Technological Knowledge and the Nature of Technology: Implications for Teaching and Learning

Summary of Final Report

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Overview

The Technological Knowledge and Nature of Technology: Implications for teaching and learning (TKNoT: Imps) research was fully funded by the New Zealand Ministry of Education for a period of two years and eight months. The contract was held by UniServices Limited, a wholly owned company of The University of Auckland. The Project Director and Senior Researcher was Dr Vicki Compton. The Co-researcher was Ange Compton. The specific focus of this research was on developing classroom based understandings of progression for the five components within the Technological Knowledge (TK) and the Nature of Technology (NoT) strands, and exploring pedagogical strategies that would support students to progress.

Classroom research was undertaken in Findings: Stage One to determine students' current understandings of these components and to begin to refine the nature of progression captured in the draft Indicators of Progession for the Technological Knolwdge (TK) and Nature of technology (NoT) strands.

Findings: Stage Two of the research sought to explore the nature of these progressions further and to begin to develop pedagogical strategies to enhance student understandings. The findings from the first two phases of the TKNoT: Imps research resulted in the May 2010 publication of classroom based Indicators of Progression. These documents now include indicators informed by student data and more extensive teacher guidance related to effective pedagogy.

Findings: Stage Three of the TKNoT:Imps research focused on the development and trialing of two teaching tools – one for 'Characteristics of Technology' (CoT) and one for Technological Modelling' (TM). The aim of these tools was to provide teachers with strategies to push student understanding to Level 4 and above. Both tools are currently under re-development and will be trialed again as part of a the Technological Literacy: Implications for teaching and learning (TL: Imps) research project.

The Technological Literacy: Implications for teaching and learning (TL: Imps) project is a new Ministry of Education-funded research project. Learning Progression Diagrams for each component of technology have been developed as part of this project.

Summary and Research Findings: Stage One

The initial stage of the research was largely explorative in nature and ran from November 2007 to the end of January 2009. The initial focus of Stage One was to ensure all research teachers had the opportunity to develop a shared understanding of the five components of the two new strands of the revised techniology curriculum - Technological Knowledge and Nature of Technology. Teachers met together in

Wellington and then were supported individually to develop and trial learning experiences across a range of contexts. As per Ministry of Education guidance for 2008-2009, all teachers were focused on providing technology programmes focused on the Technological Practice strand. Therefore in most cases the introduction of a learning focus from the Technological Knowledge or Nature of Technology strand was linked to supporting learning in Technological Practice.

Reviewing and refining the draft Indicators of Progression previously developed for the components of TK and NoT was the key focus of Stage One. An evaluation of their usefulness as a tool for mediating the acheivement objectives into classroom programmes was also undertaken to determine whether the draft Indicators of Progression:

- helped teachers develop a shared understanding of each component
- provided valid descriptions of progression
- supported formative interactions between teachers and students
- allowed for clear judgements on students pre and post-teaching understandings.

Student data was collected primarily through researcher interviews for each component. In most cases the interviews were held during the final stage of the unit or just after it had been completed. Where appropriate, students were interviewed about more than one component. A total of 359 interviews were completed, analysed and used as a basis for reviewing the draft indicators for TK and NoT. Where additional data was available from student portfolio work, this was also taken into account. The number of interviews undertaken for each component is presented in Table 1.

Table 1: Interviews per Component

Characteristics of Technology (CoT)	Characteristics of Technological Outcomes(CoTO)	Technological Modelling (TM)	TechnologicalProducts (TP)	Technological Systems (TS)
81	55	78	92	53

The refined indicators were then used to make judgments on the level of achievement each student exhibited. The results of this are presented in Tables 2 to 6. Those students categorised as emergent showed what we referred to originally as misconceptions or partial understandings and were judged as indicative of pre-level 1 or 0 understandings. Emergent as a 'sub' level 1 category was added to the indicators for each component.

Table 2: Level Distribution for Characteristics of Technology

Level	0	1	2	3	4	5	6	7	8
# of Students	19	43	16	2	1	0	0	0	0
% of Students (n=81)	23%	53%	19.7%	2.5%	1.2%	0	0	0	0

Table 3: Level Distribution for Characteristics of Technological Outcomes

Level	0	1	2	3	4	5	6	7	8
# of Students	8	24	21	2	0	0	0	0	0
% of Students (n=55)	14.5%	43%	38%	3.5%	0	0	0	0	0

Table 4: Level Distribution for Technological Modelling

Level	0	1	2	3	4	5	6	7	8
# of Students	0	39	22	7	1	0	0	0	0
% of Students (n=78)	11.5%	50%	28.2%	9.0%	1.3%	0	0	0	0

Table 5: Level Distribution for Technological Products

Level	0	1	2	3	4	5	6	7	8
# of Students	6	48	37	1	0	0	0	0	0
% of Students (n=92)	6.5%	52.2%	40.2%	1.1%	0	0	0	0	0

Table 6: Level Distribution for Technological Systems

Level	0	1	2	3	4	5	6	7	8
# of Students	17	23	10	2	1	0	0	0	0
% of Students (n=53)	32%	43%	19%	4%	2%	0	0	0	0

The majority of students were categorised as reflective of level 1 or 2 understandings. For CoT however, there was a more even split between emergent, and levels 1 and 2. TM showed a slightly higher percentage of students showing level 3 understandings although this was still only 9%. Only three examples of level 4 understandings were found, one in each of the components CoT, TM and TS.

This stage of the research found that while the initial draft versions of the TK and NoT indicators provided a useful starting point for discussions with teachers regarding what each component was about, they did not seem to reflect clear progressions and therefore were less useful in making formative or summative assessments. Many of the indicators provided in the initial draft appeared to indicate levels of understanding above or below the level they had been positioned. An analysis of the student data allowed for a significant revisiting of how each component progressed, and indicators at each level were revised accordingly. The data collected also provided additional insight into what student achievement might look like at levels 1-3, and the sorts of formative interactions that might result in shifting student understanding. The revised version of the TK and NoT Indicators of Progression were published in April 2009.

Summary and Research Findings: Stage Two

The second stage of the research was more interventionist in nature, and the refined April 2009 indicators of progression from Stage One were used extensively. The key focus of Stage Two was to explore pedagogical strategies developed specifically to progress student learning within the TK and NoT strands. This stage of the research ran from the beginning of February 2009 to the end of December 2009. The Ministry of Education guidance for 2009 was still to focus on technological practice for summative assessment and reporting purposes, so again most teachers integrated a learning focus from the technological knowledge or nature of technology strand into their learning programme for technological practice. Student data was collected primarily through student portfolios, photographs and teacher comments. All data collected was used to further refine the indicators, and some data was used to develop case studies to illustrate particular pedagogical points and form the basis for a secondary analysis as discussed below.

Misconceptions, Alternative Conceptions and Partial Understandings

The misconceptions or partial understandings that had been identified and categorised as 'emergent' in Stage One and added to the indicators, were again noted in the Stage Two data. In the analysis of this data however, it became clear that some of these 'misconceptions' were actually alternative conceptions, and the partial understandings were usually a result of a lack of experience. The points noted as partial understandings were usually resolved when students showed level 1 understandings, whereas those points that could be rightly called misconceptions or alternative conceptions, often remained with students even though they exhibited level 1, 2 or 3 understandings. It was also noted that misconceptions or alternative conceptions in one component often caused considerable difficulty in shifting understandings in other components. The points referred to in Stage One as misconceptions or partial understandings were therefore removed as precursors to level 1 (i.e. an 'emergent' category in the indicators) and were reported separately as important points for teachers to be aware of and address when working with students across all components at all levels. The Stage Two findings also provided greater insight into how easy or difficult these points were to address. The points representing misconceptions, alternative conceptions and partial understandings from Stage Two are provided in Table 7.

Table 7: Misconceptions, Alternative Conceptions and Partial Understandings

Points Related to Characteristics of Technology

- Describes technology in terms of outcomes only and as either 'good' or 'bad'.
- The development of new outcomes seen as the result of people 'playing around' and/or trial and error.
- Any process that involves using technological tools, planning and/or solving problems is seen as being technology - unable to differentiate technology from other human endeavours.
- Technology seen as only new 'things' often with qualifier that they run off 'power'.
- Changes in technology perceived as 'just happening' - no recognition of 'drivers' of technological development (e.g. new knowledge/skills/social or environmental needs etc).

These points all represent misconceptions of technology and were commonly noted across both Stage One and Stage Two findings and were common across all age groups. This is because they tend to reflect typical 'public understandings' of technology and are therefore introduced early and constantly reinforced through everyday interactions with parents, friends etc.

These misconceptions required extensive and explicit teaching to address. That is, they were often difficult to change and success in doing so relied on teachers continually probing for these ideas and challenging them across a range of contexts.

Points Related to Characteristics of Technological Outcomes

- Can't distinguish technological outcomes from other objects
- Describes a technological outcome solely in terms of what it is called
- Describes a technological outcome solely in terms of what it looks like e.g. shape, size, colour, etc.
- Describes a technological outcome solely in terms of what it does.

In contrast to the misconceptions related to CoT, the CoTO pointswere usually seen in younger students and were relatively easy to address. This is because all points reflect a basic lack in student knowledge and/or experience rather than reflecting a construction of 'common' but inaccurate concepts from everyday interactions.

Success in addressing these points was achieved through providing students with the opportunity to interact with a range of technological outcomes and non-technological outcomes and undertaking scaffolded categorisation and description activities. This was significantly enhanced when teachers provided word banks to introduce new descriptive terms and allowed adequate time for students to discuss and employ these terms.

Points Related to Technological Modelling

- Models identified as small replicas or people – for example, model trains or role models, fashion models.
- Suggests that technologists use modelling but cannot explain what it is.

The first point is more like those related to CoT and was shown to be common across age groups. Rather than being a misconception however, these represent alternative concepts of models which are often used in different everyday situations. The second point is a partial understanding tended to be caused from both a lack of knowledge and experience of technological modelling specifically and a confusion between other disciplines where modelling is employed in different ways and for different purposes.

To address these points teachers were successful if they explicitly discussed the different meanings of 'model' and modelling and provided multiple examples of technological modelling across a range of contexts in terms of its specific purpose (what design idea or outcome was it testing) and why it was useful in the decision making involved in the development of a technological outcome. When teachers tried to discuss what a technological *model* is (as opposed to technological *modelling*) – further misunderstandings or confusion arose. This was because the same model may be used in different ways – some of which may be technological, and others may not (that is, they may be used to communicative or test a theory such as in science).

Points Related to Technological Products

- Could not correctly identify materials
- Suggests materials that particular products might be made from but materials suggested are often not feasible.
- Had no idea how materials were, or could, be manipulated.

These points are all partial understandings and were noted across a range of age groups when students were asked to explore unfamiliar products. However, they were relatively easily addressed by teachers through the provision of opportunities for students to undertake product analysis. When opportunities were also provided to 'play' and work with a range of different materials. Students were able to begin to develop a more sophisticated generic knowledge of materials that was not so 'product' bound.

Points Related to Technological Systems

- Suggests a technological system is any series of steps or routines, including those undertaken by people – that is making a sandwhich, getting dressed etc.
- Identifies components that a particular system is made from but the components are not recognised as connected

The first point is a misconception that is directly linked to the CoTO lack of knowledge resulting in not recognising the difference between technological outcomes (both products and systems) and non-technological ones. In data related to CoTO it was shown to be easier to categorise technological products than technological systems and therefore this misconception tended to remain with students across all age levels.

The second point showed a partial understanding demonstrating both a lack of knowledge and experience of exploring and analysing specific technological systems. To address both these points teachers were successful if they explicitly discussed multiple examples of technological systems across a range of contexts and allowed students adequate time to explore in detail the connections between components and how these enabled the system as a whole to function, and without additional human design input.

Case Study Analysis

Alexander's *Model of Domain Learning* (MDL) [1] was used to analyse the strategies used by teachers during Stage Two. Analysing the data in terms of processing strategies, interest and topic[2] and domain knowledge[3] has provided interesting insights into pedagogical practices across all data and related to all components. For example, it has become clear from this analysis that:

- While most learning experiences allow for (and in some cases expect) students to undertake both surface and deep processing strategies, many teachers do not explicitly teach processing strategies.
- The use of surface level strategies appeared to be sufficient for developing domain knowledge prior to level 4.
- In most cases, teachers focused on both topic and domain knowledge, although in some cases their focus on domain knowledge was during their diagnostic and/or summative assessment activities, rathr than underpinning more substantive learning expriences.
- Focusing on both topic and domain during learning experiences and formative interactions resulted in greater or more consolidated shifts in achievement than relying on topic alone to provide domain shifts.
- When topic is dominant during learning experiences and the domain implications are not made explicit, shifts are reliant on students making links independently. This in turn relies on deep processing strategies and at lower levels of topic and domain knowledge, this doesn't appear to occur.
- Provision of situational interest is critical to acclimation stages of domain learning. Teachers should not expect individual interest to motivate student learning until they have sufficient topic and domain knowledge.
- From competency or level 4 onwards, situational interest would often be supplemented with individual interest, and this alongside growing deep processing capability, should allow students to develop higher levels of domain and topic knowledge.

Pedagogical Content Knowledge

The development of Pedagogical Content Knowledge (PCK) for each component of the Nature and Knowledge strands was a major focus for Stage Two of this research. The case studies highlighted a number of features that supported effective teaching of particular components, as well as some features that appeared successful across all all components. While PCK for technology (as opposed to PCK related to a particular component of technology) was not an explicit focus, analysing the teacher practice and student data showed clearly the importance of understanding each component as a separate focus for learning, as well as the importance of understanding how each component relates to the learning area as a whole. When teachers explicitly made these links, the learning within the component was enhanced and some evidence was also provided that an understanding in other components was consolidated.

The following points summarise the key features teachers exhibited when using pedgaogical strategies effectively as evidenced in case study examples across all components:

- Teacher understanding of the component as a whole - including an overview of the way it progresses from level 1 to 8.
- Teacher understanding of how topic knowledge relates to domain knowledge and vice versa in selected learning contexts.
- Teacher knowledge of students – their prior understandings.
- Teacher provision of situational interest.
- Explicit focus on domain knowledge and the identification of associated learning as a recurring part of learning experiences.
- Explicit focus on terminology and consistent use of this across a range of learning experiences.
- Provision of multiple learning experiences over time to introduce, explore and consolidate learning of focus ideas.
- Scaffolding of topic knowledge into domain knowledge using a range of examples.
- Consolidating domain knowledge by identifying examples within different contexts.

The remaining points are additional features we suggest would increase effectiveness as based on an analysis of examples in the case studies when student learning did not progress as planned:

- Teacher knowledge of the specific nature of progression for the actual learning focus. That is, if a student is working at level 1 – what *type* of shift is being expected for them to move to level 2 (or further).
- Recognition of critical links between the ideas within each component.
- Recognition of critical links between ideas across components.
- Teacher knowledge of students – their prior strategic processing capability and level of individual interest (alongside their prior understandings).
- Matching of teaching strategy to both understandings of students (prior knowledge, strategic processing capability, level of individual interest) and the specific nature of progression being sought.

- Explicit teaching of the strategic processing strategies students are expected to employ. This would include both surface and deep strategies and an understanding of the purpose and appropriatness of each.
- Selection of teaching resources (including reference material, templates, examples etc) to ensure effective support of strategy and that learning opportunities are maximised.
- Provision of opportunity to interact with 'real' examples rather than symbolic representations of these. For example, when asking students to categorise objects, provide the object itself rather than pictures or text descriptions of the object, particularly at lower levels.

The case study findings, along with other data gathered throughout the year, informed the revision of the student indicators for each component and the teacher guidance associated with these.

The Indicators of Progression for all eight components within all three strands were therefore further revised and refined as based on the findings from Stage Two. See www.techlink.org.nz/curriculum-support/indicators.

[1] For further information regarding this Model see Alexander, P. A. (2006). The path to competence: A lifespan developmental perspective on reading. *Journal of Literacy Research, 37*, 413-436.

[2] Topic knowledge is any specific knowledge required for students to succeed in particular contexts. For example, when creating a healthy food snack, nutritional knowledge would be key topic knowledge.

[3] Domain knowledge in technology is the generic knowledge and practices described in the eight components of technology.

Summary and Research Findings: Stage Three

The third and final stage of the research was focused on the development and initial trialing of two teaching tools. This stage of the research ran from January 2010 to the end of June 2010. It had became apparent in Stage Two of the research that specific teaching tools focused on deep processing strategies would be required to teach the ideas captured in the achievement objectives above level 4 for CoT and TM. It was therefore decided to develop and trial a tool for each of these components. The tool focussing on the CoT component was designed to develop students' ability to 'unpick', describe and critically evaluate the complexities of developments in technology. The second tool, focussing on the TM component was designed to develop students' ability to use ethical frameworks to support their understanding about the issues involved in practical reasoning. That is, to help students better understand how technological modelling supports both technically feasible and socially acceptable decision making about what 'should' happen and why.

The Characteristics of Technology (CoT) Teaching Tool

An analytical model, developed by Hallstrom and Gyberg from Sweden[1], was modified and used to develop the CoT teaching tool. The model focuses on the role an analysis of the history of technology can have on understanding how and why technological developments change. The model describes the 'actors and factors' that influence technological change, and provides five different 'levels of meaning' to aid deeper analysis. The tool based on this work therefore consisted of an 'Actors and Factors' template and five lenses (as related to the levels of meaning ideas).

Six teachers trialed this tool in classes as follows: 1 year 7/8, 1 year 8, 1 year 9, 1 year 11 and 2 year 12. Each teacher used the 'Actors and Factors' template as a diagnostic aid to determine 'readiness' for pushing above Level 4. This involved providing the students with appropriate case study material to work with as they completed the template. The teachers, in conjunction with the researchers, planned an intervention to run over one or two lessons. If the students demonstrated readiness to move beyond Level 4, the appropriate lens would be introduced and discussed before the students were asked to use it to analyse and discuss material to aid the exploration of the interaction between the actors and factors.

The 'Actors and Factors' template was found to be too complex for students working below level 4 (both the year 7/8 and year 8 classes). In particular the terminology caused considerable problems. For those students working between level 3- 4 (year 9 and 11 classes, and both year 12 classes initially), the 'actors' remained a confusing term on the template. During the trial, when this terminology was changed to 'users' and 'developers' students were better able to complete the template. It was also noted that the other titles tended to direct student into only thinking of the impact on the technology, rather than the impact of the technology. This again was successfully addressed by changing the titles to encompass the two way interaction and splitting the table accordingly into influences and impact.

Two of the classes of students (both year 12 classes) in this trial showed readiness to explore the lenses to extend their understandings to level 5 and beyond. The questions developed from these lenses appeared to provide some opportunity for this extension, however time was limited to test this aspect of the tools sufficiently.

The Technological Modelling (TM) Teaching Tool

The TM tool was based on the requirements of the technological modelling component from level 4 and above particularly as it relates to underpinning reasoning – namely practical and functional reasoning. Earlier findings had shown that students demonstrated a reasonable understanding of technological modelling in terms of how to explore the technical aspects of design ideas to justify decisions based on functional reasoning about 'how to make it happen' but did not reflect practical reasoning with regards to any moral or ethical aspects when testing design ideas or prototypes. Such practical reasoning would support students to justify decisions about 'what should be done'. The tool therefore consisted of modelling video[2] and pre-level 4 diagnostic template, the ethical thinking tool from Biotech Learning Hub[3], and one of two 'implications' templates to determine any impact the frameworks might have had on the students subsequent decision making.

Seven teachers trialled the TM tool in classes as follows: 1 year 3/4, 1 year 5/6, 1 year 10, 1 year 11, 1 year 12, 1 year 12/13, and 1 year 13. The teachers began with the video and template and then used the ethical thinking tool to introduce ethical frameworks to the students. The teachers then provided the students with an opportunity to apply these frameworks to their own practice, or to an additional video[4], and complete the appropriate implication template.

Both primary classes struggled to analyse the initial video in terms of technological modelling. A resource with more explicit reference to modelling was clearly required. In the year 3/4 class no attempt was made to introduce the ethical framework as all students were working at level 1 or below. In the year 5/6 class, the framework categories were briefly outlined but the biotech tool was not used as the terminology of the frameworks was too complicated for most of these students. Most students were working at level 1 TM, although some students showed some understanding indicative of level 2.

The year 10 class (all girls) did not respond well to the video and did not complete the template. They also struggled with the terminology of the ethics thinking tool and while they attempted to apply some of these ideas in their own decision making, little evidence of impact was noted. Evidence from the implications template suggested students were working between levels 2-3 of TM.

The teachers in the year 11, 12, 12/13 and 13 classes all supported the students understanding of modelling and ethical decision making with additional resources and most students completed the initial template demonstrating robust level 3-4 understandings of TM. The teachers then used the ethical thinking tool to introduce the frameworks. Overall the students found the tool difficult to use and understand. The ideas introduced in each framework required significant intervention by the teacher and it was only in the year 11 and year 12/13 classes that any of these ideas were clearly brought to bear on the student's subsequent practice (in the case of the year 11 class) or ability to analyse the wireless car resource (in the case of the year 12/13 class).

Based on the Stage Three findings revised CoT and TM tools are being developed and will be trialed as part of the new technological literacy focused research.

[1] See Gyberg, P. & Lee, F., 2009. The Construction of Facts: Preconditions for meaning in teaching energy in Swedish classrooms. *International Journal of Science Education,* 1 – 17 iFirst Article and

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*. Published online December 2009.

[2] An Adidas soccer boot development video sourced from the Australian *Beyond 2000 TV series*

[3] The Biotech Learning Hub is a teacher and student resource established by Waikato University. The tool can be found here.

[4] UniServices Inductive Power Transfer or the UniServices Wireless Car