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Teaching the nature of technology: determining and supporting student learning of the philosophy of technology

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Abstract This paper reports on findings related to the Nature of Technology from Stage Two of the *Technological Knowledge and Nature of Technology*: *Implications for teaching and learning* (*TKNoT*: *Imps*) research project undertaken in 2009. A key focus in Stage Two was the trialing of different teaching strategies to determine how learning related to the components Characteristics of Technology (CoT) and Characteristics of Technological Outcomes (COTO) could be supported. These components fall within the Nature of Technology (NoT) strand of technology in the New Zealand Curriculum (NZC) (Ministry of Education, 2007) and as such, reflect a philosophical understanding of technology as a discipline. During this stage of the research further exploration was undertaken to determine how student understanding of these two components of technology education progressed from level 1 to level 8 of the NZC (Ministry of Education, 2007). Common misconceptions and partial understandings related to these components are identified and explained and four case studies are presented to illustrate strategies employed by teachers and their impact on student learning related to these two components. The Stage Two outcomes resulted in the revision of the Indicators of Progression for CoT and CoTO in order to clarify the progression expected of students in each component and provide increased teacher guidance to support such progression.

Keywords Philosophy of technology · Characteristics of technology · Characteristics of technological outcomes · Common misconceptions · Partial understandings · Indicators of progression

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Introduction

Since the beginning of 2010, teachers in New Zealand have had the task of implementing learning programmes in technology that include a focus on the philosophy of technology. This is described through the Nature of Technology strand in the *New Zealand Curriculum* (*NZC*) (Ministry of Education 2007, p. 32). Therefore all teachers involved in year 1–10 technology programmes are expected to incorporate learning outcomes and report on student achievement using the Nature of Technology strand achievement objectives focused on the Characteristics of Technology (CoT) and the Characteristics of Technological Outcomes (CoTO) that have been developed for Leve1 1–8[1] of the NZC (see Ministry of Education 2007, pull out section for each achievement objective). Teachers providing technology programmes in the non-compulsory senior secondary sector will also be guided by these achievement objectives and will use the Nature of Technology achievement standards at Level 1, 2 and 3 of the New Zealand Qualifications Framework (NZQF)[2] to assess and credential student learning in the area of the philosophy of technology for qualification purposes. The technology achievement standards have been developed to align respectively to the Level 6, 7 and 8 technology achievement objectives and will be progressively implemented[3] for use to credential student learning towards a National Certificate of Educational Achievement (NCEA)[4] from 2011 onwards.

The inclusion of the philosophy of technology in technology learning programmes across the primary and secondary sector, and the subsequent progressive implementation of NZC aligned achievement standards in senior secondary sector, represents a significant level of change from the previous technology curriculum and achievement standards which focused primarily on technological practice (see Compton 2007; Compton and France 2007). In recognition of these changes, the New Zealand Ministry of Education funded a two and half year research project focused on the Technological Knowledge (TK) and Nature of Technology (NoT) strands. This project was the *Technological Knowledge and Nature of Technology*: *Implications for teaching and learning* (*TKNoT*: *Imps*) research project and ran from 2008 to June 2010. An overview of the theoretical and methodological basis for this project, illustration of coding methods, and the findings related to Stage One, are provided elsewhere (Compton and Compton 2009). In this paper we provide an overview of Stage Two of the *TKNoT*: *Imps* project as it related to the Nature of Technology focus, and present and discuss its key outcomes.

[1] The New Zealand Curriculum currently differentiates 8 levels of learning across years 1–13. These are loosely aligned to 2 years of learning from levels 1–5 and then single years from levels 6–8. However, it is acknowledged that students' progress at different rates, and as such, any age-level relationships are indicative only.

[2] This is a different framework to the New Zealand Curriculum. The NZQF levels run from Level 1–10 and provide pathways into the tertiary sector up to Doctorate level. There is an overlap between these two frameworks with Level 6 NZC equating to Level 1 NZQF, Level 7 NZC equating to Level 2 NZQF, and Level 8 NZC equating to Level 3 NZQF.

[3] Level 1 Achievement Standards will be available as assessment tools in 2011, Level 2 Achievement Standards will be available as assessment tools in 2012, and Level 3 Achievement Standards will be available as assessment tools in 2013.

[4] NCEA is a standards based qualification. It was introduced in New Zealand in 2002 and replaced the previous norm-referenced qualification system.

Stage two of the technological knowledge and nature of technology: implications for teaching and learning (TKNoT: Imps) research project

Overview

The *TKNoT*: *Imps* research employed a critical social science methodology with the aim of exploring how the components[5] of the TK and NoT strands progress from level 1–8 of the NZC (Ministry of Education 2007) and how teaching may support students to achieve such progressive understandings. While the levelled achievement objectives of the *NZC* (Ministry of Education 2007) provide overarching statements of progressive intent across all learning areas, they do not provide sufficient detail to guide teachers' formative or summative assessment decisions. To address this Indicators of Progression have been developed for the learning area of technology in New Zealand. As discussed elsewhere (Compton and Harwood 2005), Indicators of Progression are research based descriptors developed to mediate between achievement objectives and classroom practice. By 2007 Indicators of Progression for Planning for Practice, Brief Development and Outcome Development and Evaluation had already been developed and were therefore available for teacher use to support the Technological Practice strand of the NZC (Ministry of Education 2007). While an initial draft of the Indicators of Progressions for the Technological Knowledge and Nature of Technology strands had been drafted to support the release of the NZC they were theoretically derived from the achievement objectives rather than based on classroom based research. Therefore Stage One of this research sought to validate and/or revise these descriptors as based on student portfolio data and teacher reflections on student understanding. An analysis of interview data from 81 students interviews focused Characteristics of Technology (CoT) and 55 student focused on Characteristics of Technological Outcomes (CoTO) served to test and refine the student indicators. This analysis, including illustrative examples of how this data was coded, has been reported elsewhere as part of the description and findings from Stage One of the research (see Compton and Compton 2009). As a result of Stage One, a revised set of draft Indicators of Progression were published in April 2009 for both components of the Nature of Technology strand.

Stage Two of the research ran from the beginning of March 2009 to the end of December 2009. A total of 32 teachers and 22 schools were involved in this of the research. The schools were geographically spread across New Zealand. Nine (28.1%) of the teachers were in Northland schools, six (18.75%) in Auckland, three (9.34%) in Waikato, six (18.75%) in Wellington, and eight (25%) in Canterbury. Sixteen teachers (50%) were from the primary sector (year 1–8), with the remaining 16 teachers (50%) being from the secondary sector (year 9–13).

This stage of the research was more interventionist in nature than the largely explorative Stage One and particularly focused on identifying and describing teaching practices that successfully provided opportunity for students to progress.

In this paper we report on the learning experiences teachers provided students when focusing on developing their philosophical understanding of technology as part of Stage Two. The teachers were asked to focus a significant percentage of their teaching on aspects related to either the CoT or CoTO component. We had noted during Stage One that in

[5] The components of the Technological Knowledge strand are: Technological Modelling, Technological Products and Technological Systems. The components of the Nature of Technology strand are: Characteristics of Technology and Characteristics of Technological Outcomes.

many cases the teachers assumed their students had a higher level of philosophical understanding than they did. This resulted in rendering the subsequent learning experiences they developed largely ineffective as they were pitched too high. Therefore we placed significant emphasis on developing diagnostic tools using the 2009 version of the CoT and CoTO student indicators to determine student prior understanding. This information was used to plan learning experiences tailored to consolidate, challenge and/or extend student understanding. The draft CoT and CoTO indicators were also used at the completion of the unit to ascertain if any shifts had occurred. Student data related to the CoT and CoTO components was collected through student portfolios/booklets, photographs, assessment tasks and teacher comments. The data collected during Stage Two was also analysed to further refine the 2009 version of the CoT and CoTO Indicators of Progression as part of the iterative process of their development.

The key outcomes related to the Nature of Technology strand from Stage Two of the research were:

- The identification of common misconceptions of technology and partial understandings of technological outcomes that caused barriers to learning if not addressed;
- the development of four case studies; and
- the publication of further revised Indicators of Progression for each Nature of Technology components.

Each of these outcomes are presented and/or discussed below.

Misconceptions, alternative concepts and partial understandings

In Stage One of the *TKNoT*: *Imps* research, when students expressed ideas[6] about characteristics of technology and technological outcomes that were judged to be pre-level 1 they were categorised as 'emergent' or '0'.[7] Many of these ideas were again noted in the Stage Two data. However, during the analysis of the Stage Two data it became clear that these ideas across the five components of Technological Knowledge and the Nature of Technology strands were of different types and in some cases (misconceptions and alternative concepts) were not directly related or precursors to those ideas inherent in the level 1 student indicators for these components. We therefore decided to stop categorising these ideas as 'emergent', and instead identified them as misconceptions, alternative concepts or partial understandings. Misconceptions refer to those ideas that are incorrect and served as a barrier to student progress. Alternative concepts refer to ideas that are 'correct' in another context or discipline but not in technology, and when held, also served as a barrier to student progress. Partial understandings refer to ideas that are essentially correct but so small a part of the 'big picture' as to be unhelpful for students to progress. Table 1 presents a summary of the ideas students commonly hold about technology and technological outcomes, identifies them as misconceptions or partial understandings, explains probable reasons students hold these ideas, and discusses how easy or difficult teachers found them to address.

[6] We are using 'ideas' here as a collective term—in some cases the 'ideas' are rather a lack of ideas or an inability to identify or differentiate.

[7] See Compton and Compton (2009) for details of this analysis.

Table 1 Philosophical misconceptions and partial understandings

Ideas related to characteristics of technology (CoT)

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

All the bullet points above can be described as misconceptions of technology. They were very common across all age groups. Because these ideas tend to reflect typical 'public understandings' of technology, they are introduced to students early in their life and are constantly reinforced through everyday interactions such as conversations with parents and friends, exposure to media images and reports etc

These misconceptions required extensive and explicit teaching to address. They were often difficult to change and success in doing so relied on teachers continually probing for these ideas at all year groups and challenging them across a range of contexts. These misconceptions were often still apparent even when students exhibited level 1 or 2 understandings of CoT suggesting they did not become barriers to learning until more complex ideas were being taught. However, these ideas were no longer apparent by the time students were working comfortably at level 3 of the CoT component. It was also noted that the misconceptions associated with CoT often caused considerable difficulty in developing understanding in other components. These misconceptions are therefore important for all teachers to be aware of, even if focusing on other components

Ideas related to characteristics of technological outcomes (CoTO)

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

All the bullet points above can be described as partial understandings. In contrast to the misconceptions related to CoT, the partial understandings students had about technological outcomes were usually only seen in younger students. All these partial understandings reflect a basic lack in student knowledge, terminology and/or experience in relations to identifying and analysing technological outcomes

Teachers achieved success in addressing these partial understandings relatively easily by 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 real objects (as opposed to photographs or pictures), word banks to introduce new descriptive terms, and when adequate time was allowed for students to handle and/or disassemble items and discuss and employ the new terms. These partial understandings were no longer apparent by the time students were working comfortably at level 1 of the CoTO component

Case studies of teaching components

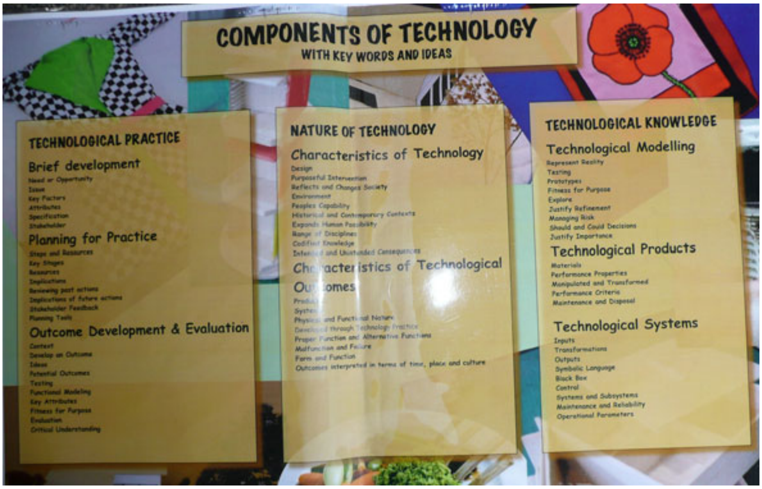
Four case studies were developed from the work of six teachers as they taught aspects related to the Characteristics of Technology (CoT) or Characteristics of Technological Outcomes (CoTO). Extracts from the CoT case studies are provided in Tables 2 and 3. Extracts from the CoTO case studies are provided in Tables 4 and 5. These extracts have been selected to illustrate teaching strategies used and resulting student outcomes.

Table 2 Summary of case study one related to characteristics of technology (CoT)

Overview of case study

The first case study was developed from learning experiences provided to year 11 students (average age 15) where the teacher focused explicitly on establishing and enhancing student understanding of the *Characteristics of Technology*. This was the focus for three lessons

Session one: **introduction and self-assessment diagnostic activity**



The teacher initially gave the students a laminated overview of all the components in the technology learning area. For each component he listed key words and ideas—see above

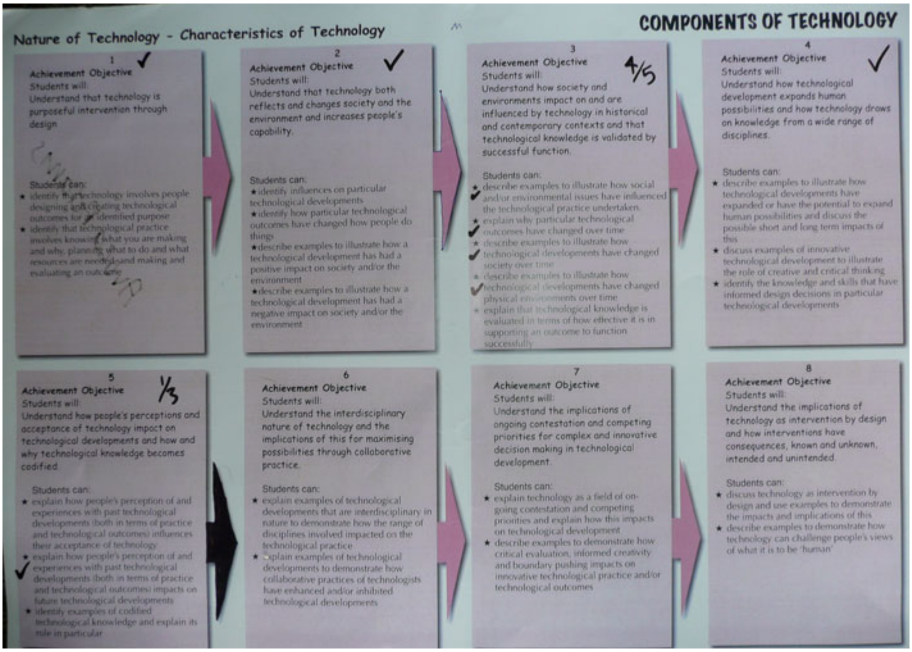
He used this sheet to explain the three strands of technology and the components within the strands. He then explained the purpose of the *TKNoT*: *Imps* research they were participating in. That is, to find out and extend the students understandings about the CoT component

The teacher then presented the students with a photocopy of all the Achievement Objectives (AO) and the student indicators from the 2009 draft Indicators of Progression for CoT (see below)

At this stage he explained what an AO was and that the student indicators were tools that teachers used to both help them teach and to establish student understanding and capability. They talked about the AO and indicators listed under level 1. The class agreed that they understood the indicators and then they gave examples that illustrated that they understood the knowledge required for achievement at Level 1. The teacher then read each AO and indicator for each level and each student marked their sheet if they felt confident they could understand and achieve what the indicator required. For example, the student in the example below marked their sheets to show they felt they were working at level 4, could understand one indicator at level 5, however she found the last indicator in level 3 difficult

Table 2 continued

Example of Student Self-Assessment



The self-assessment activity was completed by 12 students

Summary of student self-assessment

Level	1	2	3	4	5	6	7	8
No of students (n = 12)	12	12	12	9	3	0	0	0

All 12 students felt they had understanding of CoT up to level 3 with the exception of the level 3 indicator that focused on how technological knowledge is evaluated. Three of these students felt this was the limit of their understanding. Nine students felt they were working within or at level 4, and of these, three felt they also had some understanding of a level 5 indicator. This exercise provided interesting data on student perception of difficulty of each indicator

Session two: **clarification and verification through class discussion**

The teacher used the second session to verify the students' self-assessment results. To do this he asked them to contribute to a class discussion. All the indicators from Levels 2 to 4 were discussed, with the students identifying, describing and explaining their ideas in relation to each of the indictors. The discussion was videoed recorded

Not all of the students contributed to all discussion points so a comparison of individual data was not possible. However, overall the students articulated evidence that, with the exception of the level 3 indicator related to evaluating technological knowledge, all students showed good understandings at level 3. While some students could discuss some aspects related to level 4 understanding, the ideas offered by students were usually superficial and as a result of significant teacher prompting. The level 4 indicator related to critical and creative thinking was particularly difficult for these students

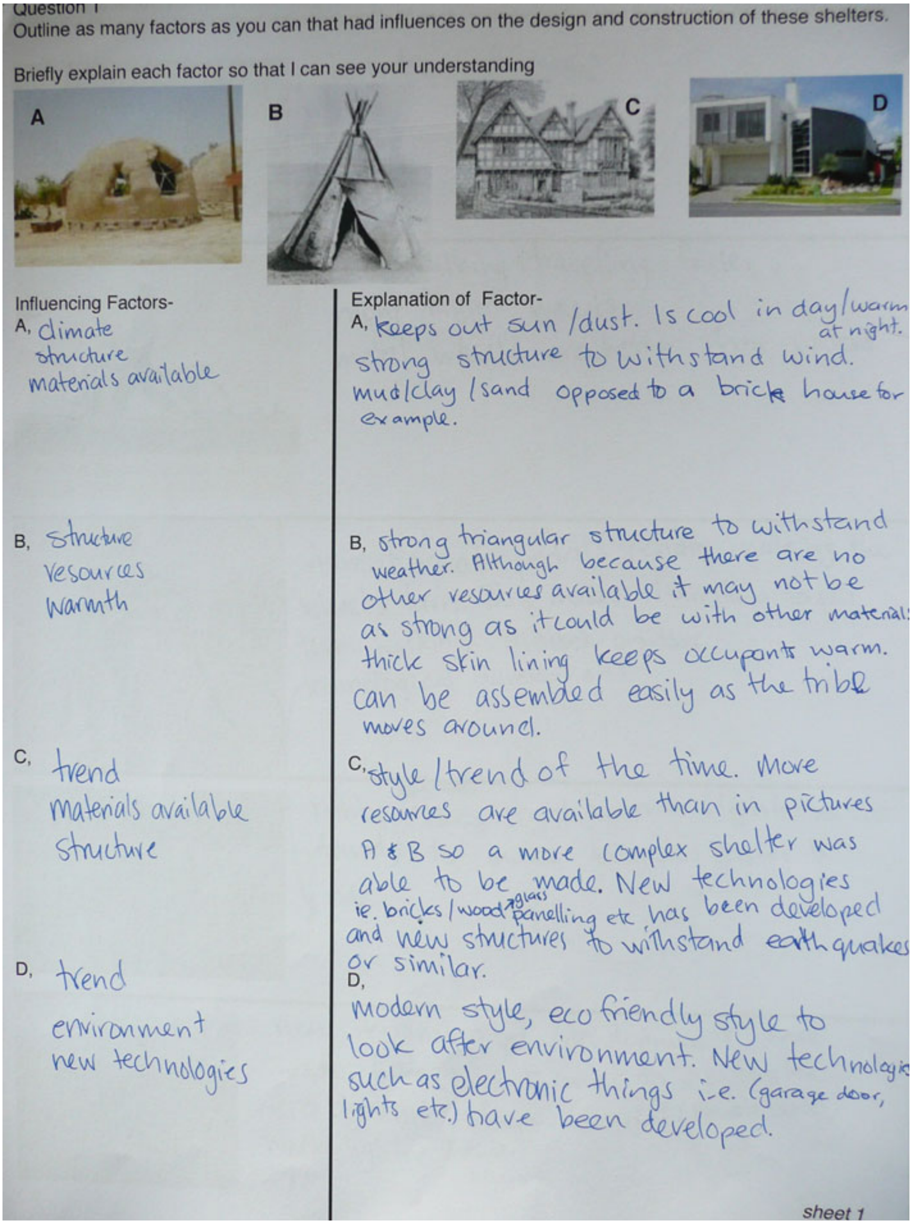
Session three: **completing questionnaires**

In the third and final session the teacher provided a written activity for the students to complete. The questions were of a general nature allowing the students to consolidate and enhance their understanding of CoT from level 2 through to and including level 4

Table 2 continued

Questions 1–3 provided opportunity for students to explore and exhibit level 2 and 3 understandings, while question 4 required students to extend their thinking to areas relating to the indicators at level 4

Student response—question 1


Question 1
Outline as many factors as you can that had influences on the design and construction of these shelters.

Briefly explain each factor so that I can see your understanding

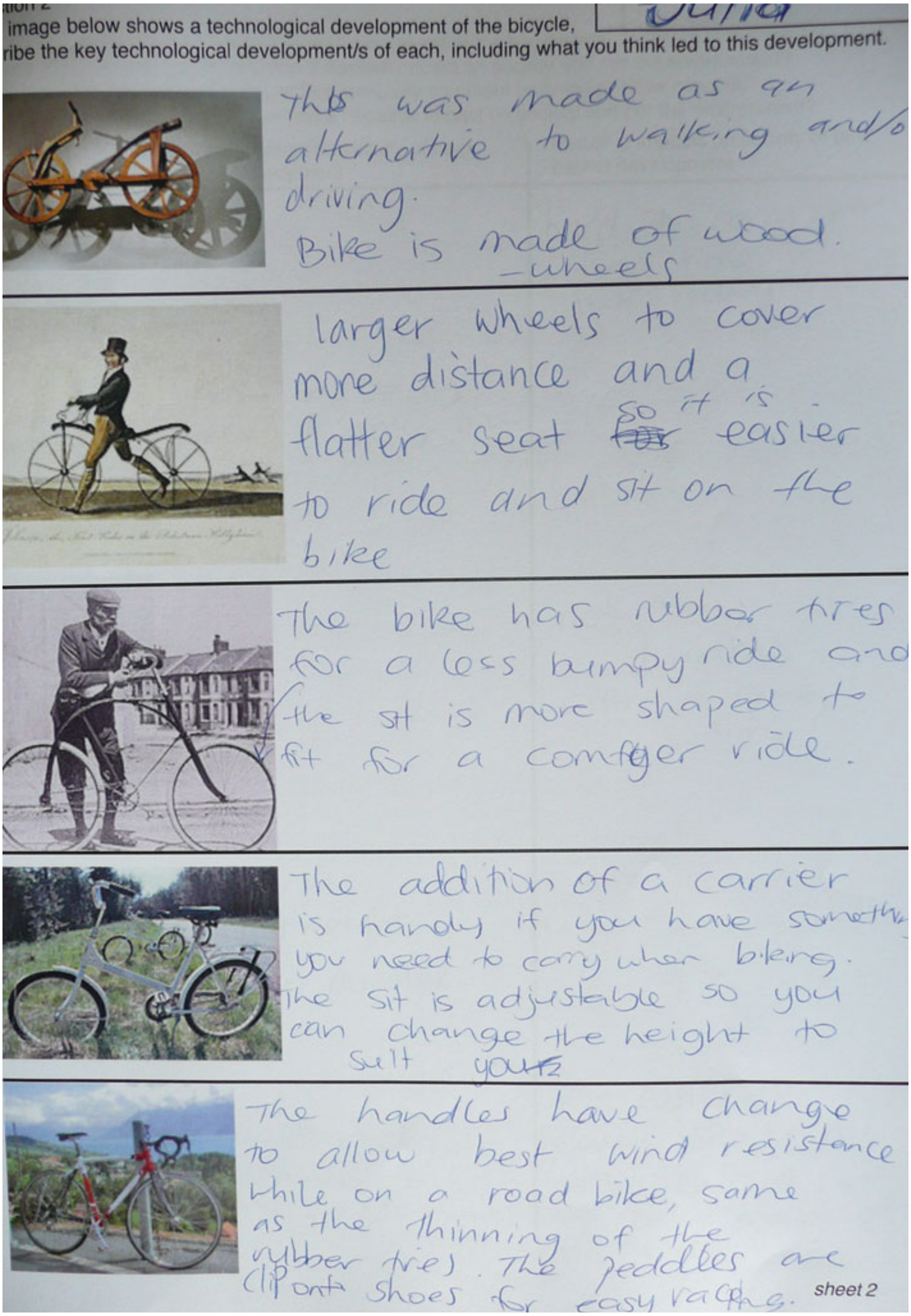
A B C D

Influencing Factors-	Explanation of Factor-
A, climate structure materials available	A, keeps out sun/dust. Is cool in day/warm at night. strong structure to withstand wind. mud/clay/sand opposed to a brick house for example.
B, structure resources warmth	B, strong triangular structure to withstand weather. Although because there are no other resources available it may not be as strong as it could be with other materials. thick skin lining keeps occupants warm. can be assembled easily as the tribe moves around.
C, trend materials available structure	C, style/trend of the time. More resources are available than in pictures A & B so a more complex shelter was able to be made. New technologies ie. bricks/wood/glass panelling etc has been developed and new structures to withstand earthquakes or similar.
D, trend environment new technologies	D, modern style, eco friendly style to look after environment. New technologies such as electronic things i.e. (garage door, lights etc.) have been developed.

sheet 1

Table 2 continued

Student response—question 2


...tion 2
...image below shows a technological development of the bicycle,
...ribe the key technological development/s of each, including what you think led to this development.

This was made as an alternative to walking and/o driving.
Bike is made of wood.
-wheels

larger wheels to cover more distance and a flatter seat ~~for~~ so it is easier to ride and sit on the bike

The bike has rubber tires for a less bumpy ride and the sit is more shaped to fit for a comfger ride.

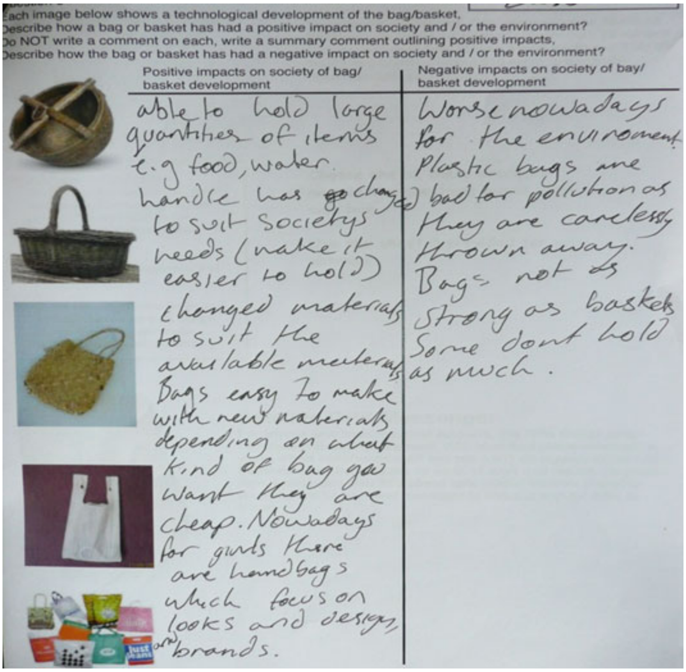
The addition of a carrier is handy if you have someth you need to carry when biking. The sit is adjustable so you can change the height to suit yours

The handles have change to allow best wind resistance while on a road bike, same as the thinning of the rubber tires. The peddles are clip onto shoes for easy racing.

sheet 2

Table 2 continued

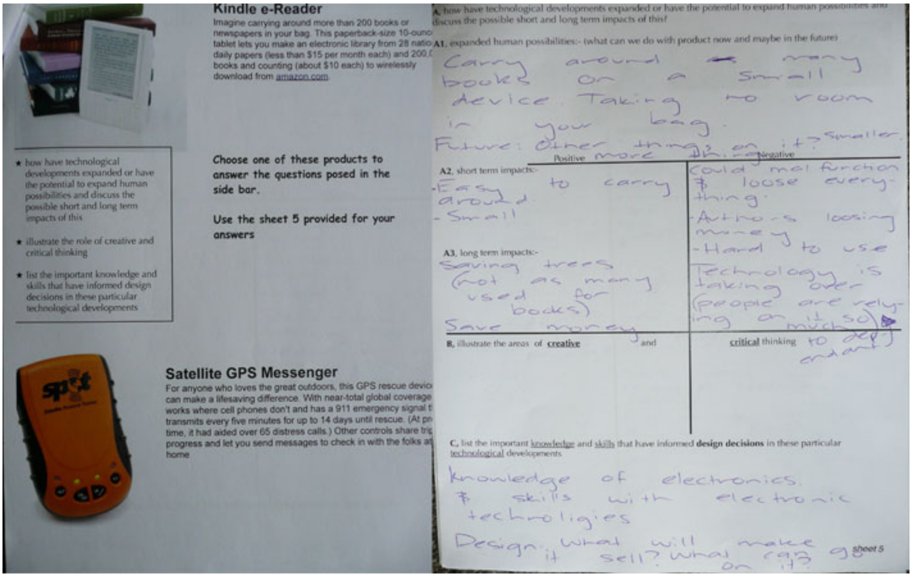
Student response—question 3



Each image below shows a technological development of the bag/basket.
Describe how a bag or basket has had a positive impact on society and / or the environment?
Do NOT write a comment on each, write a summary comment outlining positive impacts.
Describe how the bag or basket has had a negative impact on society and / or the environment?

Positive impacts on society of bag/ basket development	Negative impacts on society of bay/ basket development
able to hold large quantities of items e.g food, water. handle has changed to suit societys needs (make it easier to hold) changed materials to suit the available materials Bags easy to make with new materials depending on what kind of bag you want they are cheap. Nowadays for girls there are handbags which focus on looks and design and brands.	Worse nowadays for the environment Plastic bags are bad for pollution as they are carelessly thrown away. Bags not as strong as baskets Some dont hold as much.

Student response—question 4



Kindle e-Reader

Imagine carrying around more than 200 books or newspapers in your bag. This paperback-size 10-ounce tablet lets you make an electronic library from 28 natio[nal] daily papers (less than $15 per month each) and 200,0[00] books and counting (about $10 each) to wirelessly download from amazon.com.

- how have technological developments expanded or have the potential to expand human possibilities and discuss the possible short and long term impacts of this
- illustrate the role of creative and critical thinking
- list the important knowledge and skills that have informed design decisions in these particular technological developments

Choose one of these products to answer the questions posed in the side bar.

Use the sheet 5 provided for your answers

Satellite GPS Messenger

For anyone who loves the great outdoors, this GPS rescue devic[e] can make a lifesaving difference. With near-total global coverage [it] works where cell phones don't and has a 911 emergency signal t[hat] transmits every five minutes for up to 14 days until rescue. (At pr[ess] time, it had aided over 65 distress calls.) Other controls share tri[p] progress and let you send messages to check in with the folks at home

A, how have technological developments expanded or have the potential to expand human possibilities and discuss the possible short and long term impacts of this?

A1, expanded human possibilities:- (what can we do with product now and maybe in the future)

Carry around many books on a small device. Taking no room in your bag.
Future: Other things on it? smaller more things

	Positive	Negative
A2, short term impacts:-	-Easy to carry around. -Small	Could malfunction & loose everything. -Authors loosing money -Hard to use
A3, long term impacts:-	Saving trees (not as many used for books) Save money	Technology is taking over (people are relying on it so much) to depend and

B, illustrate the areas of **creative** and **critical** thinking

C, list the important knowledge and skills that have informed **design decisions** in these particular technological developments

knowledge of electronics. & skills with electronic technoligies
Design: what will make it sell? what can go on it?

sheet 5

Table 2 continued

As in the example above, students attempted to answer most questions, however again the answers showed superficial understanding in terms of level 4. Consistent with the earlier sessions, all students found the question relating to the role of creative and critical thinking difficult, with no students attempting this section. From the student responses it was determined the majority of these students would benefit from further learning opportunities focused on deepening and consolidating their level 4 understandings

Table 3 Summary of case study two related to characteristics of technology (CoT)

Overview of case study

The second case study was developed from learning experiences provided to year 12 students (average age 16). The teacher focused on enhancing the ability of students to analyse the practice of others to better understand technological knowledge and other knowledge and skills used in technology. They were then asked to apply this understanding in their own technological practice. Unlike the CoT case study above, this teacher focused specifically on one aspect of the *Characteristics of Technology*—the knowledge related indicators, trying to build up understandings across levels 3–6

Session one: **introduction and diagnostic activity**

As this teacher had been working with these students for 3 terms already, she felt comfortable students in her class were ready to extend their understanding of the knowledge and skills required to make design decisions. Her students had previously demonstrated the ability to identify some knowledge and skills they had used during their previous and current technological practice. From this basis she decided her students currently showed early level 3 CoT understandings and she would focus on progressing their learning from level 3 to level 6 of CoT. That is:

- explain that technological knowledge is evaluated in terms of how effective it is in supporting an outcome to function successfully (L3)
- Identify the knowledge and skills that have informed design decisions in particular technological developments (L4)
- identify examples of codified technological knowledge and explain its role in particular technological developments (L5)
- explain how and why technological knowledge becomes codified (L5)
- explain examples of technological developments that are interdisciplinary in nature to demonstrate how the range of disciplines involved impacted on the technological practice (L6)
- explain examples of technological developments to demonstrate how collaborative practices of technologists have enhanced and/or inhibited technological developments (L6)

The teacher began this session with a general discussion on uniforms and fashion. During the discussion she drew extensively from the book, "Fashion—the key concepts" by Jennifer Craik. She included the hierarchy of uniforms both in their school community and in Air NZ. Included in this discussion were issues such as:

- how their school prefects were identified
- how the school sport representatives and academic scholars were distinguished by their uniforms and regalia
- how junior students' uniforms differed from senior students
- the significance of the 'masculine' garments that were included in the school uniform—tie, shorts
- the differences in cabin crew uniforms with different airlines– e.g. Singapore air has different coloured uniforms—red, blue and green for cabin crew

The students were then directed to the case study on Techlink—"Air NZ Uniforms[a]" and asked to complete a task as part of a diagnostic activity to verify the teacher's view of their current level of understanding

The task was to:

Identify the knowledge and skills that you think have informed design decisions in the development of the Air NZ uniforms

Task response—student recordings

One student listed specific knowledge and skills but provided no links to how these may have impacted on decisions. Another six students listed their ideas regarding what information would be useful and made some explanatory notes. These lists and explanations were directly influenced by their own technological practice. For example:

- *Research—environment, climate, functions to be performed*

Table 3 continued

- *A brief—things important to the designing e.g. cost, environment, functionality*
- *Suggestions/information from who will be wearing the uniform* ("*clients*")
- *Information/suggestions on what is good/bad about old uniform, changes that need to be made*

Feedback from "*clients*" *throughout the design process*
(**Student HW**)

The remaining five students listed ideas of what was needed as well as ways of doing things and often included some ideas linked to considerations and other consequences. These students all wrote in paragraph form and some students used arrows to show the linking. The links demonstrated a variety of depth of thinking. For example:

Key factors established and prioritised, e.g. comfort and appearance could both be key factors and prioritization Would inform everyone of which was to be more important and therefore more of a focus when designing.
(**Student LC**)

Comparing and contrasting their old uniforms/discussing them → *which allows them to come up with a better, more functional, attractive, user-friendly uniform.*
(**Student TL**)

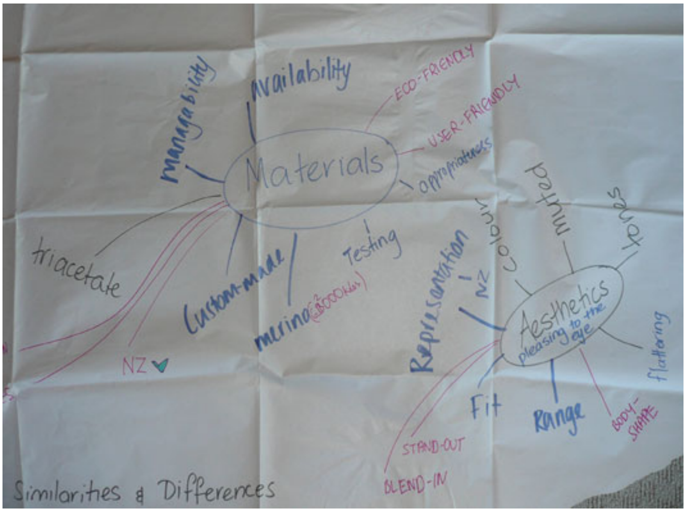
Research: *e.g.…climate and atmosphere, style* → *to represent New Zealand [and] also have a unique recognizable design…*
(**Student ST**)

Session two: **identifying knowledge and skills**

In the following session the students were shown two DVDs—'Fly me a Look' and the 'Country Calendar' programme outlining the production of merino for the uniforms. The class brainstormed what they had gained from the DVDs. This activity provided the students with the opportunity to further examine technological practice outside their own

The brainstorm functioned to help student identify the many aspects of knowledge and many skills required to produce a technological outcome. It provided the opportunity to compare and contrast their own practice with that of the production team for the Air NZ uniforms

Example of student brainstorm



The explanatory notes from the technology achievement standard the teacher was using as an assessment tool for qualifications provided the headings for the students to use in their brainstorm

It was interesting to note that having these organising headings (e.g. materials, aesthetics, function, reliability, ergonomics, people etc.) seemed to have a negative impact in terms of connections between ideas. For example, no students appeared to recognise any relationships between the headings and/or the points made around them

Table 3 continued

Session three: **synthesising**

In the final session the students were asked to use their brainstorm and accompanying discussions to provide evidence of the knowledge and skills that have informed design decisions in the development of the Air NZ Uniforms

None of the students provided any evidence of understandings related to the level 3 indicator focused on how technological knowledge is evaluated. However, this was not a specific focus of any of the learning experiences

All students discussed the difference between their practice and that of Zambesi in terms of producing a one-off for one person and producing many items for many people, and the implications of this. All students provided evidence therefore for the level 4 indicator showing how knowledge and skills resulted in different types of decisions for particular developments. For example:

The difficulty of designing for that many people is also amplified by the range of sizes, body shape and heights that one [design of] *uniform will have to accommodate. The environment the Air New Zealand staff work in requires clothes that are easy to wash, durable, long lasting, breathable, stain resistant, allow for ease of movement, comfortable and flame resistant but still formal enough to reflect well on the company. This makes the selection of fabrics much more difficult, as one fabric is hardly likely to perform all of these tasks. This means special fabric needs to be devised and manufactured to fulfil the needs and that each fabric has to go through rigorous testing*
(**Student HW**)

Students could give examples of the use of codified knowledge in terms of the fitness of purpose of the fabric showing some understanding related to level 5 indicator, however no students explained how or why technological knowledge becomes codified. Codified knowledge was mentioned in relation to the testing and standards they saw in producing the uniforms and not in relation to the fabrics they had used in their own garments. For example:

Many different fabric tests had to be carried out…fire safety, durable, wrinkle, stain [resistance], *if a fabric didn't meet one standard it was not suitable… Air New Zealand and Zambesi designers had to go through many fabric tests for the suitable one whereas…all I had to do was drive to a few fabric stores and buy a fabric that I felt was suitable for my design*
(**Student GB**)

The uniform had to allow for movement (*such as closing overhead lockers, emergency procedures*)*, the fabric had to be fire safe, durable, comfortable for those long flights and look good. There was definitely a lot more to take into consideration compared to mine—basically because a uniform has a lot more purpose that that of streetwear*
(**Student TL**)

In terms of the level 6 indicators, while most of the students noted the collaborative nature of the technological practice undertaken to produce the uniforms, little mention was made of cross disciplinary impacts or issues. For example:

It was very interesting to see all these talented people who have a specialty e.g. pattern making, crowded around a table…to discuss the best possible design…having that many people in a team I believe leaves no room for error as everyone is expressing their opinion, noticing issues other members may not…the group really needed to co-operate…collaborate with everything that was done
(**Student TL**)

In several students' work some aspects of knowledge were explored in more depth and links were now made between the organising headings used in the brainstorm. On the occasions that this happened, the connections made appeared to hold a special interest or relevance to students. This supports a notion of increased individual interest leading to deeper processing that enabled both domain and topic knowledge to be connected. For example:

I love the fact that they [Zambesi] *captured all of this* [the koru, paua, the silver of the silver fern, the history of previous uniforms] *into the Air New Zealand uniform…the minute you see the airline uniform of your home country you feel you are already home. I believe I could have gone into more detail when it came to the physical appearance of my garments so it could have more depth and meaning to them—as I really believe that 'Streetwear' is what makes a person who they are, what they feel like and where they're from—what journey our world has offered them so far.* (**Student TL**)

[a] See http://www.techlink.org.nz/Case-studies/Technological-practice/soft-Materials/zambesi-style/index.htm

Table 4 Summary of case study three related to characteristics of technological outcomes (CoTO)

Overview of case study

This case study was developed from learning experiences provided by three teachers that focused on the *Characteristics of Technological Outcomes.* Three classes were involved—one class of year 3/4 (average age 7/8) and two classes of year 5/6 (average age 9/10) students. The school focus for the year was 'communications' and so the teachers felt they could use this context to learn about technological outcomes that are used to communicate and from here develop understanding of the CoTO. The teaching strategies focussed particularly on how to establish understandings of what a technological outcome is and then encouraged students to be able to describe technological outcomes in terms of their physical and functional nature

Session one: **diagnostic activities**

The Year 3/4 teacher collected initial diagnostic data by asking her students to cut out pictures of objects and place them into one of three columns—'Items that we *think* are technological outcomes, Items that we *know* are technological outcomes and Items that we *know aren't* technological outcomes'

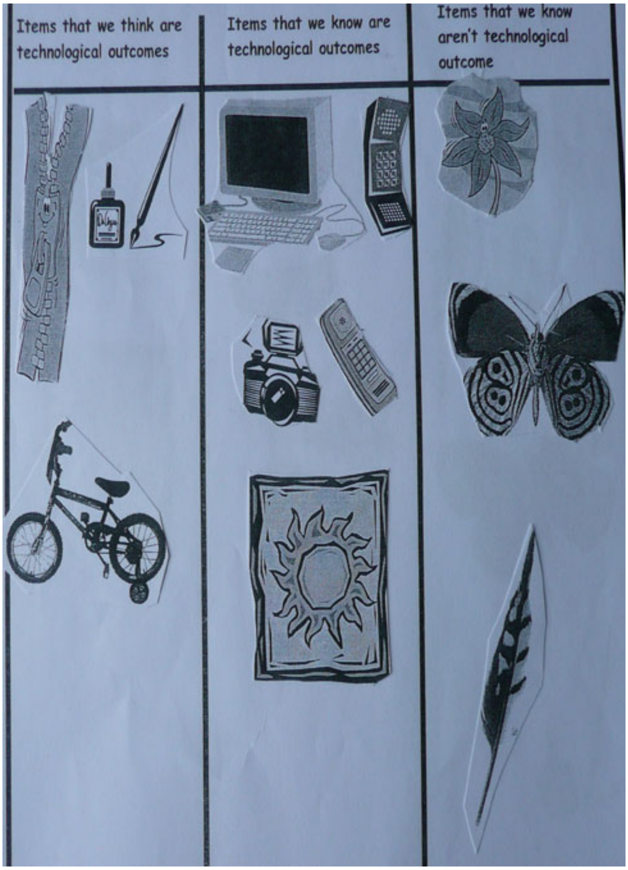
The teacher decided that next time she did this activity she would use actual objects if possible rather than pictures of objects as some of the students were confused by having to interpret an image of an object—e.g. the zip with the face and the picture of the sun

The picture of the sun was particularly interesting; some students interpreted it as an artwork—and then placed it the 'think' it is a technological outcome. Others interpreted it as being the sun itself—and therefore placed it in the 'aren't' a technological outcome column. And yet others interpreted it as a mat—and placed it in the 'know' it is a technological outcome column (as can be seen in the example given opposite)

From this activity, the teacher could see that most of her students linked technology with modern electrical items. All students knew that natural objects were not technological outcomes

The teacher used the indicators to analyse both this data and the comments made by students during the discussion arising from this activity. She concluded that all the Year 3/4 students were working pre or within level 1 of CoTO and therefore would benefit from learning experiences focused on consolidating level 1 understandings and developing level 2

Year 4 student response



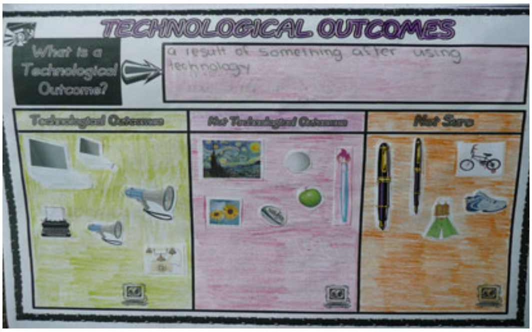
This was a typical response from the Year 3/4 students. All except one student put the electronic objects as technological outcomes (the one student wasn't sure that a computer was a technological outcome). All knew that natural objects were not technological outcomes. Most students were unsure about the zip, bike, pen and ink, or categorised them as not technological outcomes

Table 4 continued

The Year 5/6 teachers developed a technology portfolio booklet for each student. In this booklet they included pre and post assessments for the unit. These assessment activities required the students to classify objects by cutting pictures of the objects and sticking them into one of the columns (‘Technological Outcome, Not Technological Outcomes, Not Sure’)

On this page the students also had to write what they thought a technological outcome was

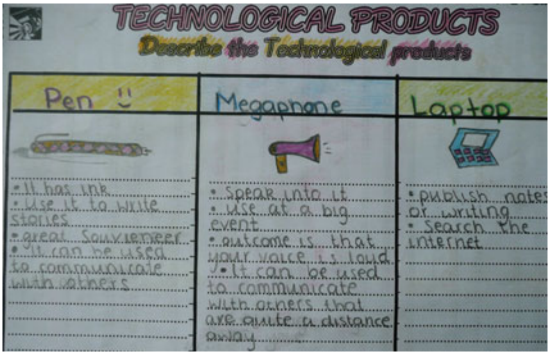
Year 6 student response



The following page in the year 5/6 booklet required the students to choose three items they thought were technological outcomes and describe them

Overall, the students in the Year 5/6 classes were confident the lap-top, megaphone old telephone and typewriter were technological outcomes. Most classified the artwork, apple and flowers as not being tech outcomes. The other items were spread throughout the three columns

Analysing the Year 5/6 student responses to the diagnostic activities showed all but two of the Year 5/6 students were working within level 1. The remaining two students had correctly classified all the objects and were able to describe outcomes in terms of their physical and functional natures. These two students were therefore judged to have shown level 1 understanding and were working within level 2



From this data the two teachers decided to focus their learning experiences on consolidating level 1 understanding and challenging their students to progress to level 2 and 3. This involved not only being able to differentiate and describe technological outcomes in terms of their physical and functional nature, but also to developing understanding of the relationship between an outcome’s physical and functional nature (L2) and how this in turn relates to its fitness for purpose (L3)

As shown above, many student descriptions of technological products focused on what the item was used for—its functional nature

The remainder of the portfolio contained spaces for the teacher and peer feedback on the student’s learning. This space was dated, contained a comment for feedback and a suggestion about the student’s next learning step. Templates were included to record student responses to activities at various points throughout the unit. The required responses always focused on the learning outcomes of the unit. That is, explaining what technological outcomes are and describing these outcomes

Sessions 2–4: **exploring technological outcomes**

All three teachers began addressing student understanding about what technological outcomes are by exploring a variety of brooms they brought into the classroom. The teachers discussed why a broom was a technological outcome and got the students to discuss the similarities and differences between the brooms. They repeated the activity with a variety of brushes and writing instruments over the next few days. With each set of objects the teachers encouraged the students to discuss why they were technological outcomes (That is, that they had been developed by people for a specific purpose). The students were also encouraged to describe each set of items in terms of their physical and functional nature

Table 4 continued

The teachers then focused on exploring the physical and functional nature of modern communication technological outcomes, comparing such outcomes as pens, phones, and computers. Once again they questioned and reinforced earlier learning by asking: What makes this a technological outcome? What does it look like? What does it do? They reinforced the terms ‘physical nature’ and ‘functional nature’ as they did this

The teachers constantly reinforced two ‘big ideas’’ throughout these sessions. That is, what a technological outcome was and how to describe them. They allowed the students to work in groups and handle the technological outcomes in order to discuss the similarities and differences

By using many different items the teachers increased domain knowledge about technological outcomes. They were able to challenge the students’ narrow view of what technological outcomes were. Getting the students to compare and contrast the items within sets and between the sets of outcomes encouraged the students to learn to use deeper processing strategies

Session 5–6: **describing technological outcomes**

Introducing terminology

The teachers used the teacher guidance notes from the 2009 indicators of progression for CoTO to help the students to begin to explore how the relationship between the physical and functional nature of outcomes related to the outcome being fit for purpose. This was difficult for most of the students to grasp but the activity did serve to reinforce how outcomes can be described by focusing on their physical and functional nature. All teachers reinforced the terminology used by creating word lists and displaying posters of key words around the room

The Year 3/4 students completed hand-outs describing selected technological outcome’s in terms of their physical and functional nature

The dividing line between the physical and functional nature used on the worksheet helped them to think of both, but may have impeded the student linking these attributes. It is important to encourage students to make this link and to allow space for students to link these attributes on any template. Being able to link physical and functional attributes indicates that the students are working at Level 2 in this aspect

Year 3 student response

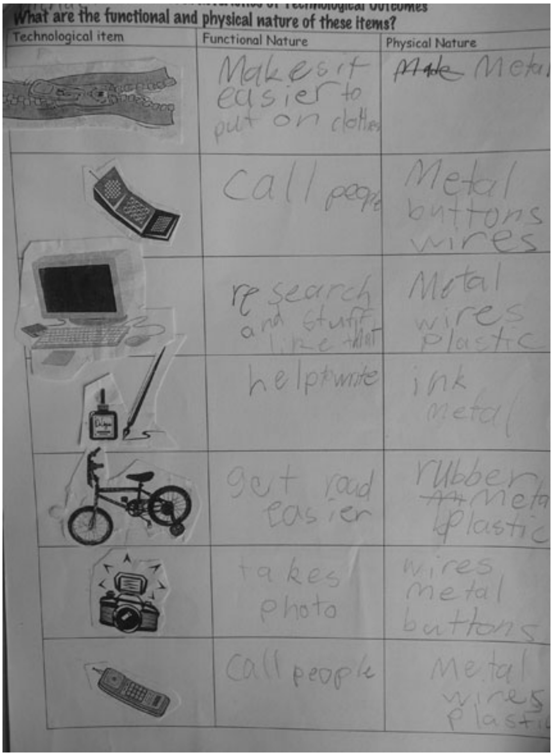


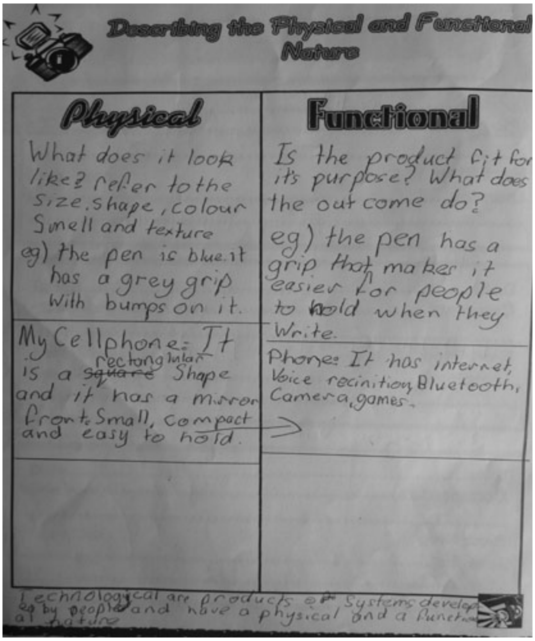
Table 4 continued

The year 5/6 teachers gave their students the component descriptor from the explanatory paper which defines what a technological outcome is [a]

The students analysed this paragraph by discussing known and unknown words and relating the definition to their growing understanding of what a technological outcome was. To further support the concept of 'fitness for purpose' the teachers provided the students with other objects such as different looking scissors and talked about such things as: Who they were made for? What were they designed to cut? and Did they perform the purpose they were designed for?

The year 5/6 students recorded what they thought the physical and functional nature of a technological outcome meant and described technological outcomes using these categories

Year 6 student response



Visit: **technological outcomes of old**

A highlight of the unit was a trip to Ferrymead Heritage Park. Ferrymead features an early 1900s Edwardian township complete with homes, picture theatre, schoolhouse, church, jail and railway station, as well as a fascinating array of museum and heritage collections. The students were able to apply their growing understanding of technological outcomes by exploring communication artifacts from the early 1900s and comparing them to the communication devices they had today. This part of the unit could also have focused on Characteristics of Technology but the teachers decided to limit the breadth of the unit to concentrate on consolidating a depth of understanding within Characteristics of Technological Outcomes. Once again the teachers used different learning experiences to reinforce the same ideas. The language used to describe technological outcomes was now becoming 'second nature' to the students

Table 4 continued

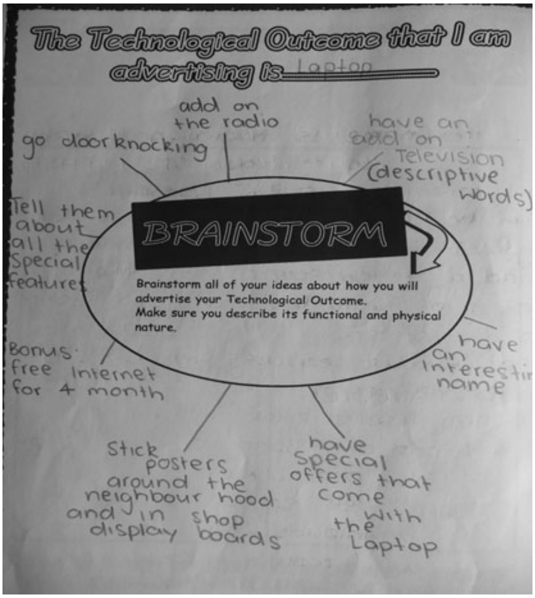
Session 7–8: **synthesising activity** (**Year 5/6 only**)

The year 5/6 students were then given a task to advertise a technological outcome. In this way the teachers provided the students with multiple opportunities to demonstrate their new learning

Initially the students were asked to select a technological outcome and 'brainstorm' ideas

The instructions on the brainstorm asked the students to note down ideas about how they would advertise their outcome. Although the next instruction asked them to make sure to describe its physical and functional nature, most students concentrated on the methods they could use to advertise (as can be seen in example)

Year 6 student brainstorm



The students were then asked to write a script and finally develop a storyboard for their advertisement.

As can be seen in the script and storyboard examples provided, the students' description now included reference to both the physical and functional nature of the outcome and explanation was also offered as to why it is a technological outcome

Year 6 student script

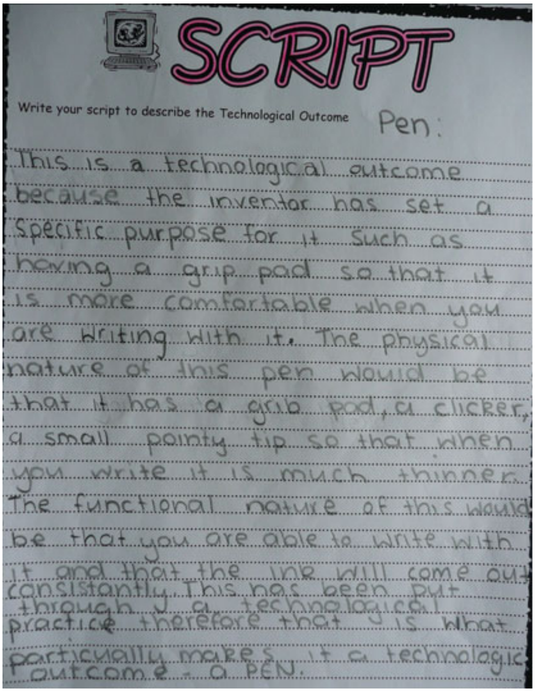


Table 4 continued

Year 6 student storyboard

Final session: **Post-test**

The three teachers repeated the pre-test/analysis activity that they had used at the beginning of the unit. Using the results from this and from formative assessments made throughout the unit, all teachers could see significant progress in their students CoTO understanding. The year 3/4 teacher judged all her students could now confidently identify and describe both the physical and functional nature of these (L1), and some students could explain how they differ to other objects (L2). The year 5/6 teachers also felt their students had made progress through this unit with all students confidently identifying technological outcomes and explaining why they were, and all able to describe relationships between the physical and functional nature of these outcomes (L2)

[a] See http://www.techlink.org.nz/curriculum-support/papers/nature/char-tech-out/index.htm

Table 5 Summary of case study four related to characteristics of technological outcomes (CoTO)

Overview of case study

This case study was developed from learning experiences provided to year 13 (average age 17) students. The teacher initially estimated his year 13 students' understandings of *Characteristics of Technological Outcomes* and used this as a basis for his subsequent teaching of this component. This teacher was particularly interested possible relationships between these understandings and the students' technological practice, particularly *Outcome Development and Evaluation*. The teacher initially planned to focus on CoTO over a series of three lessons, however time constraints meant he had to compress his three sessions into a single lesson

Pre-teaching estimation

The teacher used the Indicators of Progression to analyse the students understanding related to the components of the Technological Practice and Nature of Technology strands. The analysis was based on his knowledge of his students' current work (in Year 13), their previous years work and their learning experiences in technology programmes during years 9–11. Results of his initial formative assessment/estimation are as follows:

	Technological practice			Nature of technology	
Student	**Brief development**	**Planning for practice**	**Outcome development and evaluation**	**Characteristics of technology**	**Characteristics of tech outcomes**
A	5–6	5–6	6–7	3–4	1–2
Jk	5	4–5	4–5	3	1–2
D	5	5	4	3	1–2
Js	5	5	4–5	3	1–2
K	4–5	4	4	3	1–2
E	4–5	4–5	5	3	1–2
N	4–5	4	3–4	3	1–2
O	3–4	3	3	2–3	1–2
Dv	4–5	4–5	4–5	2–3	1–2
Jh	2–3	2–3	2–3	3	1–2

Teacher explanatory comments

A general weakness in ODE is the student's lack of exploration, including the researching of other's designs. For many, functional modelling within practice is limited (O particularly, and N and K), while for E and A this is very strong

Without any specific teaching or assessment of CoTO in their past technology programmes, this is my best guess of where the students' understandings would sit currently. I expect their capacity to understand is not the issue here, rather that we have not explored this area in previous technology programmes

Table 5 continued

With regards to CoT, I think that with time to reflect, most of these students would have a good understanding at level 3 due to the work done in our junior programme. There is no evidence of this in their senior work as it is not a part of our senior programme at present. This could (and should) be integrated into our senior programme over the next few years as well as being expanded on within the junior programme as the new strands are introduced formally from 2010

The teacher therefore planned to focus his teaching on the understandings captured in Level 2 and perhaps Level 3 of CoTO.

Part one: **exploring technological outcomes**

The focus of the teaching was to be on the physical and functional nature of technological outcomes. The teacher decided that that he would explore these ideas with the use of a range of examples that the students were familiar with and therefore should relate to well. The teacher provided the students examples to explore and initiated a general discussion about technology. He gave them a questionnaire worksheet and asked them to record their responses. This was seen as the most efficient way of capturing specific formative data for him to work with later in the lesson. The results of this assessment are as follows:

	Questions				
Students	How would you define a technological outcome?	What is meant by the **functional** nature of a tech outcome?	What is meant by the **physical** nature of a tech outcome?	What is meant by a technological **product**?	What is meant by a technological **system**?
A	A final product which follows a set of guidelines/specifications given by clients and/or stakeholders. It has to be man made and not natural.	This is how the outcome acts/works. A cog for example rotates, it is how something works	What it visually looks like. The size, weight, colour, texture etc. The materials it is made from, how it is put together	This is a technological object which has a use	This is multiple technological objects contained into one single object/system which can have multiple functions
Jk	A finished product that has been planned and designed	It has been made to do something and has a purpose to fulfil	How it looks and feels	An object which has an easy use.	A system is a series of things you have to do to make it work or what it does
D	Its the final product which follows the brief and its specifications given by the client	It means that it tells us the general function of the product and how the product works	A brief description of what it will generally look like and its dimensions, the material it is made of, texture and any other physical aspects	Something that has been successfully made and is able to be used	It means that a product has a system in which it has functions it can do
Js	A finished man made product that has been designed and developed through different stages	It works in the environment it is meant for	Describing the look and the materials it is made of	A product used to do stuff and it is a final product	A technological system is broken up into several different things.
K	Man made design that has been completed	What it does, the way it works	The way it looks	A finished object	Something that has multiple functions

Table 5 continued

E	A man made object taken and developed from an original idea by a technologist	What purpose it is used for	How it looks, feels and what materials it is made out of	A finished object (is what it is).	A series of components working together
N	Something that has been designed and modified by a technologist using knowledge from general areas	What purpose it serves and what it is like at doing this	Physical textures, appearance and what it's made of	Something that is made by a technologist	Something that has multiple functions
O	A finished product that has been completed by someone	What purpose it serves	The way it looks.	A finished product.	Something that functions to achieve a purpose
Dv	A finished man made product	Something that fulfils the purpose of what it is designed to do	How something looks and feels	Something that has been finished	Something that will function to achieve a purpose
Jh	Man made objects that have gone through stages to get made	How bits of the outcome work	What it looks like, what it's made from and how it feels	The final product, final outcome	What makes the product work, what it does

The teacher felt the students all demonstrated good understanding of CoTO at level 1, with some beginning to show understanding about defining a technological outcome (L2). He then discussed the answers and asked them to describe a particular technological outcome.

Student Response:

The physical nature of my pen is that it is long spherical, yellow, and smooth. It has a clicker, ink, and a ball point. The functional nature of my pen is that it clicks down and the ink is transferred onto the page
(**Student Js**)

Part two: **exploring technological outcomes as products and systems**

The teacher discussed the way the physical nature of a technological product may be described and compared this to what information is important when describing the physical nature of a technological system.	**Student responses** All students were able to apply their general understanding of what makes an object a technological outcome to their selected example
Objects used: cell phone, tape measure, battery drill, hand held grinder. 1. Choose one of the above items. Explain what makes it a technological outcome	All students could describe the physical nature of a product but were less confident in describing the physical nature of a technological system. Examples of descriptions of the physical nature of systems included:
2. Choose one of the items that you would consider a technological product. 3. Describe its physical nature in terms of the materials it is made from.	*Battery drill. It has a handle, battery, trigger, chuck, slip clutch and a motor.* (**Student K**)

Table 5 continued

4. Choose one of the items that you would consider a technological system. 5. Describe its physical nature in terms of the components within it and how they are connected	*Cell phone. This is a system, because of its functions, such as the camera, phone, organiser, phone book etc. It is connected together through the battery as a power source, to charge the mother board, which runs the programmes to allow functions to work.* (**Student D**)
The students were then asked to consider their own technological outcome (project). 1. Would you consider it to be primarily a **product** or a **system**? Why? (Explain your answer).	In many cases the students found deciding if their project outcomes was a product or system difficult. This usually reflected confusion as to the definition of a technological system. For example:
2. Describe its **physical** nature in terms of the **materials it is made from** (product) or the **components within it** and **how they are connected** (system)	*Modular, stackable blu-ray disc storage system. It is a system because it is used to store cases in it and it is capable of changing its structure and separating. It is made of pine wood, then stained in a golden rimu colour and its surface is polyurethaned to keep it smooth. The pieces of wood were cut up at certain measurements, then using glue they were stuck together.* (**Student D**)
Part three: **relationships between the physical and functional nature**	
The teacher provided the students with a screwdriver and a chisel and asked the following questions:	**Student response**
1. Describe the physical nature of a blade screwdriver	The students' responses to the four questions were all very similar. A typical example was:
2. Describe the physical nature of a chisel	(*screw driver*) *It has a long handle which can fit in a hand. It is long and has a long metal shaft with a sharp end.*
3. Describe the functional nature of a blade screwdriver	(*chisel*) *A handle which can be hard enough to be hit by a hammer. It is short and has a metal shaft with a sharp tapered end.*
4. Describe the functional nature of a chisel	(*screwdriver*) *This sharp end allows the screwdriver to fit into a head of a screw.*
The teacher and students discussed these questions. The teacher made the point that both of these objects have a similar physical nature in broad terms though different in important ways due to their respective functions.	(*chisel*) *It is designed to dig into wood and wedge it away with every hit* (**Student A**)

Table 5 continued

The teacher facilitated a discussion on the link between the physical and functional nature of technological outcomes. He then explained he wanted the class to design something to open the lid of a tin of paint and used the following as prompts: 1. How might it function? 2. What might it be like physically? 3. How are the physical and functional natures of this potential outcome linked? 4. What materials might we be limited to in order for this to function well?	**Student response** After the discussion and questioning most of the students showed a sound understanding of the link between physical attributes with the functional attributes of an outcome. For example: *It might use a lever as a tool. It would be quite long and thin at one end to fit into a paint lid. It would have to be metal so it doesn't snap. Since it is long and hard it can lever with less effort and won't snap under the force. 15–30 cm to allow good leverage. We have metals at school and metal working tools.* (**Student A**)
5. What physical dimensions might we be limited to? 6. What do we have available here at school to make it from?	At the end of the session, the teacher felt the students were confident in their ability to link physical with functional attributes, but the discussion did lead to any responses that indicated students could then link this to fitness for purpose in any depth.
This was chosen to try and push the student to think about how physical and functional nature can be related to fitness for purpose as both the screw driver and chisel might be useful for opening a tin of paint—however neither would be ideal for this purpose. The teacher felt the understanding of these students progressed even within this short timeframe, particularly in relation to their understating of the link between the physical and functional nature of technological outcomes. He felt the end result of this single lesson was an extension and/or consolidating of all students' understandings of CoTO. He now considered all these students were working comfortably at level 2 and subsequent learning experiences should focus on developing level 3 understandings	

Publication of revised indicators of progression

The data provided in the Tables 2, 3, 4 and 5, alongside data collected from other students and teachers, was used to further refine the April 2009 CoT and CoTO Indicators of Progression as discussed below.

Revising the April 2009 version of the indicators of progression for characteristics of technology (CoT)

Both of the case studies summarised in Tables 2 and 3 provided evidence that verified the level 1 and 2 indicators, and most of the level 3 indicators, provided useful diagnostic and formative assessment tools to support student learning in terms of the related achievement objectives. However, in both cases the following indicator seemed too difficult for level 3.

- explain that technological knowledge is evaluated in terms of how effective it is in supporting an outcome to function successfully (L3)

The first case study also raised issues with the following two level 4 indicators.

- describe examples to illustrate how technological developments have expanded or have the potential to expand human possibilities and discuss the possible short and long term impacts of this (L4)
- discuss examples of innovative technological development to illustrate the role of creative and critical thinking (L4).

Related to the first of these, the students had difficulty with the concept of 'human possibilities' suggesting the wording required changing to better communicate the intent. In terms of the second, students had difficulty 'illustrating' the role of creativity and critical thinking in supporting technological innovation as they could not identify what creativity and critical thinking in technology might look like.

The remaining indicator at level 4 regarding identifying and categorising knowledge and skills from inside and outside the discipline of technology seemed to cause no particular learning problems for students. This was also verified in the second case study.

The level 3 and 4 April 2009 student indicators for CoT were therefore modified as a result of these and similar findings from student data from other classes and subsequent discussions with teachers. The related student indicators were changed to read as follows:

- identify that technological knowledge is knowledge that technologists agree is useful in ensuring a successful outcome (L3)
- identify examples where technology has changed people's sensory perception and/or physical abilities and discuss the potential short and long term impacts of these (L4)
- identify examples of creative and critical thinking in technological practice (L4)
- identify and categorise knowledge and skills from technology and other disciplines that have informed decisions in technological development and manufacture (L4)

Revising the April 2009 version of the indicators of progression for characteristics of technological outcomes (CoTO)

Both of the case studies summarised in Tables 4 and 5 provided evidence that verified the level 1 indicators provided useful diagnostic and formative assessment tools to support student learning in terms of the related achievement objective. However the teachers experiences with using the level 2 indicators suggested the indicators themselves, and the related teacher guidance, should more clearly communicate the importance of linking the physical and functional nature of technological outcomes—whether they be described as technological products or systems.

Both of the case studies also showed the link between physical and functional nature and the outcome's fitness for purpose was difficult for students, and understanding related to this could be better developed by breaking this down into smaller ideas and introducing them across more than one level.

The level 2, 3 and 4 April 2009 student indicators for CoTO were therefore modified as a result of these and similar findings from student data from other classes and subsequent discussions with teachers.

The student indicators were changed to read as follows:

- identify a technological product and describe relationships between the physical and functional attributes (L2)
- identify a technological system and describe relationships between the physical and functional attributes (L2)
- explain why a technological outcome could be called a 'good' or 'bad' design. (L3)
- explain possible physical and functional attributes for a technological outcome when provided with intended user/s, a purpose, and relevant social, cultural and environmental details to work within. (L4)

The teacher guidance material for CoT and CoTo was extensively revised to provide more specific guidance, particularly in terms of ensuring students are provided with real examples of technological outcomes to explore and analyse and that new ideas are introduced across a range of contexts when developing foundational understandings and/or challenging misconceptions related to the Nature of Technology across levels 1–3.

All the research teachers were brought together to discuss their respective experiences of teaching the components of the Technological Knowledge and Nature of Technology strands. From this basis they were able to provide a classroom practice informed critique of the suggested refinements based on their usefulness as both planning and assessment tools. The refinements were also discussed with both in-service and pre-service technology teacher educators prior to their publication in October 2010. The revised version of the Indicators of Progression for the Nature of Technology are available at http://techlink.org.nz/curriculum-support/indicators/nature/index.htm.

Conclusion

The findings and outcomes related to the Nature of Technology strand from Stage Two of the *TKNoT*: *Imps* research allowed significant progress to be made in terms of providing research-informed guidance and support for the teaching of the philosophy of technology in New Zealand.

There was an overall shift in the level of student achievement related to both Characteristics of Technology (CoT) and Characteristics of Technological Outcomes (CoTO) between the Stage One and Stage Two data. In the interview data collected from Stage One, the majority of the 81 students showed understanding related to CoT at or pre level 1 (62 students or 76%). Only 16 students provided evidence of level 2 understanding (19.7%), two students showed partial level 3 understanding, and one student showed partial level 4 understanding. The majority of the 55 students showed understanding related to CoTO at or pre level 1 (32 students or 57.5%). Twenty one students provided evidence of level 2 understanding (38%), and two students showed partial level 3 understanding. This therefore meant the April 2009 student indicators for level 3 and above were tested against a very small and partial data set and due to this were published as draft discussion documents only.

In contrast, the Stage Two data set provided many examples related to both CoT and CoTO of students progressing from pre-level 1 to level 1, level 1–2 etc. and showed many older students working comfortably at levels 3 and 4 even after relatively minimal teaching. This allowed for greater confidence for both the CoT and CoTO indicators to be verified or changed as required. The resulting October 2010 Indicators of Progression were therefore published as support documents for teachers to use for planning and assessment purposes—that is no longer in draft form. However, it should still be noted that even in Stage Two, the majority of students did not progress beyond level 4 in either component. From teacher discussions we concluded that for CoTO this was an issue of time rather than teachers having difficulty in developing learning environments to progress their students further. However in relation to CoT, the teachers were less confident they could develop learning experiences to support student learning above level 4. Therefore as part of the final stage of the TKNoT: Imps research a pilot trial was set up to specifically explore deeper processing strategies to support the teaching of the CoT at level 4 and above. The findings from this trial will be reported on in a separate paper.

Many teachers kept a reflective journal during this stage of the research allowing us to gain deeper insight into the complexities of the learning environment they and their students were involved in, and the success or otherwise of their teaching practices. Teacher data, along with the material presented in Tables 2, 3, 4 and 5 was further analysed using the Model of Domain Learning (MDL) (Alexander 2003, 2006) to further explore the case studies in terms of factors that impact on effective teaching of technology. This will also be reported on in a subsequent paper.

Acknowledgments We would like to thank all the teachers and students involved in this research. Their willingness to share their thinking with us was critical to the success of this project. We are thankful to the New Zealand Ministry of Education for funding the *TKNoT*: *Imps* research specifically, and acknowledge the high level of support they provide technology education through funding ongoing research and curriculum development.

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