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The Technological Knowledge Strand: Is that all there is?

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Abstract

Many years' experience in Initial Teacher Education (ITE) training, reveals a disjunct between student career experience in communities of practice[i] and aspects of the technology learning area.

ITE students find that little of the knowledge they bring from their careers is recognised by the strand designated to technological knowledge.

After nearly twenty years of settlement and two national curriculum iterations, it is timely to review the efficacy of the learning area. This will establish whether there is indeed a common community understanding of the technology learning area and its intent.

This paper looks at the Technological Knowledge strand. Further emphasis is placed on the strand's Technological Modelling component, as this is an area familiar to students from their feed–in career experience.

Key Words: *Technological Knowledge, communities of practice, procedural, conceptual, tacit knowledge, design practice.*

Introduction

This paper begins its discussion on the Technological Knowledge strand, by relating the initial stage of ITE training with career changing specialists. Students are initially introduced to the nature and purpose of the learning area of Technology. Parallels are then drawn between communities of practice related to technological activity, seminal and current theory, curriculum and learning area material to eventually inform student pedagogy and classroom practice.

The stage in training where students find the learning area material is contrary to or restricts their own familiar practice is explained as it occurs.

An exploration into the theoretical background that contributed to decision-making at the time of the two iterations of technology education curriculum material follows with reference to the first Maori technology curriculum; *Hangarau i roto te marautanga o Aoteoroa.* (Ministry of Education, 1999)

The part played by design within past and current curriculum materials is also brought to the fore. Parallels are then drawn between the knowledge bases inherent in and emerging within communities of creative design and technology practice to make comparisons with the intent of the learning area strands. Categories of knowledge are then introduced to indicate the broad and often unforeseen nature of knowledge bases within and around technological activity.

This paper's aim is to draw attention to the wealth of potential learning that underpins and accompanies the actual practice carried out by communities of practice across a range of contexts. The Technological Knowledge strand and component materials in *The New Zealand*

curriculum (Ministry of Education, 2007) are reviewed to identify areas where an alignment may or may not occur between practice and technology curriculum materials.

From career specialist to teacher of technology

The Diploma of Teaching (Secondary) ITE technology education course at the Faculty of Education, the University of Auckland, begins by acknowledging student career knowledge and experience developed through their previous engagement within a community of practice (Wenger, 1998, p. 214). Lucas and Claxton's (2010) observations on communities of practice describe members of a community pursuing a common interest, helping each other as they do so. "They work and solve problems together, so their learning habits and attitudes rub off on each other. New members watch carefully how the more established members talk, respond and deal with challenges…" (p. 116). They cite Lave and Wenger (1991) as they refer to this aspect of a community of practice as "legitimate peripheral participation" (p. 116).

Students enter secondary graduate ITE training from technology related communities of practice that include architecture, spatial, product, landscape, graphic and interior design food, hospitality, fashion, textiles and architecture. Engineering related fields including electrical, mechanical, civil, structural, sustainable and environmental design also feature. The rapidly expanding digital realm of website, software, animation and interactive game software design presents a seemingly infinite array of qualifications and career backgrounds.

Valuing their background career experience helps students to maintain confidence in their own ability and to build conceptual bridges towards educating about technology and technological literacy (McGlashan & Wells, 2013, p. 238). This focus also provides a benchmark, an acknowledgment of each student's expertise and knowledge base in a technology related field, as a starting point to build on and develop their teacher persona and pedagogy in the learning area of technology.

An introduction to *The New Zealand Curriculum* (Ministry of Education, 2007) aims to help ITE students form parallels between the curriculum Vision, Key Competencies and Values with their own practice and lives. They can identify with the underlying ideals of the NZC broad vision, being able to relate these to effective practice. They recognise conditions that acknowledge the inherent meaning and identity within the practice of their feed-in career communities of practice, where "three key dimensions of mutual engagement, joint enterprise and shared repertoire are present" (Wenger, 1998, p. 73). These students are confident in their stance provided by prior training and experience gained within an area that provides at best "a privileged locus for the acquisition of knowledge" (Wenger, p. 214).

An initial exploration of the nature and structure of the learning area of technology in the first weeks of the ITE course sees a shift in student acceptance of the material. Most students can see relevance in the underlying purpose and philosophy statements of the learning area. Students track their developing understanding of the learning area through readings, discussion and practicum experiences towards a personal pedagogy. As a first impression, they note parallels with the intent and essence statement of the learning area with their familiar career practice.

They see that the Nature of Technology strand provides a broad lens to view the symbiotic relationship between technology and society. They also relate to and contribute to robust discussion about the development of technologies to meet human needs in historical and cultural contexts within this learning strand.

Students who have recent experience within a community of practice that includes architecture, product, graphic, digital and fashion design, the trades, food and hospitality and engineering identify easily with the Technological Practice strand. The strand's reference to processes and skills provides a familiar matrix to align with their recent practice.

From personal experience as an ITE educator in technology, observations over many years have revealed that it is when examining the three components of the Technological Knowledge strand, a consistent number of students begin to voice their concern through in-class discussion and documentation. Reflective statements are prepared by students to document their developing pedagogy for teaching technology, as part of their course assessment. They write of the rich store of domain area knowledge that they bring from career training and practice being only partially acknowledged in the technology learning area curriculum material.

Indication of student discontent occurs as they begin to unpack the *Explanatory Papers*, and *Indicators of Progression* within the *Curriculum Support Document* (Ministry of Education, 2010) prepared to guide teaching and learning in technology. This document provided a basis for the more accessible terminology in *Key Ideas* (Ministry of Education, 2014) about each strand component.

Students were concerned that the three components of the Technological Knowledge strand (Technological Modelling, Technological Products and Technological Systems) focussed on narrow bands of knowledge selected from the potential wealth of knowledge that could be accessed through experience within and around technological activity. The distillation of knowledge bases to select areas of knowledge that pertain only to technological activity, was a direct research focus for the preparation of *The New Zealand Curriculum* (2007) learning area material. Compton and France (2006) identified Technological Modelling as "a key concept in technology [which] can be differentiated into two related forms - functional modeling and prototyping functional modeling" (p. 7). They saw the Technological Product component as encompassing the knowledge of materials that underpin technological products, and Technological Systems as related to understanding of technological systems, that can be defined as having "inputs, outputs and a non-disclosed transformatory process or series of processes" (p. 9). These components were perceived to contain the knowledge bases necessary to inform learning towards technological literacy.

The selected areas of knowledge are valid, but appear to address only part of the knowledge within practice across a wide range of contexts. A frequently noted omission observed by ITE students is the essential knowledge relating to the human interface within practice that relates to meaning, community and identity. Hence, the title of this paper provided by a student exclamation: "Is that all there is?"

Our main aim as educators in the field of technology education is to develop a broad technological literacy in all learners, where they construct and co-construct knowledge, through a wealth of experience, set in a wide variety of contexts (Ministry of Education, 2007, p. 32). The knowledge bases within and on the periphery of technological activity are multifarious, as identified by each cohort of ITE students. It would then seem essential that we adopt a more flexible, all encompassing approach to acknowledge the wealth of potential for gaining and developing knowledge through each experience.

Theoretical background relating to technological knowledge

A review of seminal historical and current literature provides an insight into key decision making at the time of the first and second technology curriculum statement.

Literature available at the time of the first *Technology in the New Zealand Curriculum* (Ministry of Education, 1995) identified broad perceptions of technological knowledge. The resultant Strand A of the *Technology in the New Zealand Curriculum* (Ministry of Education, 1995, p. 31) entitled *Technological Knowledge and Understanding* promoted links with all three strands (including *Technological Capability* and *Technology and Society*) in students' technological experience. The strand also required that:

when involved in any technological activity, students should adapt and apply knowledge, strategies and skills from a variety of sources.

Within a range of technological areas and contexts, students should develop an understanding of:

1. The use and operation of technologies.

2. Technological principles and systems.

3. The nature of technological practice.

4. Strategies for the communication, promotion and evaluation of technological ideas and outcomes. (Ministry of Education, 1995, p. 31)

These requirements were explained further to include that Technology makes "use of knowledge from other disciplines" (Ministry of Education, 1995, p. 6); and "Technology derives from a variety of knowledge bases, values, processes and skills" (Ministry of Education, 1995, p. 28).

When involved in observing, examining and experiencing applications of technology, both in their immediate environment and in other settings, students are both developing and employing knowledge from a range of sources.

> Students will explore how and why technologies are used and how they operate. They will also recognise the principles that underlie technological developments. Such as modification, adaptation, user-friendliness, fail-safe features, flexibility of use, reliability, fitness for purpose, efficiency, ergonomics, aesthetics and optimisation…. They will identify and understand the components of technological systems, as part of developing technological knowledge…. Different methods and codes of practice have arisen in different technological areas…. Students will investigate the distinctive features, as well as common principles, of how technologists work in a number of fields…. Students will explore … strategies used for the communication, promotion and evaluation of technological ideas … to help students incorporate aspects such as explanatory instructions, advertising, packaging, marketing, in their own technological practice. (Ministry of Education, 1995, p. 31)

These requirements indicated a flexible approach to the development and use of knowledge and understanding as those that arose out of technological activity from a range of settings. At that time, teachers were given licence to look at knowledge inherent in and related to a wide range of technological activity.

At this time, the *Hangarau i roto te marautanga o Aoteoroa* (Ministry of Education, 1999) document was prepared "to develop Maori students' technological literacy by prioritising Maori knowledge and values in the understanding and undertaking of technological practice" (Ferguson, 2009, p. 27). It aligned with the aims and concepts of the English medium *The Technology in the New Zealand Curriculum* to some extent, but with a significant difference:

> Two main strands were identified: Marautanga Hangarau and Hangarau a Iwi. Marautanga Hangarau incorporated aspects from the technological knowledge and technological capability strands. Hangarau a Iwi reflected aspects of the technology and society strand. (Ferguson, 2009, p. 28)

The decision to combine the knowledge and capability (or practice) strands in the Hangarau document could be said to show foresight as it acknowledges that knowledge is embedded within and developed through practice.

Positioning of design in technology education

Attempts were made throughout the curriculum development stages, to situate design and its related knowledge bases into the technology curriculum, even though the word Design was left out of the curriculum title, differently from the British and Australian subject Design and Technology. The *Technology in the New Zealand Curriculum (Draft)* (Ministry of Education, 1993c) saw design designated as a technological area to address the procedural events within the practice of technology to include "the use of different materials, graphics and modelling to develop designs and to communicate ideas and technical information" (p. 9).

The part of design is seen as an overarching statement across all technological areas in the *Technology in the New Zealand Curriculum* (Ministry of Education, 1995) document in that "whichever technological area is selected, **design**, including the process of specification and development and testing of prototypes, is an essential component of the activity" (p. 12). The decision to not include design as a technological area, acknowledged the place of design and the human decision maker at the core of all technological practice. It is possible, however, that the decision to mention design as an overview and not a specific area of its own, caused it to be overlooked in many school programmes. The part played by design in the current *The New Zealand curriculum* technology learning area essence statement, "technology is intervention by design" (Ministry of Education, 2007, p. 32), could be also seen as significant recognition.

The knowledge base related to design includes much to inform and enrich technological practice. Associated knowledge bases include proportion, the use of colour, ergonomics (with the associated anthropometrics), the effect of light, texture, space, sound on the human interface are a selection of those that are housed within the architectural domain. Two main categories that have guided the broad fields of creative design education and practice are the awareness of the *aesthetic* and *functional* aspects of a design. The *aesthetic* is explained as the effect and feeling created by appearance of a design. Key aesthetic elements are the effect of shape, form, colour, texture, finish and environment. The knowledge base around the aesthetic includes the knowledge of:

- Proportion - relationship in size between parts of an object;

- Balance - formal, informal and radial;

- Harmony - elements are equally important;

- Contrast - different elements clash or oppose;

- Pattern - natural or purpose made;

- Movement - lines or flowing forms, which draw the eye in a particular direction;

- Rhythm - repetition of elements give sequence of movement; and

- Style - reflecting the cultural way of life, needs and interests of a society and its designers.

Functional considerations provide the second category that looks at how well a design works and performs when used. Key functional elements include strength, durability, efficiency, safety, ergonomics, construction, optimisation and cost. These elements are not a conclusive list, as each task and its context dictate the nature of potential influences to guide design decision-making.

The New Zealand Curriculum (Ministry of Education, 2007) learning area material refers, however, to the physical and functional nature of technological outcomes with little or no mention of the aesthetic.

There is, therefore, a part to be played by design within technological practice. There are design roles addressed in *The New Zealand Curriculum* (NZC) (Ministry of Education, 2007) Technological Practice and Nature of Technology strand materials. ITE students from design

career backgrounds however, note that the broad knowledge base of design is not addressed by the Technological Knowledge strand.

In 2006, research into the Technological Knowledge and Nature of Technology strands (TKNoT) was undertaken to define the two new strands proposed for the draft New Zealand Curriculum, (Compton & France, 2007a, 2007b, 2007c). Key components of technological knowledge were established through "exploration of the philosophy of technology internationally and the technological knowledge located in New Zealand communities of practice" (Ferguson, 2009, p. 35). Key aspects identified in the research were seen to cross over all technological contexts; these became the three components of the Technological Knowledge strand of technology in the learning area of NZC: technological modelling; technological products; and technological systems (Ministry of Education, 2007, p. 32).

Interpretation of the Technological Knowledge components

Technological Modelling

Key Ideas for each component within the Technological Knowledge strand derived from explanatory notes in the *Technology Curriculum Support* document (Ministry of Education, 2010) have been published online by (Ministry of Education, 2014). These describe Technological Modelling as the testing of design ideas to see whether they can contribute to a fit-for-purpose technological outcome. There are two types of technological modelling:

- functional modelling - the ongoing testing of design concepts; and

- prototyping - the realisation of a fully functioning model.

All exploration and communication of the ideation to the realisation stages of design processing are seen as functional modelling. These are explained in the *Key Ideas* as consisting of:

> the technologist thinking through their design ideas and discussing them with other technologists and/or stakeholders to test their suitability. As the development progresses, selected designs may become drawings on paper or computer, then more formal written explanations and annotated diagrams. The next step may be three-dimensional mock-ups made from easily worked materials such as clay, cardboard, or polystyrene foam, or virtual CAD/3D models, which enable design ideas to be tested and evaluated to determine their technical feasibility and social acceptability. (Ministry of Education, 2014)

The use of the term modelling, especially functional modelling, as a blanket term for every act of designing and manipulation of thought, from the first concept roughs is unfamiliar to the community of design practitioners. The domain of creative design refers to the initial idea generation event as *ideation* or *conceptualisation*. Three-dimensional representations of ideas used to visualize designs further, however, are referred to by designers as models, either conceptual or prototyping towards a final *prototype*. Communities of design practice use of these terms is varied: IDEO, an American design firm, speak of employing rapid prototyping "in a series of quick iterations" (Kelley, 2001, p. 6) throughout all idea generation stages of their processing. ITE students at this stage need to adjust their understanding, to come to terms with technology learning area terminology. The Technological Modelling component as it stands does not reflect key design processing events within the communities of practice that they are familiar with.

The Technological Products component focus is predominately on the performance properties of materials. It is explained in the *Key Ideas* as being:

primarily about the identification, description, use and development of materials, and the impact that selection of materials has on the fitness for purpose of technological outcomes.

Different products require different knowledge bases, depending on the kinds of materials to be used. For example, the knowledge bases required for understanding and/or developing food products, garments, or furniture will all be very different. (Ministry of Education, 2014)

The title of this component indicates a broad scope of potential exploration of the knowledge bases around the design of products. Products in design refer to a broad range of outcomes from jewellery to automobiles. However, the curriculum material written to guide learning for this component places focus on understanding the material nature of products alone. Further research into the full potential of this component is planned to better reflect actual knowledge related to products across a wide range of communities of practice.

Technological Systems are seen in *Key Ideas* as:

… a set of interconnected components that has been designed to fulfil a particular function without further human design input.

The specialised knowledge required to develop or understand a particular type of technological system (for example, biotechnological or electronic control) will vary greatly, but the same concepts underpin all systems: inputs (for example, raw materials, information or energy) are transformed into outputs in a controlled manner. (Ministry of Education, 2014)

The systems addressed in this component relate to a specific selection of system broadly explained as encompassing input, transformation and output. Much discussion has focussed on all technological related systems that could feature in this component, but have been excluded due to the term "without further human input" (Ministry of Education, 2014). Again, further in-depth research into the knowledge bases that are embedded in a broad range of technological systems is required to ascertain whether a less restrictive view would enrich learning.

It is the specific focus of these components that ITE students find lacking in relation to the broad domains of technology related communities of practice that they know well.

Knowledge bases relating to technological activity

In an attempt to identify the kinds of knowledge actually inherent in technological activity, it is useful to look first at what instigates technological activity. Early research by McGinn (1978) attempted to identify the expansions of "the humanly possible" by suggesting six different modes to define the driving purpose that causes the activity. This also provides insight into the breadth of contexts that instigate and support technological activity. McGinn's six modes are:

1. Direct extension: providing a direct extension of some existing human function or capacity as in the case of the telescope….

2. Qualitative innovation: offering a qualitatively new addition to the repertoire of human capacities; as with the airplane….

3. Risk reduction or elimination: enabling one to do something, previously done, but only with the risk of incurring certain costs, with or without significantly reduced risks; in the case of the birth control pill….

4. Improvement of performance: offering the ability to do something easier or more efficiently than it would have done previously; in the case of chainsaws….

5. Substitution: enabling one to [carry out a task] previously precluded, but now possible through new technologies e.g. reading while one's lawn is being watered by an automatic sprinkler system.

6. Increasing the means for expression of the inner life: providing for the aesthetically or otherwise motivated representation of emotions, beliefs, perceptions and other states or conditions of consciousness in external, tangible forms, as in the case of musical instruments, sculpture, perfume, etc. (This might be viewed as the provision of additional means whereby humans can express their capacity for the representation of consciousness or experience) (p. 183).

The modes identified offer a broad scope of potential technological activity with tangible reasons for such development. The development and resolution of each activity or technological practice occurs within social and cultural settings and is context specific. Modes one to five suggested solutions to resolve perceived problems and expand or enhance human capability. McGinn's sixth mode presented a variety of contexts that relate to the enhancement of life, to address the deeper levels of human need and value. He related that specific and related knowledge was inherent within each mode identified and its context.

Reviews of the way technological related activity evolves provide some guidance as to the nature of technological practice, to identify the embedded and related knowledge in that practice. Seminal theorist Arnold Pacey (1983), whose research has informed national and international curriculum development, identified three operational elements in his model of technological practice: technical, organisational, and cultural.

- *Technical aspect*: knowledge, skill and technique; tools, machines, chemicals, liveware; resources, products, wastes. (Pacey saw the technical aspect as a restricted meaning at that time);

- *Organisational aspect*: economic and industrial activity, professional activity, users and consumers, trade unions; and

- *Cultural aspect*: goals, values and ethical codes, belief in progress, awareness and creativity. (p. 6)

ITE students' understanding of their own familiar practice is heightened and informed by Pacey's view, often focusing for the first time on an aspect of practice that they took for granted such as belief in progress or how creativity was planned for.

An insight into the practice of architects was provided by Schön (1983) in his observations of lecturer and student interactions. He saw the creative designer as the decision-maker at the centre of design practice, who carried out ongoing reflective conversations to provide an insight into the knowledge of designing:

> A designer makes things. Sometimes the final product is, more often a representation - a plan, programme, or image of an artefact to be constructed by others. This work occurs in particular situations, using particular methods and employs distinctive medium and language.

> The designer shapes the situation, in accordance with his [sic] initial appreciation of it, the situation talks back and the designer responds to the situation's talk back. In a good process of design, this conversation with the situation is reflective. In answer to the situations' talkback, the designer reflects-in-action on the construction of the problem, strategies in action, or the model of the phenomena, which have been implicit in the moves. (p. 78)

Schön provided a real world example of the knowledge that drives and is embedded within a field of design or technology related activity. He noted significant features in the practice which

were often unspoken. His findings relate to McGlashan's (2011) documentation of graphic design director Dean Poole's observation that "all ideas come from conversations; design is like a silent conversation… an internal dialogue…whether it is with an artefact, business or experience" (p. 243). These accounts provide examples of knowledge gained through the experience of designing that observes, explores, interrogates, makes connections and comparisons related to the context, human interactions and purpose of the design task with each experienced activity having encountered knowledge embedded within and related to the activity.

Layton (1987), in his discussions on scientific and technological knowledge also placed emphasis on the act of designing being at the core of technological activity; he goes further in saying that a design embodies the knowledge needed to produce a technological outcome. He saw design as constituting "the cognitive bridge across a spectrum from abstract, idealized conceptions to the concrete, as knowing how at the highest level" (p. 604). Comparatively, he noted that technological knowledge "can extend from the most abstract to the most concrete and from the most intellectually demanding to the least intellectual of routine jobs" (p. 604). He also cited Vincenti and Rosenberg (1978) that "Technological knowledge is tailored to serve the needs of design" (p. 605).

Many authors have written about the categories of knowledge within technological activity (Baird, 2002; Benedict, 1999; Compton, 2004; Compton & France, 2007; Cross, 1984, 2001; Custer, 1995; Glaser, 1984; Lawson, 1997; Layton, 1987; McCormick, 1997; McGinn, 1978; Meijers & deVries, 2009; Pacey, 1983). Common threads emerge to inform the nature of knowledge bases that drive, evolve within, are embedded in, and relate to technological activity.

Custer (1995) acknowledges the creative act involved in the design of an artefact by defining the realisation of the artefact as a dual approach from a systematic application of rules and process to an holistic/expressionist approach. He focuses on the cultural expressions around the design of artefacts, looking into self-expression, the search for meaning, entertainment, recreation, communicating truths, expanding human capability, representing cultural values and reality, to explain the purpose of cultural artefacts that we create. This view encompasses the broad contexts related to the human interface and endeavour impacted on by design decisions.

Lawson (1997) offered a view of the varied nature of design tasks and the inherent and related knowledge bases involved by citing Matchett's (1968) definition of design as "the optimum solution to the sum of the true needs of a particular set of circumstances" (p. 30). Matchett's use of the terms optimum and true needs indicate that the outcome can be measured against set criteria and that the true needs of a circumstance can be listed. Lawson alludes to the scope of design activity by noting that this "may well be the case for the design of a machine where the output can be measured" (p .30). He stated that this would hardly be the case for the design of a "stage set or building interior," where uncertainty goes with the territory, as "designers are by no means sure of all of the needs of a situation" (p. 30).

Lawson (1997) contributed further to the discussion by suggesting that having the ability to recognise and frame the nature of the design task, to respond with an appropriate design is one of the most important skills in design. He added that the control and combination of rational and imaginative thought is a most significant skill in a designer's repertoire. He exemplifies his observation by noting the effect of landscape features and the influence of climate on building construction and form across the world and throughout history that become major generators of architectural form. These considerations align and interact with other knowledge bases. Architects are expected to take more notice of their clients and end-users because the final outcome is often such a public matter. Architects are also required to respect the knowledge base of legislative control.

An analysis of the nature of design problems and the way towards resolution requires a way of thinking that defines convergent and divergent thinking as central to conceptual and procedural activity. Lawson states that it is "obvious that taken as a whole, design is a divergent task [and]

since design is rarely an optimisation procedure leading to one correct answer, divergent thinking will be required" (p. 145). Lawson's observations allude to a wide variety of types of knowledge that are inherent within and inform design and therefore technological practice.

Sharma and Poole (2010) allude to a knowledge base that underlies the act of designing, to inform design pedagogy. "Design…is changing; where once it was purely a matter of signs and objects, now it has entered the realm of behaviour and perception" (p. 65). They also refer to design practice as "a way of knowing through thinking and doing. … Design is not just something that is done to things – it is a way of doing things" (p. 65).

From the field of architecture, Benedikt (1999) in his work to refocus the intent of designing spaces that work for people alludes to expansive knowledge bases to inform decision-making. He suggests that in order to raise the "popular connoisseurship of the qualities of buildings [to] equal [those]... devoted to the valuation of music, cars and movies" (p. 7) a new approach is required. He suggests that architectural design seeks "powerful new or forgotten ways of talking about the intimate connections between people and places, perhaps [he suggests] by rereading Bachelard and Borges, Freud and Proust" (p. 6). He recommends a new kind of theorizing and explaining that can:

> … explore the circle route from architecture through cosmology, thermodynamics, and complex systems, through biology and evolutionary theory, through social psychology and psychology, through economics and economic history and back again to architecture to show that the activities of designing and making buildings … and planting the land … must elaborate themselves alongside all other human activities, not self-simplify and flatten, if we are to be happy on this planet. (p. 6)

This thinking aligns with McGinn's (1978) sixth mode relating to the purpose of technological activity to place the human and their real needs at the centre of decision-making. This leads into a wealth of knowledge bases to inform designing within technological practice.

More recently, Meijers and de Vries (2009) noted when making comparison between scientific and technological knowledge that technological knowledge is much more context-specific than scientific knowledge. They noted also that, until recently, philosophers tended to think of science as knowledge and of technological artifacts as merely the application of that knowledge.

> Now we realise that the learning area of Technology at best encourages not only the application of knowledge but also the learning of new knowledge from that application in the design and creation of artifacts. (p. 19)

When discussing evidence of technological knowledge within technological activity, Meijers and de Vries (citing Baird, 2004; Ferguson, 1992) note that engineers often express their knowledge in drawings, mock-ups, Marquette's, prototypes and the like. Architects, interior, spatial and product designers also communicate through conceptual modelling (mock-ups) and prototyping, fashion designers use the toile, graphic designers use the thumbnail to inform compositional decision-making. These observations can be seen to have informed the Modelling component of the Technological Knowledge strand as an event that informs practice. The learning area achievement objectives indicate that this strand relates to the knowledge of how modelling informs practice, rather than the actual practice of modelling. This is addressed in the Technological Practice, Outcome Development and Evaluation component of the NZC (Ministry of Education, 2007).

Concluding statement

This paper has examined the development of the curriculum and learning area material with a specific focus on the part played by technological and related knowledge bases within technological activity, and whether this faithfully reflects practice.

Many theorists offered significant reasoning and actual evidence on the nature of technological knowledge. The domains of science, engineering, education and design provide detailed definitions and descriptions of knowledge to guide curriculum decision-making and provide material for further debate on the intent of the Technological Knowledge strand. Research also categorised types of knowledge, with some referencing the artefact and others the process of design within technological activity to identify numerous areas of embedded and emerging knowledge.

Theorists agree that the knowledge within and related to technological activity varies in relation to the context and needs of the end-user of the project. Types of knowledge embedded in the practice, along with related knowledge, also vary across the broad range of communities of practice or technology disciplines. For example, designing tall buildings will draw from the knowledge base of structures, and strength of materials, amongst others. Similarly, the design of a garment for the trash to fashion awards may require knowledge about structure, properties of materials, as well as anthropometrics and perhaps contemporary style.

To define technological knowledge is as complex a task as it is to define the ways of design. Mc Cormick (1997) observed that defining "a knowledge base, and the search for a unique common set of procedures or concepts is particularly difficult" (p. 144). The variety of contexts that support technological activity, he suggested, "is found in all spheres of life" such as "food, textiles and civil engineering" and the knowledge disciplines that they are based upon are multi-faceted and numerous (p. 144). Technological activity is also seen to involve rational and logical processes alongside intuitive and imaginative processes. If technological activity is informed by the convergent and divergent thinking of design decision-making (Custer, 1995; Layton, 1987) then the knowledge base that comes with this practice is to be acknowledged and learned. Design is also as a way of constructing knowledge (Schön,1983).

Looking back to a broad range of research findings to inform an inclusive approach for the Technological Knowledge strand, the *Technology* in *The New Zealand Curriculum* (Ministry of Education, 1995) provided some benchmark thinking that could be re-examined. The Strand A; Technological Knowledge and Understanding appears to have offered a broad scope for the recognition and gaining of knowledge within technological activity. If so, should aspects of the early curriculum have remained to guide us towards an informed pedagogy? The additional intent of the 1995 strand indicated by the word: *Understanding*, (n) explained as being: compassionate, forgiving, perceptive, forbearing, sensitive, considerate, generous, sympathetic, discerning and as having aptitude, competency, capability, comprehension, talent, skill, dexterity and intelligence amongst others (Thesaurus.com, 2015) implies further human attributes to consider. Has the removal of this word from the current Technological Knowledge strand title and intent, disadvantaged our current learning area and pedagogy?

There are specific knowledge bases and types of knowledge that relate to design/technological activity that are obvious within each domain. There are also knowledge bases inherent within the practice or from other domains (external to the practice) that come to light only once the practice is underway. Teaching and learning in technology needs to allow space to acknowledge emergent knowledge that comes from within the practice.

Considerable further research is required to identify key and related knowledge bases that underpin technological activity in both education and community of practice settings. Findings will reveal a wealth of knowledge that is accessed and developed to inform and guide practice.

The benefits of acknowledging the potential knowledge bases that emerge within technological activity across a range of contexts will not only better reflect authentic practice for all learners; it will enable learners to translate knowledge across technological activity, context and curriculum boundaries towards a robust technology literacy.

Parry (2011), in her observation of design and technology students, offers further connections to the broad potential of knowledge within and around technological activity. She observed that "they [students] would do well to show attributes such as being: analytical, evaluative, entrepreneurial, technical, scientific, artistic, physically fit, philosophical, emotionally intelligent, mathematical and reflective" (p. 25).

These attributes developed through practice will empower our young to become informed citizens, better able to face their future.

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[i] Communities of Practice are seen by Wenger (1998) as those where three key dimensions of mutual engagement, joint enterprise and shared repertoire are present.