact to empower technological practice. One could argue, that if this understanding of technological knowledge is not well developed, it is not surprising that teachers struggle to see the relevance.

These three levels of knowing (technical, procedural and conceptual) in technology are important for teachers to develop with students for them to become technologically literate and to empower their technological practice. It is important for teachers to understand how these levels of knowing might look within the curriculum and within technology and to actively plan for student learning at all of these levels.

In the strand of technological practice for example within the component of planning for practice the three levels of knowing might be approached in the following way.

At the technical level students can be taught how to use a common software package such as excel, to develop a time and resource management tool such as a Gantt Chart. They might be taught how to lay out a time line to identify important procedures and identify start & finish times while visualising any overlaps. They can also plan for key milestones in production. This *doing* knowledge is often seen as having a direct relevance to the technological practice at hand.

Procedural knowledge can be developed around the same idea with students developing understandings of the different ways to manage time and resources through a project. What are the advantages of using a Gant Chart? What other alternatives are there? How do technologists make decisions about what approach is best? This knowledge is again applicable in context but is in many ways future focussed, thus leading the student to an understanding of how to approach similar yet different technological projects in the future. This knowledge is a powerful. It enables students to be creative and make valued judgments in the future with their technological practice.

Conceptual knowledge in this area can be developed with students understanding the issues of estimated costs and cost overruns in production planning. Issues of efficiency, reliability and optimisation all relate to conceptual knowledge. Conceptual knowledge can also be knowledge drawn from out of the context and applied and contextualised through links with procedural knowledge.

The important issue here however, is McCormick's insistence that conceptual knowledge gives power to technological practice. There is no educational benefit in simply teaching conceptual knowledge that is not related to the technological practice being considered. If this occurs then we simply mark a return to related studies where we simply keep students busy with 'book work'. It is the understanding that conceptual knowledge empowers technological practice. That the links between the knowledge's, are as important as the knowledge's themselves.

In the technological practice strand within the component of outcome development and evaluation, technical knowledge contains the knowledge of constructing technological outcomes. This is where students develop the skills of creating high quality technological products with the educational emphasis on developing students' skills and techniques.

The development of procedural knowledge within this component can take the form of knowing what the range of different techniques are that will give a certain outcome, and why these skills and techniques might be used in different situations. How do you make, communicate and justify valued judgements about different approaches in different situations. Again this knowledge is future focussed and empowers student's technological practice in the current situation and in their future in other situations.

Conceptual knowledge within this component again gives power to technological practice. So here the candidates are knowledge of needs and wants, what characteristics of success are explicit in a technological outcome and what values are placed on different aspects of success. For a technological outcome to be successful, knowledge at this level is required.

And finally, an example from the strand of technological knowledge within the component of modelling. Here at the level of technical knowledge, students can develop skills such as sketching and rendering, 3-dimensional modelling and digital rendering techniques. Progressing to procedural understandings students begin to understand why different techniques are used in different situations and how valued judgements can be made to decide what the best approach is in any situation. At the conceptual level students can begin to understand the reasons why modelling is fundamental to technology and the way in which it minimises risk and allows for testing of design ideas while keeping resource costs to a minimum.

Conclusion

Recent changes to the New Zealand curriculum have implications on technology teacher's classroom practice and their concepts of what being a successful teacher in the learning area of technology means. Understandings of education, design and the roles of knowledges in technology are important for technology teachers.

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