STRATEGIES FOR PROGRESSING UNDERSTANDING OF TECHNOLOGICAL MODELLING

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Abstract
This paper reports on the trial of a teaching resource developed to support student learning in the technological modelling component of the Technological Knowledge strand in the New Zealand Curriculum (Ministry of Education, 2007). The trial was part of the Technological Knowledge and Nature of Technology: Implications for teaching and learning research project. Earlier findings from this research had shown that while students demonstrated a reasonable understanding of how technical feasibility aspects of design ideas and prototypes may be tested by technological modelling, they often struggled to show understanding of how technological modelling may be involved in testing aspects linked to social acceptability. The majority of students therefore never exhibited understandings related to technological modelling above Level 3. A resource was developed to help stimulate discussion that would support learning and provide opportunity to identify student understanding up to and including Level 3 of the technological modelling component, with follow up material aimed at pushing students to Level 4 and beyond. The resource was trialed by two primary teachers and four secondary teachers. This paper describes the resource, how it was used in each class, the resulting impact on student learning and the implications of the trial with regards to teaching this component.

Introduction
This paper reports on the trialing of a resource within two primary and four secondary classrooms. The resource was developed to support student learning in the technological modelling component of the Technological Knowledge strand in the New Zealand Curriculum (Ministry of Education, 2007). The trial was a part of Stage Three of the *Technological Knowledge and Nature of Technology: Implications for teaching and learning (TKNoT: Imps)* research project. This research was fully funded by the New Zealand Ministry of Education the third and final stage of ran from January 2010 to the end of June 2010. The overall focus of the *TKNoT:Imps* 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 their understandings. For a summary of the research findings from Stage One and Two see http://www.techlink.org.nz/curriculum-support/TKNOT-Imps/index.htm. It had became apparent from findings in Stage Two of the research that specific teaching focused on deep processing strategies was required to teach the ideas captured in the achievement objectives above Level 3 for technological modelling, and that students needed specific help to understand and use ethical frameworks to support their practical reasoning. That is, reasoning to determine how things ‘should be done’. This is a key progressive shift in the technological modelling component. For students to progress their understandings of technological modelling from Level 3 to Level 4 they are required to understand how technological modelling supports both technically feasible and socially acceptable decision making about what ‘could’ and 'should' happen and why.

The Technological Modelling Resource

The initial part of the technological modelling resource was developed to ensure students were working comfortably at Level 3 and were therefore ready to progress further. The remainder of the resource was focused 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 (see Compton (2010) for further explanation of these forms of 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'. However, few students exhibited practical reasoning ability particularly with regards to any moral or ethical aspects when testing design ideas or prototypes. Such practical reasoning supports student ability to justify decisions about 'what should be done' and as such is a key feature of robust technological decision making.

The resource consisted of a video showing different forms of modelling (An Adidas football boot development video sourced from the Australian *Beyond 2000 TV series)*, a pre-Level 4 diagnostic template (see Appendix A) and the ethical thinking tool from Biotechnology Learning Hub, or a resource derived from it. This tool is a teacher and student resource developed by Waikato University and is available at http://www.biotechlearn.org.nz/thinking_tools/ethics_thinking_tool/ethics_thinking_tool#/). The ethical thinking tool was selected to increase the domain knowledge of ethical and moral aspects by providing a framework of ethical approaches. This framework provides and explains five approaches as follows:

- *Consequentialism* - to do with the consequences of actions. Using this ethical approach we weigh up the benefits and harms resulting from our actions
- *Rights and Responsibilities* - closely related as rights imply responsibilities (or duties) of others to ensure those rights. Using this ethical approach we establish what rights are important for a particular issue and who would be responsible for ensuring these.
- *Autonomy* - recognises the right for people to choose for themselves. Using this ethical approach we weigh up what individuals want for themselves.
- *Virtue Ethics* – a virtue is something that the community accepts as being 'good', such as honesty, kindness and patience. Using this ethical approach we make decisions so we will be 'good'.
- *Multiple Perspectives* - Ethical decisions are viewed differently by different people. When considering an issue, it is important to explore a range of world views and respect diversity, for example, cultural, socioeconomic and spiritual or religious diversity. Using this ethical approach we weigh up what social groups think and want.

The focus on the ethical framework was incorporated into the middle of a learning sequence that explored technological modelling. The teacher spent at least 3 lessons introducing and working with technological modelling ideas. We were also interested in exploring the link between understanding technological modelling and the students' ability to see implications for their own technological practice. Therefore an 'Own Outcome' implications template was developed as part of the resource (See Appendices B).

Note: For those students not involved in undertaking technological practice at the time, a video about inductive energy transfer was provided for viewing (see http://www.youtube.com/user/researchworkswonders#p/u/15/xWkczywjmAo) and an alternative 'Wireless Car' implications template was developed. This template asked similar questions to those in the 'Own Outcome' template but with a focus on decision making and ethical issues surrounding the wireless car development.

Primary School Trial

The resource was trialed in two primary classrooms – one Year 3/4 class and one Year 5/6 class. In both these classes the teachers were already teaching a unit of technology with a major focus on the technological modelling component.

In the Year 3/4 unit the technology context was that of developing a conceptual design for an eel habitat. The unit also had a focus on characteristics of technology. Prior to watching the Adidas video the students had already discussed what technology was and had discussed what functional modelling and prototyping was. They had also undertaken two types of functional modelling of their own to test their initial design ideas for their eel 'homes'. The students were then shown the Adidas video and the class worked together with the teacher to complete the template. During this session it became clear that most of the students could not identify different types of technological modelling from the video. Even after the teacher intervened to replay parts of the video and make extensive links back to their own experiences when designing a suitable eel habitat, the students were unable to identify or explain the purpose of the modelling. In fact during this session a number of them stated that their paper models were in fact prototypes that would be suitable to trial in the water! From these discussions it was clear that the majority of these students were still working within Level 1. A few students showed beginning Level 2 understanding by explaining their paper model was used to test their idea of what size a house would need to be to fit eels in and that they had drawn pictures of their design with labels of what materials it could be made from to ask others if these materials would be safe for the eels. These students could not identify the purpose of the modelling in the Adidas video, although they did say the prototyping was used to 'pick which one is the best'. At this stage it was decided the students were not ready for the rest of the technological modelling resource (which required solid Level 3 understanding) and additional learning experiences were developed to further consolidate their Level 1 and/or 2 understandings related to why different types of modelling might be needed to test design ideas prior to developing a prototype.

In the Year 5/6 unit the context was that of developing a school garden and a plan for its ongoing care, produce cultivation and harvesting. Because there were a number of issues to think about regarding keeping the garden pest free and the desire to cultivate and sell produce, the teacher had spent a significant amount of time talking to the students about ways of finding out information and testing their ideas before they could begin to work on developing their outcomes. Many of the groups were involved in significantly different types of outcomes and therefore a variety of ways of undertaking functional modelling and prototype testing would need to be understood so the students could make good decisions for their particular practice and outcome. Prior to watching the Adidas video the students had already worked through a number of models to test different aspects of their respective designs. However, in most cases the students focused on testing a very narrow range of factors – the majority of which focused around aesthetic factors, although some students also talked about using modelling to '*figure out what you have to do*' and testing to '*see if it will work*' in a technical sense. No students discussed or undertook modelling to determine any wider social acceptability factors. A number of students were also busy making scale models of their outcome but when asked why they were doing so they could not explain what the model would help them make any decisions about.

The teacher showed the class the Adidas video and the class worked together with the teacher to complete the template. Through the discussions surrounding the completion of the template the students exhibited that they could clearly identify different types of functional modelling from the video and correctly identified the prototyping. They also related this to their own practice in developing their garden. In most cases the students were also able to explain what the purpose of the modelling was. For example when asked about functional modelling one student stated *'it's a good way to figure out what you are going to do – if your idea is good.* From these discussions it was clear that the majority of these students were working at Level 2. Some students also exhibited beginning Level 3 understanding related to the benefits and limitations of functional modelling and therefore why both were important when making decisions.

At this stage it was decided that while the students were probably not able to use the ethical thinking tool online, we would try and introduce the ethical framework underpinning this tool. We began by discussing issues which are 'tricky' – that is, things that don't have a clear 'right' answer. We then introduced each ethical approach and discussed this with the students to see if they could identify any implications of these ideas to their own work. The students struggled with this discussion overall. For example, while many students were comfortable discussing the benefits of their garden, most found it difficult to consider the possible harm. The students found it very difficult to identify how their decision making might impact on others and others on theirs, and could not see how 'being a good person' was important to the way they should work. They all considered they had the 'right' to make any decision they liked - including members of the irrigation group thinking it was a great idea to 'steal' a family members pump to get water up from the river! Early on in this discussion it became clear the students were not able to manage these ideas and no students were able to make links to how modelling might help them sort through any issues associated with their gardens. The discussion was largely teacher/researcher led and after 20 minutes was discontinued.

The final part of the trial in this class was to ask each group to reflect on their own modelling and identify examples of functional modelling they had undertaken and describe the design idea/s being tested, what they found and how they used this information in their decision making. All groups completed this task successfully. The lack of 'readiness' for this class to move beyond Level 3 however was confirmed when each group was also asked about ethical issues their group needed to think about, the impact of their decisions on other groups and how other group's decisions affected them. Only one group correctly identified an ethical issue (around whether people could be trusted). Three of the seven groups did not answer the question regarding who would be affected by their decisions or vice versa, one group identified the liaison group, while another group identified every group but the liaison group. The remaining two groups identified particular groups important to theirs, however only one of these gave reasons for this and this group was supported by the teacher to do so.

Secondary School Trial
The resource was also trialed in four secondary classrooms – in a Year 10, 11, 12 and 13 class.

In the Year 10 class the technological modelling trial was undertaken during a textiles unit where the students were designing and making a garment to be modeled at a school fashion event. The teacher had previously discussed functional modelling and prototyping using a range of examples to work with students to develop their understandings. She then showed the students the Adidas video and asked them to complete the template to confirm they were working comfortably at Level 3. Eight students completed this template and all successfully identified at least two examples of functional modelling, identified the design ideas being tested and the information gained and six students (75%) could identify the impact this information had on the overall development. Only two students (25%) noted additional things that could have been modeled and in both cases these were related to comfort and aesthetics. Six students also clearly identified the prototype and explained how it was tested and why. Only one student answered the final questions regarding whether they thought the predator boots were a 'good' design and if they were 'good' for football or not, and she did not explain this.

The students did not enjoy this video perhaps as this was a girl's school and they were in a textiles class. The teacher therefore began the next phase of the trial with a presentation and discussion of Venus William's 2010 tennis outfit (with the flesh coloured underwear) and used this as the context to introduce the ethical framework. The teacher had explored the ethical thinking tool online and considered it was not suitable for her students to work though. She was particularly concerned about the terminology used. Therefore she introduced the ethical approaches herself and during the 'outfit' discussion attempted to explain each term using many examples. This was a highly successful and animated discussion with students engaging with the concepts used on the ethical framework more comfortably as the session progressed and they became familiar with the language used. For these students, autonomy (often expressed as the 'right' of the individual, for example that of Venus, to 'do as she liked'), appeared to be the ethical perspective most prioritised during this discussion.

After the students had undertaken more work on their garment they were asked to complete the 'Own Outcome' template. Because of the timing of the trial however, no students had completed their garment to prototype stage and therefore only the questions related to functional modelling were asked. Ten students completed this template and all of them identified examples of the functional modelling they had undertaken. Examples included discussions (with peers, teacher and parents), drawings, and numerous mockups focused on different parts of the garment. The design ideas being tested showed a range of foci, with all students testing ideas related to aesthetics and fit, and most also testing different ideas related to construction techniques and material selection. All students clearly explained what they had found out and how this information informed their decision making. All but one student listed a number of additional functional models they intended to undertake prior to the final construction and finishing of their garment. The explanations given by these students showed they were taking into account what would be 'appropriate' (usually by way of dress length and/or revealing nature of the bodice) as well as was feasible in terms of translating their design ideas into a finished garment.

The majority of student responses to how the five ethical approaches impacted on modelling undertaken and/or decision making were focused on determining what would be appropriate or offensive and then making a decision in relation to that. Five students (50%) made the decision to ensure their design was not offensive to others by lengthening the skirt and/or decreasing the amount of 'flesh' being shown. The remaining five students stated that they would go ahead with their design despite the possibility it could offend others or be deemed inappropriate. For example one student stated:

> *I do think my design is on the inappropriate side… a little disrespectful in some people's eyes because it is quite revealing and tight, also it is quite gothic and this could offend people…*

However she continued to say that:

> *I believe I have the right to present and express my garment… it shows I have chosen to do what I want. I have the right to make it, show it and do what I want with it.*

The focus on offensiveness was perhaps not surprising given the earlier discussion to introduce the framework using the example of Venus' outfit. However it was interesting to note that none of the students explored any other ethical issues. In addition to the template questions these students were also asked which of the approaches they considered most important in their own decision making and what they felt they had learnt from exploring the ethical framework. In keeping with the earlier conversations around Venus, seven students explained that the most important approach for them was autonomy. Two students claimed that the consequentialist approach was most important in their decision making. As far as commenting on the usefulness of the focus on technological modelling, five students considered they had realised there was a lot more complexity to designing than they had thought, stating *'Rather than thinking does it look OK - I now think about the consequences – how will it affect others. I never realised how much planning and thought goes into designing a dress.'* Three students explained how it enabled them to have a better understanding of the reason they made design decisions, and one student stated that while '*modelling helps you design better*' the ethical activities were '*a bit boring*'. The remaining student did not answer these questions.

In the Year 11 class, the technological modelling trial was undertaken during a graphics unit where the students were developing an architectural design. The teacher had previously spent a number of sessions discussing social and ethical issues with the students – both in general and as they applied to architecture. He had shown the students a video about product lifestyle and sustainability and had expanded their ideas about types of modelling and the purpose and nature of technological modelling by using a video called '*Sketches of Frank Gehry'*. The teacher then showed the students the Adidas video and asked them to complete the template to confirm they were working comfortably at Level 3. Seven students (54%) successfully identified three examples of functional modelling with the remaining six students identifying two examples. All students identified the design ideas being tested, explained the information gained and discussed how this information impacted on changes to the boot and/or the way it was tested. All but two students (85%) discussed additional things that could have been modeled including comfort and fit, durability, colour and materials used. Of these students, seven specifically mentioned issues related to sustainability. Nine students (69%) clearly identified the prototype and explained how it was tested and why. Six students (46%) did not answer the final questions regarding whether they thought the predator boots were a 'good' design and nine students did not answer the question on whether they were 'good' for football or not.

Seven students felt the 2006 version was a good design, with three of these going on to say the development of 'predator' boots was good for football because they will attract more players and/or make the game more exciting. One student felt it was neither a good design nor good for football. At this stage the teacher could see that all students were working within Level 3 and many students were showing good Level 4 understandings. He therefore moved on to focus on the ethical thinking tool. Before using the tool however, he took the class on a field trip to the Waterfall Chapel. This is a privately built and owned chapel that has won the New Zealand Institute of Architecture Supreme Award 2004 and the Origin Timber Design Awards Joint Supreme Winner 2005. He used this amazing building as an opportunity to expand the students thinking about the nature and possibility of architectural design and how a range of different drivers can result in a community approach to decision making. He then used the chapel as an 'ethical issue' for the online tool– specifically asking the students to think about what should happen to the chapel in the future. Fourteen students worked through the online tool, all of them completing all aspects of each approach. After this, the teacher asked the students to relate what they had learnt to their own design work. As a first step he asked them to describe three different social/ethical issues designers have tried to solve with their designs and how three important social/ethical issues have affected the design of products. He then asked them to identify social/ethical issues they thought they would like to address in their own design and how modelling could help them solve the issues identified.

After the students had undertaken more work on their architectural designs, they were asked to complete the Own Outcome Template. Because the students were developing a conceptual design, only the questions related to functional modelling were asked. All fourteen students identified examples of the functional modelling they had undertaken. Examples included freehand and instrumental drawings, CAD and scale models of all or part of the building. The design ideas being tested reflected a range of social/ethical issues alongside technical issues with the students testing ideas related to material suitability and sustainability, energy efficiency, aesthetics – across senses including visual/sound/smell/temperature and spatial layout. All students clearly explained what they had found out and how this information informed their decision making. Ten students (71%) listed a number of additional functional models they intended to undertake prior to finishing their final design. The explanations given by all students throughout completing this template all showed they were taking into account what would be 'appropriate' (by way of resource sustainability, energy efficiency and aesthetics especially) as well as what as technically feasible in terms of building layout, number of rooms, textures and material durability.

The majority of student responses (85%) to how the five ethical approaches impacted on modelling undertaken and/or decision making were focused on environmental issues and identified consequentialism as a key approach to help them make decisions to ensure their design was 'environmentally friendly'. Rights and responsibilities was another approach identified as useful to support their decision making, with ten students (77%) highlighting this particularly mentioning building codes and legal issues that needed to be adhered to. Only one student considered autonomy to be a useful approach claiming that '*it is MY building… I want to make the decisions*'. Four students (31%) felt virtue ethics provided a useful approach to their decision making as this related to being a good person in terms of the environment and possible neighbours. Three students (23%) identified multiple perspectives approach as useful in that it allowed them to ensure their design did not offend others.

This data showed a number of these students were beginning to develop quite sophisticated practical as well as functional reasoning abilities to support their decision making – hallmarks of Level 5 technological modelling understandings.

In the Year 12 class, the technological modelling trial was undertaken within an ICT context prior to the students undertaking technological practice to develop a software solution for an identified client. The teacher had previously spent a number of sessions discussing functional modelling and prototyping and the differences between them and how these terms relate to modelling as it is often discussed in an ICT environment. The teacher then showed the students the Adidas video and asked them to complete the template to confirm they were working comfortably at Level 3. Six students completed this template. Four of these students (66%) successfully identified three examples of functional modelling with the remaining two students identifying two examples. All students identified the design ideas being tested, explained the information gained and discussed how this information impacted on changes to the boot and/or the way it was tested. All students discussed additional things that could have been modeled including materials, long-term impacts, maneuverability, and affect on playing in different positions. All students clearly identified the prototype and explained how it was tested and why. One student (17%) did not answer the final questions regarding whether they thought the predator boots were a 'good' design 'good' for football or not. One student felt it was good design with the remaining four students saying it was not as it did not appear to have the features of the earlier design. One student stated they felt the predator boots were not good for the game of football, with the remaining four students giving well supported arguments as to the potential benefits *and* disadvantages.

At this stage the teacher could see that all students were working within Level 3 and four students in particular showed good Level 4 understandings. She decided to proceed with the next phase of the trial – that of using the ethical thinking tool. Seven students worked through the online tool completing all aspects of each approach. These students also provided a critique of the online tool – suggesting improvements that would make it more user-friendly. As the students were not involved in their own technological practice at this time, they were asked to watch the inductive energy transfer video and complete the 'Wireless Car' implications template. Seven students completed this template and all identified a large range of functional models that could be used (including such things as public discussions, mathematical calculations, computer simulations, 3D modelling, scale models) to test design ideas related to a wide variety of social and technical aspects of the design. All students also identified and explained in detail a wide range and number of ethical issues such a technological development would raise. These issues included such things as impact on people, animals, the environment, NZ job market and economy, and increased energy generation requirements possibly leading to a move towards nuclear power in NZ and/or support of nuclear power internationally leading to increased chances of nuclear weapon proliferation. The students were then asked to choose two ethical issues, restate these as a question and discuss which of the ethical approaches could be useful to answer each question and how functional modelling might help make decisions related to these issues. Only three students (43%) completed this task. Two students selected two issues and one of these illustrated how each approach could be useful and included examples of functional modelling that could inform decision making. The other student who selected two issues, and the student who only selected one issue, both identified consequentialism as being useful and neither included examples of functional models.

The template included two further questions relating to the students future project work. Only two students (29%) responded to these questions, identifying an ethical issue they would need to, or had already, considered as part of their project set up. In both cases this issue related to the responsibility they felt towards their client. The data related to the wireless car showed highly sophisticated practical functional reasoning in keeping with Level 5 technological modelling understanding, however this Level of understanding was not evident in any responses related to their own technological practice.

In the Year 13 class, the technological modelling trial was undertaken in the context of a unit where students were developing an outcome for an identified client using resistant materials. The students were well underway with their projects and at the time of the trial many were at the stage of completing their prototype. A general discussion about technological modelling and the difference between functional modelling and prototyping was held with the students at the beginning of the trial. In this discussion the students identified the role of functional modelling mentioning such things as the importance of not wasting expensive materials during early design phases, the need to discuss initial design ideas with their client before doing too much development work with them and that while modelling could be time consuming it usually resulted in a more efficient process overall because you '*checked things out first*'. There was some confusion about prototyping with some students thinking it was a scale model of the outcome. The teacher showed the students the Adidas video and asked them to complete the template as an activity to further explore the level of technological modelling individual students were working at. Of the eleven students, only four (36%) successfully identified three examples of functional modelling, with one student identifying two examples, and the remaining six students (55%) only identifying and explaining one example. However all students successfully identified the design idea being tested in the example/s, explained the information gained and discussed how this information impacted on changes to the boot and/or the way it was tested. Eight students (73%) discussed additional things that could have been modeled including the role of the studs on the sole of the boot, comfort, support, weight and flexibility. Seven students (63%) clearly identified the prototype and explained how it was tested and why, with two students (18%) identifying the professional player testing as the prototyping. However two students identified an early functional model as 'the prototype' and the remaining student did not respond to this question. and testing Three students (27%) did not answer the final questions regarding whether they thought the predator boots were a 'good' design and five students did not answer the question focused on whether the predator boots were 'good' for football or not. The nine students answering the first question all felt the 2006 version was a good design as it incorporated the additional design feature to control the ball but '*looked better*' or '*was not as strange looking*' as the earlier prototype. Four students felt the development of 'predator' boots was good for football because they will allow players to control the ball better and/or make the game more exciting, while the two remaining students felt it was good as it 'promoted Adidas'.

At this stage, the teacher could see that while some students were working within Level 2, many students were still showing some confusion and/or lack of understanding indicative of pre-Level 1 understanding. He therefore decided to complete the online ethical thinking tool as a whole class activity. The teacher developed a question for use in the tool environment he thought the boys would be interested in. The question was: Should we be investigating alternative fuels for our school pocket bikes and go-karts? Eight students worked through the online tool with

the teacher. They only completed the aspects related to the consequentialism and virtue ethics approach due to time constraints. These students were then asked to complete the Own Outcome template. They all identified examples of the functional modelling they had undertaken to make help them make design decisions about such things as material selection, cutting, jointing and finishing in order to ensure their outcomes were strong, durable and safe, specifically mentioning the use of mockups to test their design ideas. Seven students (87%) clearly explained what they had found out and how this information informed their decision making. Four students (50%) listed a number of additional functional models they intended to undertake prior to making final design decisions and three of these students included discussing or showing particular design features to their clients. The explanations provided showed these students were mainly focused on what would be technically feasible although some did mention safety and aesthetic considerations.

As these students had only been introduced to consequentialism and virtue ethics in the online discussion, they were only asked to respond to these approaches in relation to their own work. Six students (75%) identified consequentialism as being related to their project, and identified at least one potential harmful effect (usually related to safety of the end-user) they would have to take into consideration. Three students (37.5%) also identified virtue ethics as related to their decision making around being a good person in terms of the caring for the environment or the safety of others. Six students judged their prototype as being a 'good' design, with four of these students making clear links to it being 'good' as it has incorporated a number of improved features based on information gained by earlier modelling. Only one student discussed a plan to test their prototype 'in situ'. Three students discussed testing their prototype in terms of strength only and the remaining four students had no plans to test their prototype at all. While this data provided some evidence of incorporating some ethical issues into their decision making, no links were made between this and possible modelling that could be undertaken to inform such decision making. These eight students now showed some understanding of functional modelling indicative of Level 3 and six of them showed Level 2 understanding of prototyping also.

Discussion

This trial has provided a number of valuable insights into the teaching of technological modelling and how student learning can be best supported. Firstly, it can be seen that the support resources such as the Adidas video can be a useful prop to introduce students to, and consolidate student understanding of, technological modelling up to and inclusive of Level 3. However, a significant amount of support material must be provided around such a resource to ensure students, particularly younger students, get the most out of it. We would also recommend the use of multiple resources as the subject matter of a single resource may not be of high interest to all students and this can have a negative impact on its usefulness. However, most students did relate well to this particular resource. Secondly, the ethics thinking tool on the Biotechnology Learning Hub would appear to be a useful resource for introducing an ethical framework to support technological modelling understandings at Level 4 and 5. Using this tool online was judged by most teachers and many students to be too time consuming and/or somewhat 'user-unfriendly'. This said, introducing the five ethical approaches it is based on, particularly when embedded in a number of contexts and scaffolded by teacher/student discussions, was very useful in progressing student understanding beyond Level 3. However if students are not working comfortably at Level 3, introducing them to this ethical framework does not result in any gains in their technological modelling understandings.

Finally, this data provides strong support that an increase of student technological modelling understanding from Level 1 to Level 3 can result in an increase in student's own technological modelling ability and a related increased sophistication in their technological practice – outcome development and evaluation in particular. However increases of understanding above this, and particularly at Level 5, do not appear to translate into an increased ability to undertake technological modelling and thus do not result in a greater sophistication of technological practice. In the one instance where there was some conflicting evidence to this assertion (the Year 11 graphics class) a number of additional factors were at play. These being, an ongoing teacher focus on social and ethical issues underpinning technological developments within the unit (that is a focus on CoT) and a context which had an authentic requirement for practical and functional reasoning to support sound decision making (in this case the architectural design of a building). When students are undertaking technological practice to develop a realised outcome rather than conceptual design within the schooling environment, (with the design, equipment, skill and material constraints inherent in that), it is unlikely their practice will be truly dependent on such high level reasoning requirements. Therefore student technological practice will often not be socially or technically complex enough for students to either develop or explore technological modelling understanding above Level 3. The implications of this is that to push student understanding of technological modelling above Level 3, students should be provided with rich and diverse examples of other people's practice where complex and contentious technical and socio-ethical issues are a clear and explicit factor in the decision making surrounding the technological development as whole and the specific technological practice being undertaken.

Conclusion

The two key parts of this resource – the Adidas video and template, and the online ethics thinking tool and associated implications templates, require significant modification and/or additions if the resource is to be useful for shifting student understandings of TM above Level 4. The idea of a video with an associated template appears to have merit however a video with a richer insight into technological modelling would have been more effective. Context was shown to be very important and therefore a range of contexts would be useful for teachers to select from to best suit student interest. The need for students to be given access to ethical frameworks from which to critique their own and others decision making was clearly evident from this trial. However, the format and terminology of the online ethical thinking tool was often counterproductive to the usefulness of this part of the resource. To support student progression in technological modelling, a number of additional resources will need to be developed across a variety of topics that allow students, and indeed teachers, the opportunity to develop the conceptual understanding of technological modelling required to work from Level 1 through to Level 8 of the NZC. Material which more simply introduces ethical frameworks for students should be included in such resources and must be matched with strategic processing strategies appropriate to the level the students are working within and towards.

References

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Appendix A: 'Adidas' Template

Adidas Predator		
Watch the Adidas boot development video Identify examples of functional modelling from the video: Choose three examples and answer the following:		
Describe the design idea being tested: What did they find? How did/might this have influenced the development?	Describe the design idea being tested: What did they find? How did/might this have influenced the development?	Describe the design idea being tested: What did they find? How did/might this have influenced the development?
Are there any other things you think they should have modelled? Describe the prototype in the video: What did they do to test it and why?		
2006 Version 	Do you think the 2006 prototype is a 'good' design? Why/why not? Do you think the development of 'predator' boots is 'good' for football? Why/why not?	

Appendix B: Implications for 'Own Practice' Template

Outcome Being Developed:		
Identify examples of functional modelling you have undertaken to help you make decisions: Choose three examples and answer the following:		
Describe the design idea/s you were testing: What did you find? How did you use this information?	Describe the design idea/s you were testing: What did you find? How did you use this information?	Describe the design idea/s you were testing: What did you find? How did you use this information?

What ethical issues are relevant to your work?

Complete the table below to show how you could use the ethical approaches discussed to help your modelling and/or decision making?

Approach	**Relevant Issues**	**Describe how you could use modelling to support your decision making**
Consequentialism		
Rights and Responsibilities		
Autonomy		
Virtue Ethics		
Multiple Perspectives		

Describe examples of functional modelling you plan to undertake and why

Do you think the prototype you are currently working on is a 'good' design? Why/why not?

What plans have you made to test your prototype?