20 The Importance of the Conceptual in Progressing Technology Teaching and Learning

Cliff Harwood and Vicki J. Compton

Abstract

This chapter argues that technology education has a key role in enabling young people to actively participate in a world facing complex sociocultural and environmental challenges and an economy that is shifting from being knowledge driven to being innovation led. The aim of technology education internationally is to develop student technological literacy, and in New Zealand this literacy has been described as becoming increasingly "broad, deep, and critical" in nature as it progresses (Compton and France 2007; Compton and Harwood 2008). Further work in New Zealand to explore the transformatory nature of this literacy, as learning in technology progresses, resulted in three phases being identified as foundational, citizenship, and comprehensive technological literacy (Compton et al. 2011).

The chapter discusses what teachers need to know and do, to support student learning in technology and become more technologically literate, particularly related to foundational and citizenship technological literacy. It also discusses how the relationship between student decision-making and their undertaking of technological practice supports their progression toward a more comprehensive technological literacy. Findings from New Zealand classroom-based research are provided to support these discussions.

C. Harwood (✉)
Chanel College, Masterton, New Zealand
e-mail: c.d.harwood@mohsl.co.nz

V.J. Compton
Ministry for Primary Industries, Wellington, New Zealand
e-mail: vicki.compton@mpi.govt.nz

© Springer International Publishing AG 2018

M.J. de Vries (ed.), *Handbook of Technology Education*, Springer International Handbooks of Education, DOI 10.1007/978-3-319-44687-5_17

Keywords
Phases of technological literacy (foundational • citizenship • and comprehensive) • Learning environments • Strategic processing • Subject matter knowledge • Pedagogical content knowledge

Contents

Introduction 252
Technological Literacy: Phases of a Transformatory Journey 253
The Learning Environment: Teachers' Pedagogical Practices and Learning Contexts 257
What Should Technology Teachers Know? 258
  Strategic Processing 258
  Motivational Interest 259
What Should Students Know to Enhance Decision-Making During Technological Practices? 261
Conclusion 262
References 263

Introduction

The Organization for Economic Cooperation and Development (OECD) in 2012 reported that "innovation" will play a central role in addressing the current disconnect between economic growth and people's well-being. To do this, communities need to move beyond having a simple focus on economic growth and place emphasis on improving the overall well-being of all groups in society (OECD 2015). Critical to addressing this disconnect is the capacity of people to develop innovative solutions to the "numerous, complex and urgent" social challenges communities face (OECD 2011, p. 7). These challenges include aging societies, climate change, energy efficiency, resource management and sustainability, and security. Formal education through schooling is identified as a key mechanism for developing people who can contribute to conversations about these social challenges and think through the "not yet thought and unthinkable" (Wheelahan 2010, p. 68) to imagine alternative future solutions. Technology education, which asks students to develop innovative solutions to problems embedded in real-life contexts, is ideally poised to prepare students to engage in conversations which enable innovative solutions to be created that address current and likely future sociocultural and environmental challenges.

As discussed elsewhere (Compton et al. 2011), general education internationally is now focused on the development of multiple literacies, one of which is technological. The development of multiple literacies has been argued as a means of supporting an overarching "literacy for citizenship" that prepares students for "self-expression, participatory action, and solidarity in a pluralistic society" (Elmose and Roth 2005, p. 21). Such a focus emphasizes a need for critical dialogue and decision-making as enablers for students to develop as "empowered citizens" (Skovmose 1998). According to Elmose and Roth, developing this criticality relies upon three forms of knowing – "knowing that, knowing how, and knowing why" (2005, p. 22).

The three strands that define the technology in the New Zealand Curriculum [NZC] (Ministry of Education 2007) are underpinned by these three forms of knowing and provide a framework to enable students to develop a technological literacy which is broad, deep, and critical in nature (Compton and France 2007). For this to be realized in classrooms, key conditions are needed that support student learning in technology and encourage the development of this technological literacy. The remainder of this chapter discusses these conditions, drawing from New Zealand and international literature and classroom-based research findings.

Technological Literacy: Phases of a Transformatory Journey

Considerable classroom-based research funded by the New Zealand Ministry of Education has been undertaken in New Zealand to determine the nature of progression that underpins learning related to the level 1–8 achievement objectives presented in the NZC (Ministry of Education 2007). The critical social science framework employed across this research allowed for the use of both constructivist and sociocultural learning theories (Greeno 1997; Packer and Goicoechea 2000; Compton and Harwood 2004; Compton et al. 2011). As described by Greeno (1997), bringing different perspectives together allows different aspects of learning and thinking to be in focus for different purposes. For example, "the cognitive perspective emphasizes conceptual understandings and strategies of problem solving and reasoning; and the situative perspective emphasizes participation in practices of inquiry and sense making of a community, and development of individual's identities as thinkers and learners" (1997, p. 87).

The research which focused on understanding how learning progressed within the curriculum strands of the technology (e.g., Technological Practice see Compton and Harwood 2005; Technological Knowledge see Compton and Compton 2013a; Nature of Technology see Compton and Compton 2013b) primarily employed constructivist perspectives. This was to emphasize the procedural and conceptual learning required for students to show achievement across the levels of each curriculum component. This research resulted in the development of Indicators of Progression (available at http://technology.tki.org.nz/Technology-in-the-NZC/Indicators-of-progression) and the Learning Progression Diagrams (available at http://technology.tki.org.nz/Technology-in-the-NZC/Indicators-of-progression/Learning-Progression-Diagrams).

The *Technological literacy: Implications for teaching and learning* (*TL: Imps*) (Compton et al. 2011; Compton 2013) also used constructivist perspectives when supporting teachers to implement the 2007 New Zealand technology curriculum components over a 2-year technology program and when analyzing data to develop understandings as to how the components best work together at each level. However, when exploring and documenting notions of technological literacy, a sociocultural perspective was emphasized to better capture the transformation of students as a result of engagement in their technology programs (Compton et al. 2011). While such transformations occur in a complex and spiraling manner for individual students, Alexander (2003) argues it is useful to identify phases of learning in any domain. This research therefore sought to identify phases to gauge how students progress their technological literacy and guide teachers to support future student learning in relation to the leveled curriculum achievement objectives. The resulting description of phases is presented below.

Foundational technological literacy reflects the transformation of students once they have achieved curriculum level 3 across all 8 technology achievement objectives (Ministry of Education 2007). Consistent implementation of technology programs based on technology in the NZC (Ministry of Education 2007) in the first 6 years of schooling would lead to the majority of students working at curriculum level 3 by age 10 (approximately). Students exhibiting a foundational technological literacy can be described as having an understanding of the key concepts and practices in technology as a discipline, can comprehend the implications of these across a broad range of contexts, and can apply this knowledge in reasonably straightforward ways to undertake their own technological practice. More specifically, they can typically:

- State the purpose of technology, describe what technological practice involves, and differentiate between technological and non-technological outcomes.
- Describe how and why particular technological outcomes have changed over time and provide examples of how technological practices and outcomes have impacted on the made, natural, and social world.
- Describe the relationship between the physical and functional nature of technological outcomes and how this can be used to judge the outcome as a “good” or “bad” design.
- Explain why different forms of functional modeling and prototyping are used in technology and explain benefits and limitations of models.
- Describe properties of common materials and the inputs, outputs, and transformations of simple systems and how materials and components enable technological products and systems to work.
- Generate design ideas for products and systems that meet given needs or opportunities, establish key attributes, and use these to evaluate and refine design ideas to develop conceptual designs.
- Identify key stages and timelines, select appropriate materials and components for use from resources provided, and explain progress made and next steps when making products and systems.
- Use a range of different materials and equipment with guidance to make a variety of different products and systems, evaluate final outcomes against key attributes, and explain how well they meet the need or opportunity.

Citizenship technological literacy reflects the transformation of students once they have achieved curriculum level 5 across all 8 technology achievement objectives (Ministry of Education 2007). Consistent implementation of technology programs based on technology in the NZC (Ministry of Education 2007) in the first

10 years of schooling would lead to the majority of students working at curriculum level 5 by age 14 (approximately). In New Zealand, technology is required to be offered to all students as a compulsory subject for 10 years. Students exhibiting a citizenship technological literacy show an increased depth of understanding related to the key concepts and practices in technology, can analyze developments in terms of technical feasibility and social acceptability, can explain diverse drivers and impacts, and can synthesize their own and other's knowledge and experience to undertake informed and creative technological practice. More specifically, they can typically:

- Explain how technology changes the capability of individuals and/or groups and how past experiences of technology influence perception and acceptance of technology.
- Explain how technological development relates to social acceptability and technical feasibility and how it often involves trade-offs that require functional and practical reasoning to support decision-making.
- Explain how and why technological knowledge becomes codified, and discuss examples of creative and critical thinking that has led to technological innovation.
- Analyze technological outcomes to determine design intent, function, user/s, and location in place and time, and explain why the judgment of technological outcomes as "fit for purpose" can change over time and across different contexts.
- Explain how technological outcomes are realized to meet technically feasible and socially acceptable specifications based on knowledge of material manipulation, transformation, and formulation.
- Identify needs and opportunities, and generate design ideas for creative solutions that reflect technical feasibility and social acceptability considerations.
- Undertake research and functional modeling to test design ideas and competently use a range of equipment and materials to produce and trial prototypes to evaluate "fitness for purpose."
- Analyze, select, and use planning tools to effectively record key stages, review points, and effectively manage time and other resources, to ensure completion of their outcome.

Comprehensive technological literacy is the transformation seen in people that have developed significant expertise within the discipline of technology. It is reasonable to think this may require years of experience to develop. Students after 10 years of engagement in compulsory technology programs, followed by a further 3 years of technology as a specialist subject in senior secondary schooling, can only be expected to exhibit movement toward a more comprehensive technological literacy. That is, they can exhibit more specialized knowledge related to concepts and practices in particular sectors of technology. They also show increased ability to critically analyze complex scenarios and developments and can explain the complexity of balancing technical feasibility and social acceptability of technological outcomes. They also show an increasing ability to undertake technological practice within authentic contexts and employ sophisticated, functional, and practical reasoning to support decision-making that allows them to develop innovative solutions that can be evaluated and justified as “fit for purpose in its broadest sense.” Fitness for purpose in its broadest sense extends the idea of fitness for purpose of an outcome to also include the fitness for purpose of the practices involved in the development of the outcome (Compton 2007; Compton and France 2007). More specifically, students demonstrating a comprehensive technological literacy may typically exhibit some of the following:

- Critically analyze and discuss the interactions between technological outcomes, people, and social and physical environments, and explain how technology impacts on and is influenced by complex sociocultural factors – including those related to global issues.
- Discuss technology as a site of human endeavor that is based on competing factors, contestations, interdisciplinary collaboration, functional and practical reasoning, and critical evaluation and informed creativity to determine priorities and support compromises required for innovative technological decision-making.
- Explain how and why technological developments may produce differing costs and benefits for different individuals, groups, and environments, and discuss the role of technological modeling in risk identification and mitigation and in justifying decisions to push boundaries based on “acceptable” risk.
- Critically analyze examples of past and contemporary technological developments to identify known and unknown, intended and unintended consequences and justify a position on whether technologists (as individuals or collectively) have social and/or environmental responsibilities above and beyond those of the general public.
- Critically analyze technological outcomes to determine their “fitness for purpose in its broadest sense” as based on the relationship between their physical and functional nature and the socio-technological environment in which they were positioned.
- Justify how and why innovative technological outcomes are realized based on specialist knowledge and practices within technology, shifts in other disciplines, and wider environmental and sociocultural contexts.
- Explore authentic contexts to establish issues and related needs or opportunities and justify potential outcomes taking account of wider contextual considerations.
- Develop design ideas informed by research and critical analysis of a range of relevant technological outcomes, knowledge of material and/or process innovation, and/or “solutions” found in the natural world.
- Critically analyze, select, and use functional modeling and evaluative practices to ensure decision-making is based on sophisticated functional and practical reasoning.
- Establish specifications that reflect social acceptability and technical feasibility, resources available, and the appropriate practices used to design, develop, maintain, and ultimately dispose of the outcome.
- Skillfully use equipment and materials to produce and trial quality prototypes to gain evidence to make a justifiable decision to refine, modify, or accept the prototype as “fit for purpose in its broadest sense.”

- Critically analyze project management techniques, and use this to inform management of the project through effective and efficient coordination, resource management, and informed and justified decision-making based on critical reviews of progress, to ensure a quality outcome is completed.

The Learning Environment: Teachers' Pedagogical Practices and Learning Contexts

Historically, teacher pedagogy in technology education has emphasized, through authoritative instruction and modeling, the development of student's declarative and procedural knowledge, with a focus on function through offering students a variety of teacher-led practical "doing" experiences (Parkinson and Hope 2009). As a result, students developed a technological literacy that emphasized the development of procedural knowledge, and declarative knowledge focused on knowing "that" as opposed to developing concepts of knowing "how" or "why." According to Keirl (2006), the learning environment in this instance is "transmissive," simply encouraging students to recall "factual knowledge" and replicate this within discussion and the technological outcomes they create. As a result, the technological literacy students developed from this pedagogical approach could be described as "functional" in nature (Compton and Harwood 2008).

According to Lave (1988) when teachers present learning environments that require authentic socio-technical problems to be resolved through "real" design activity, students are offered an opportunity to mediate theoretical (concept) knowledge "into practice," instead of it solely residing as an "in the head" experience. When these learning environments are also "transformative" (Mezirow 2000), students are encouraged and supported to be critically aware of their own and others' tacit understandings and expectations and how these influence decision-making. Key to such learning environments is the balance between teachers supporting student's understanding of appropriate declarative knowledge (knowing that) and providing them the opportunity to develop conceptual understandings (knowing how and why) (Harwood 2014). Thompson (1990) suggests that when teachers impose their own "pre-digested experience and expectations..." on students, this leads to them displaying "... a lack of creative and individual thought through the development of uniformity, dependence and acceptance" (p. 104). On the other hand, when students engage in technological practice without appropriate teacher intervention, this can result in "learner helplessness" and the constrained and restricted use of knowledge, skills, and practices (Compton and Harwood 2001). However, if teachers are discerning as to "whether, when, and how" to intervene in student technological learning, students have the opportunity to develop their intellectual skills (Johnson 1997; Harwood 2014) and begin to develop an understanding of the network of concepts that underpin technology education (de Vries 2013). The knowledge teachers bring to the learning environment therefore plays an important role in the nature of student learning in technology and the resulting technological outcomes they produce.

What Should Technology Teachers Know?

Rohaan (2009) reviewed the literature available in the area of technology education (focused mainly on primary education) and identified six technology-specific knowledge aspects, which she further organized into three categories that work together to support effective teaching in technology. These categories were:

- *Subject matter knowledge* (SMK): This includes technological concepts and the concept of technology as discipline.
- *Pedagogical content knowledge* (PCK): This includes knowledge of student interest, prior knowledge, and/or misconceptions related to technological concepts, knowledge of technology as a subject. It also includes knowledge of pedagogical approaches and teaching strategies suitable to address student needs.
- *Attitude:* This includes a teacher's attitude to and confidence in teaching technology. (summarized from Rohaan et al. 2010).

The *TL: Imps* research, discussed above, employed the *Model of Domain Learning* (MDL) (Alexander 2003), both to support teacher professional development and as a tool to analyze data (see Compton and Compton 2013a, b). The MDL recognizes three categories similar to those identified by Rohaan et al. (2010) for effective teaching in technology. These are *subject matter*, including both situated topic knowledge and generic domain knowledge; *strategic processing*, including surface level and deep processing strategies; and *motivational interest*, including individual (general/professional) and situational interests (Alexander 2003, p. 11). The use of the MDL enabled the *TL: Imps* research to explore Rohaan et al.'s (2010) aspects of SMK and PCK and identify how these interacted to support effective teaching and learning within and across the phases of technological literacy.

Strategic Processing

As explained by Alexander, "surface-level strategies allow learners to function when content is unfamiliar or task demands are novel or complex, whereas deep-processing strategies permit learners to query the message in a more critical, analytic manner" (2003, p. 11). Exploring the link between strategic processing and student knowledge was of particular interest in the *TL: Imps* research due to concerns about the "open" inquiry learning approach commonly employed in technology in New Zealand primary schools. Open or "true" inquiry encourages students to formulate their own research question(s), design and follow through with a developed procedure, and communicate their findings and results (Banchi and Bell 2008). Banchi and Bell continue to describe this approach as requiring domain-specific reasoning and placing a high cognitive demand on the student (Banchi and Bell 2008). Effective open inquiry learning relies on the student knowing about and employing deep-processing strategies, and this in turn relies on the student having sufficient domain knowledge (Alexander 2003). The research found that the use of this open inquiry learning with the majority of students was ineffective in supporting student learning. Given this research included a focus on the then five new components of the Technological Knowledge and Nature of Technology strands of technology in the NZC (Ministry of Education 2007), many of these students, even those in the higher-year groups, were unfamiliar with the concepts and were therefore working well below curriculum level 4. In addition, many held misconceptions that served as a barrier to their learning (for details please see Compton and Compton 2013a, b; Compton 2013). This would suggest employing open inquiry learning would only be effective when students were working at curriculum level 4 or above.

When age-appropriate surface level strategies were used to support these students in a more "guided inquiry" approach, they were able to engage in the learning activities, and many, particularly the older students, developed their domain knowledge up to and including level 3 across all 8 achievement objectives of technology in the NZC (Ministry of Education 2007). This in turn allowed them to exhibit characteristics of a foundational technological literacy.

The research also identified that when the SMK of teachers was not strong, they found it difficult to provide students with effective deep-processing strategies to progress student learning past curriculum level 4 and toward the citizenship phase of technological literacy. This was particularly apparent in the concepts related to the curriculum components of Characteristics of Technology and Technological Modeling (Ministry of Education 2007). To address this, the researchers introduced specific deep processing support tools. These tools proved to be effective in the development of both teacher and student conceptual understanding of these components. For example, to support deeper and more critical understandings related to Characteristics of Technology, the "model of techno-historical interplay" (Hallstrom and Gyberg 2009) was used to help identify, describe, and evaluate the drivers and impacts of developments in technology (for details please see Compton and Compton 2011a). Similarly, to support broader and more critical understandings related to Technological Modeling, the use of an ethical thinking tool (Biotechnology Learning Hub 2009) was used to focus on ways technological modeling is used to explore aspects of social acceptability alongside technical feasibility (for details please see Compton and Compton 2011b).

Motivational Interest

The research also explored student interest in technology, particularly in emerging and/or disruptive technologies. Many of the students showed a deep individual interest in such technologies, often displaying far more topic knowledge related to these technologies than their teachers did. This topic knowledge was a result of their exposure to everyday encounters with such technologies as toys, games, and increasingly "smart" information and communication technologies. The research identified that when these technologies were utilized effectively in learning activities, and students were encouraged to use them as a context for learning domain knowledge (key generic technology concepts and practices), they were highly motivated to learn. In the past teachers had resisted using such technologies as they felt their own experience with them was too limited. By drawing on the students' topic knowledge and making explicit links to the teacher's domain knowledge, this resistance reduced and the learning environment improved. As a result, teachers also developed a better understanding of new technologies, further strengthening their SMK.

Combining Rohaan et al.'s (2010) categories, the following points provide a summary of the key understandings teachers exhibited when they were effective in supporting student learning related to the leveled technology achievement objectives in the NZC (Ministry of Education 2007) and their developing technological literacy.

Understanding:

- The key concepts and practices underpinning the achievement objectives and how they progress from curriculum level 1–8 (SMK and PCK)
- How topic knowledge relates to domain knowledge and vice versa in selected learning contexts and the need to make these links explicit for students (SMK and PCK)
- How student's prior understanding is related to domain and topic knowledge – particularly knowledge of student misconceptions, partial understandings, and/or alternative conceptions related to each achievement objective (see Compton and Compton 2013a, b for discussion of these as related to Technological Knowledge and Nature of Technology) (PCK)
- The importance of situational interest for students working at lower curriculum levels and how to develop student individual interests to drive learning of domain knowledge (PCK)
- The importance of terminology and consistent use of this across a range of learning experiences (SMK and PCK)
- The need for students to be presented with multiple learning experiences over time to introduce, explore, and consolidate their learning (PCK)
- The need for teaching resources (including reference material, templates, examples, etc.) to support student strategic processing appropriately to ensure that learning opportunities are maximized (PCK)
- The importance of "real" examples rather than symbolic representations of these (i.e., when asking students to categorize objects, provide the object itself rather than pictures or text descriptions of the object, particularly for students whose understanding is at lower curriculum levels) (PCK).

The research also indicated that, as students began to progress from a foundational technological literacy toward citizenship and a more comprehensive technological literacy, teachers needed to focus more specifically on supporting student's deep strategic processing skills and provide them with increasingly "rich" learning environments that encourage and support them to take risks and become more critical. Such environments need to value innovation and creativity in order to support the development of curious minds that value new ways of thinking and doing and stimulate informed decision-making.

What Should Students Know to Enhance Decision-Making During Technological Practices?

Decision-making is often referred to as a mental process that deliberates on multiple options (or alternatives) to select one that best meets the goals of the decision maker (Hardy-Vallée 2007; Milkman et al. 2008). The outcome of decision-making manifests itself as a conscious action or "opinion of choice" (Bohanec 2009, p. 24) that may in turn lead to a change in a decision maker's disposition toward a certain topic (Ferrand 2007). While such deliberation on alternatives may be "explicit and complex or implicit and rapid, without consideration of alternatives no decision making can be said to have taken place" (Galotti 2002, p.2). Considering alternatives within an informed decision-making process is therefore important for determining which alternative or decision to follow. While decision-making is the process of determining what to do or selecting an alternative (Beyth-Marom et al. 1991), it is reasoning that enables assessment of the probable success of considered alternatives (Fischhoff et al. 1999). "Reasoning" is a process that allows humans to change (or not change) their views and conclude a proposition that is reflective of their present-day understandings (Harman 2009). As such, reasoning allows beliefs and desires to be integrated into intentions or actions (Carruthers 2003), supporting decisions to be made.

Functional and practical reasoning are identified as important forms of reasoning in the New Zealand technology curriculum statement (Ministry of Education 2007). These two forms of reasoning are considered to underpin and support student decision-making when undertaking technological practice and analyzing the practice and outcomes of others. The use of functional reasoning within technology enables the technical feasibility of design ideas and outcomes to be explored allowing an understanding of "how to make things happen" and an understanding of "how it is happening" to be developed (Compton and France 2007). Practical reasoning within technology supports social considerations such as moral, cultural, and ethical viewpoints surrounding a design idea and the testing of an outcome to be explored (Compton and Compton 2010; Compton and France 2007). This form of reasoning uses normative understandings to regulate action (Railton 1999). When students use normative practical reasoning in the act of developing outcomes that are "fit for purpose," it provides them with a framework from which to consider diverse opinions on knowledge types and views of the world and explore potential impacts on immediate and wider community stakeholders and environments.

The technological modeling achievement objectives in the NZC (Ministry of Education 2007) explicitly present the need for students to develop conceptual understandings about the importance of these two forms of reasoning (Compton and Compton 2010). However, it is the learning environment that teachers present to students and the pedagogies that they adopt that determine how well (if at all) these develop and are therefore available to take into practice (Harwood 2014).

A study conducted by Harwood (2014) demonstrated that when teachers focus their support on developing student conceptual understanding of practical and functional reasoning, the student's reasoning becomes more sophisticated. This however relies on a learning environment where explicit teaching and authentic contexts are used and students are encouraged to employ their understandings of practical and functional reasoning for their own decision-making, when developing technological outcomes. This study identified that students who possessed sophisticated reasoning could discuss conceptually how practical and functional reasoning worked together to determine risk and support informed and justifiable design decisions to be made. This led to the students being able to justify and defend the technological outcomes they developed as "fit for purpose in its broadest sense," or not. These findings support Breukelen et al. (2016) call for a greater learning focus on supporting students to develop understandings of the concepts underpinning technology, when developing technological outcomes.

The findings from this study also supported Rowell's (2004) contention that when teachers assist students to take their conceptual understandings into their technological practice, it equips them to be able to develop increased understandings of *knowledge in technological practice* (Rowell 2004). Rowell (2004) describes this as the knowledge that helps to define a problem and determine the physical and functional features required in a "fit for purpose" outcome and the actions and their sequence required when developing such an outcome. When such knowledge is combined with understandings about the nature of technology and technological developments, particularly that focused on ensuring that outcomes from technological practice are socially acceptable as well as technically feasible, then this knowledge is considered to be critical for students developing technological outcomes that address the complexities of authentic needs and opportunities (Compton and Harwood 2005). This emphasis on developing student conceptual understandings and supporting them to take these into their practice offers opportunity to develop in students the aptitude to contribute to conversations about, and create solutions to, the social challenges they will likely face in the future.

Conclusion

Learning in technology can cultivate minds that are curious, critical and creative in nature. It allows progression in technological literacy that enables people to do things differently, as they participate in society's current debates and make contribution to the future. Technology needs to be taught by teachers who possess an in-depth understanding of technology *subject matter knowledge* and *pedagogical content knowledge* and whose *attitude* inspires in students a sense of curiosity and willingness to accept challenge. Teachers need to know *whether*, *when,* and *how* to intervene in a student's technological learning, including decision-making that supports innovative problem solving. They will also need to increasingly engage students in authentic socio-technical problems to inspire them to be critically reflective and to effectively utilize conceptual and procedural knowledge in their undertaking of technological practice to address such problems.

Students in technology programs can then be supported to participate in a transformational journey, which allows them to first establish a *foundational* technological literacy and move beyond to become critical consumers and therefore possess a *citizenship* technological literacy. Some may continue their journey to a more *comprehensive* technological literacy enabling them to be socially and environmentally attuned developers of future innovative technologies, as well as critical consumers.

References

Alexander, P. A. (2003). The development of expertise: The journey from acclimation to proficiency. *Educational Researcher, 32*(8), 10–14.

Banchi, H., & Bell, R. (2008). The many levels of inquiry. *Science and Children, 46*(2), 26–29.

Beyth-Marom, R., Fischhoff, B., Jacobs-Quadrel, M., & Furby, L. (1991). Teaching decision making to adolescents: A critical review. In J. Baron & R. V. Brown (Eds.), *Teaching decision making to adolescents* (pp. 19–60). Hillsdale: Lawrence Erlbaum Associates.

Biotechnology Learning Hub. (2009). Ethical thinking tool. Retrieved 1 Mar 2011 from http://biotechlearn.org.nz/thinking_tools/ethics_thinking_tool/ethics_thinking_tool#/login

Bohanec, M. (2009). Decision making: A computer-science and information-technology viewpoint. *Interdisciplinary Description of Complex Systems, 7*(2), 22–37.

Breukelen, D. H. J., Vries, M. and Schure, F. A., (2016) Concept learning by direct current design challenges in secondary education.

Carruthers, P. (2003). The mind is a system of modules shaped by natural selection. In C. R. Hitchcock (Ed.), *Contemporary debates in philosophy of science*. New York: Blackwell.

Compton, V. J. (2007). *The role of technology education in supporting a democratic literacy*. Paper presented at *technology education New Zealand*, Biannual conference, Auckland 3–5 Oct 2007. Retrieved 25 June 2009, from: http://www.tenz.org.nz/2007/2007-conference-papers.htm

Compton, V. J. (2013). Technological literacy: Implications for teaching and learning – Final report to ministry of education.

Compton, V. J., & Compton, A. (2010). Technological knowledge and the nature of technology: Implications for teaching and learning – Summary of final report. Retrieved 13 May 2016 from: technology.tki.org.nz/index.php/content/. . ./TKNOT-Implications.docx

Compton, A., & Compton, V. J. (2011a). Strategies for progressing student understanding of the characteristics of technology. *Published in conference proceedings of technology education New Zealand, 8th biennial conference*. Dunedin. 26–28 July 2011.

Compton, V. J., & Compton, A. (2011b). Strategies for progressing student understanding of technological modelling. *Published in conference proceedings of technology education New Zealand, 8th biennial conference*. Dunedin. 26–28 July 2011.

Compton, V. J., & Compton, A. (2013a). Teaching technological knowledge: Determining and supporting student learning of the technological concepts. *International Journal of Design and Technology Education, 23*(3), 637–674.

Compton, V. J., & Compton, A. (2013b). Teaching the nature of technology: Determining and supporting student learning of the philosophy of technology. *International Journal of Design and Technology Education., 23*(2), 229–256.

Compton, V. J., & France, B. (2007). Redefining technological literacy in New Zealand: From concepts to curriculum constructs. *Proceedings of the Pupils' Attitudes Towards Technology*

(PATT 18). International design and technology education conference: Teaching and learning technological literacy in the classroom (pp. 260–272). Glasgow.

Compton, V. J., & Harwood, C. D. (2001). Developing technological literacy: A framework for technology education in New Zealand. *Published in conference proceedings of Technology Education New Zealand, Biannual conference* (pp. 39–54). Wellington. 1–3 Oct 2001.

Compton, V. J., & Harwood, C. D. (2004). Technology education achievement standards: Are they fit for the purpose? *Published in peer reviewed conference proceedings from the 3rd biennial international conference on technology education research. Learning for Innovation in Technology Education* (Vol. 1, pp. 140–149). Gold Coast: Crowne Plaza Hotel Surfers Paradise. 9–11 Dec 2004.

Compton, V. J., & Harwood, C. D. (2005). Progression in technology education in New Zealand: Components of practice as a way forward. *International Journal of Design and Technology Education., 15*(3), 253–287.

Compton, V. J., & Harwood, C. D. (2008). Discussion document: Design ideas for future technology programmes. Retrieved 10 Jan 2009 from: http://nzcurriculum.tki.org.nz/content/download/482/3705/file/technology-design-ideas.doc

Compton, V. J., Compton, A., & Patterson, M. (2011). Exploring the transformatory potential of technological literacy. *Proceedings of the joint Pupils' Attitudes Towards Technology international design and technology education conference and Creativity in Primary Technology conference (PATT 25/CRIPT 8)*. London. 1–5 July 2011.

Elmose, S., & Roth, W.-M. (2005). Allgemeinbildung: Readiness for living in a risk society. *Journal of Curriculum Studies, 37*, 11–34.

Ferrand, F. (2007). Natural decision. In B. Hardy-Vallée (Ed.), *Cognitive decision making: Empirical and foundational issues* (pp. 1–14). Cambridge Scholars Publishing: Newcastle.

Fischhoff, B., Crowell, N. A., & Kipke, M. (1999). *Adolescent decision making: Implications for prevention programs. Summary of a workshop*. Washington, DC: National Academy Press. (ERIC Document Reproduction Service No. ED441185).

Galotti, K. M. (2002). *Teaching reasoning and decision-making in introductory cognitive science courses*. Retrieved 23 Apr 2011 from: http://www.linguistics.pomona.edu/Hewlettcognitivescience/essays/assets/GalottiReasoning.pdf

Greeno, J. (1997). Theories and practices of thinking and learning to think. *American Journal of Education, 106*(1), 85–126.

Hallstrom, J., & Gyberg, P. (2009). Technology in the rear-view mirror: How to better incorporate the history of technology into technology education. *International Journal of Technology and Design Education, 21*(1), 3–17.

Hardy-Vallée, B. (2007). *Cognitive decision-making: Empirical and foundational issues*. New Castle: Cambridge Scholars Publishing.

Harman, G. (2009). Practical aspects of theoretical reasoning. Retrieved 23 Dec 2009 from: http://docs.google.com/viewer?a=v&q=cache:w0VnxNSjylkJ:citeseerx.ist.psu.edu/viewdoc/download%3Fdoi%3D10.1.1.94.9271%26rep%3Drep1%26type%3Dpdf+practical+reasoning+pdf&hl=en&gl=nz&pid=bl&srcid=ADGEEShm1zepQF9w5fFwAnq8k1EwxWVuszsBsM3IdCn0JcGIpp2ATDMRimOggy52OB5VqzKOsTRlTF1q_-Rd6Zxiocoy8qsekB15i6xvURP4b60TwHrYOoRxZ5YoZ4DS7FAK38w0_s0&sig=AHIEtbQLrqDBm71DidM38me2tn92LOx-_w

Harwood, C. D. (2014). Enhancing student decision making in technological practice: A thesis submitted for the degree of PhD Education. Palmerston North: Massey University. Retrieved 13 May 2016 from: http://mro.massey.ac.nz/handle/10179/5494#sthash.jLEZcniI.dpuf

Johnson, S. D. (1997). Learning technological concepts and developing intellectual skills. *International Journal of Technology and Design Education, 7*(1–2), 161–180.

Keirl, S. (2006). Ethical technological literacy as democratic curriculum keystone. Chapter 6. In J. Dakers (Ed.), *Defining technological literacy: Towards an epistemological framework* (pp. 81–102). New York: Palgrave MacMillan.

Lave, J. (1988). *Cognition in practice. Mind, mathematics and culture in everyday life*. New York: Cambridge University Press.

Mezirow, J. (2000). *Learning as transformation: Critical perspectives on a theory in progress*. San Francisco: Jossey Bass.

Milkman, K. L., Chugh, D., & Bazerman, M. H. (2008). How can decision making be improved? Retrieved 2 Jan 2010, from: http://www.hbs.edu/research/pdf/08-102.pdf

Ministry of Education. (2007). *The New Zealand curriculum*. Wellington: Learning Media.

OECD. (2011). Fostering innovation to address social challenges. Retrieved 2 Jan 2016 from: https://www.oecd.org/sti/inno/47861327.pdf

OECD. (2012). Innovation for development a discussion of the issues and an overview of work of the OECD directorate for science, technology and industry. Retrieved 2 Jan 2016 from: http://www.oecd.org/innovation/inno/50586251.pdf

OECD. (2015). OECD innovation strategy 2015 an agenda for policy action. Retrieved 2 Jan 2016 from: https://www.oecd.org/sti/OECD-Innovation-Strategy-2015-CMIN2015-7.pdf

Packer, M. J., & Goicoechea, J. (2000). Sociocultural and constructivist theories of learning: Ontology, not just epistemology. *Educational Psychology, 35*(4), 227–241.

Parkinson, & Hope, G. (2009). Beyond knowing how to make it work: The conceptual foundations of designing. *Design and Technology Education: An International Journal, 14*(1), 49–55.

Railton, P. (1999). Moral explanation and moral objectivity. *Philosophy and Phenomenological Research, 58*(1), 175–182.

Rohaan, E. (2009). *Testing teacher knowledge for technology in primary schools*. Published doctoral thesis. Eindhoven University of Technology, The Netherlands.

Rohaan, E., Taconis, R., & Jochems, W. M. G. (2010). Reviewing the relations between teachers' knowledge and pupils' attitude in the field of primary technology education. *International Journal of Technology and Design Education, 20*, 15–26.

Rowell, P. (2004). Developing technological stance: Children's learning in technology education. *International Journal of Technology and Design Education, 14*, 45–59.

Skovmose, O. (1998). Linking mathematics education and democracy: Citizenship, mathematical archaelology, mathemacy and deliberative interaction. *International Reviews on Mathematical Education, 30*(6), 195–204.

Thompson, E. (1990). Promoting individuality and originality. In L. Tickle (Ed.), *Design and technology in primary classrooms*. London: Falmer Press.

de Vries, M. J. (2013). Understanding technology structure and function. In J. Hallstrom & C. Klasander (Eds.), *The Ginner handbook of technology education. Some theses about technology, school and society* (pp. 156–166). Sweden: Elanders.

Wheelahan, L. (2010). Why knowledge matters in curriculum: A social realist argument. In *New studies in critical realism and education*. Oxfordshire: Routledge.