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Developing designerly thinking in technology

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Introduction

In this booklet we explore a number of design ideas relevant to teaching technology to Years 1–8 students. We provide several stories to share some of the teaching approaches the InSiTE teachers developed over the course of the project. The snapshots of practice show how the teachers supported students to express and develop technology ideas and highlight aspects related to students learning how to learn in technology. The ideas and examples may be used as a resource for teachers wanting to explore the various approaches in their own classrooms and to make links to the key competencies of *The New Zealand Curriculum* (Ministry of Education, 2007), in particular exploring *using language, symbols and text*. They may also expand teachers' technology-teaching knowledge and practice.

Each story has accompanying notes that explore some of the underlying principles related to teaching and learning in technology education. This booklet is divided into several sections:

- Designing with materials, structures and function in mind
- Using design drawings to guide making
- Direct teaching of graphical drawing
- Talking and drawing alongside students

Reference

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

Designing with materials, structures and function in mind

Technology units are usually undertaken over the course of several days or weeks. They often use a cycle of planning, designing, making and testing. Many young students need help to connect activities and ideas between days and tasks. For example, they may not see the connections between planning, drawing, making and testing. They do not always understand the need to create a plan that can be realised, or to construct using their plan as a guide, or to test as they go along in order to maximise their artefact's functionality and form. They need support to make the connections as the unit progresses. If they do not understand the links, they may undertake each stage and/or task in a step-like, isolated and disconnected manner. The ingredients of interconnectivity and iterative thinking and action are absent. However, with teacher intervention such discontinuities can be minimised. To help students make connections and to work iteratively between planning, making and testing, teachers need to cue students.

If teachers want students to include particular aspects in their design and making in a thoughtful manner, they need to guide students by helping them to identify relevant aspects before they make, and indeed before they even make a blueprint plan for their making. Students need to be guided to think about what it is they are going to make, ways it can be made, what it can be made of and its functionality and its form. When teachers help students to identify and develop these kinds of ideas, students can then include these in their planning. Students are able to image more clearly when they have information and ideas to think with and through. Working directly with materials assists students to think in three dimensions. It seems essential for students to work kinesthetically with materials so that they have opportunities to explore their qualities. They also need opportunities to explore and consider techniques for fixing and joining materials.

To help students to design with materials, structures and functions in mind, teachers need to focus students on:

- analysing the essential features of the artefact they will design and produce, so that they can include these features in their own design
- thinking about the materials they might use, and examining what is actually available for them to use, so they can design with these materials in mind
- investigating the structural qualities of the artefact, including the fixing and joining devices and mechanisms, so they can include these details in their plans.

Julie and her Year 1 class

In the first example, Julie's Year 1 students were to design and make a kite using their own action plan. Before she began the unit, Julie collected several kites similar to the diamond-shaped kite that her students were going to design.

When she began to teach the unit she handed out these kites to the students. As a class they examined and discussed:

- the diamond shape, their size and the component parts (the essential features)
- the plastic skin, light bamboo struts, plastic tails, handling string and tape for fixing (the materials)
- how the struts were fixed to each other in the middle and at the corners, the reinforced corners and how and where the tail and holding string were fixed (construction and attachment methods) (Figure 1).

< She knew that with her guidance her students were capable of designing and making a simple diamond-shaped kite. She also knew that if she provided a variety of kites for examination the technology task would then be too complicated and difficult for her young students—the designing and making would be beyond their reach.

Figure 1. Simon examining reinforced corners

They also went outside and flew these real kites to judge their effectiveness. They talked about the relative merits of each kite and discussed their reasons for any differences in performance.

Altogether, these activities prepared and helped Julie's students think about and focus on all the aspects to include in their kite design, as well as how they might make it. They had accumulated ideas and were thinking ahead to designing and making a kite. They were able to image with information, they had resources to support their imaging of a design for a kite and strong connections between imaging, designing and making were made. Exploring and investigating along with teacher-led discussions led to successful designs.

Questions for you

- What might be the value of a close examination of a range of relevant artefacts as a prompt to designerly thinking?
- How would you encourage your students to draw on their previous experiences with artefacts and material exploration?

What could you do?

You may like to experiment with different ways to help your students identify strengths and weaknesses of a real artefact, so that they can then use these ideas for developing their own artefact. For example, you could:

- record student ideas and opinions for future reference or review
- ask a student to give their opinion of the functionality and form of an artefact verbally
- ask your students to fill out a comment form to indicate what they like least or most about an artefact, what the parts are, what the materials are, how it is put together.

Jenny and her Years 4–5 class

> One of Jenny's aims was to foster the students' understanding of recycling through the reuse of found materials. Hence, the gathering and use of found farm materials.

In the second example, Jenny's Years 4–5 students were designing and making their own percussion instruments for a school production. These instruments were to be made from recycled farm materials. The students visited a dairy farm as part of their social studies programme and, while they were there, they were able to gather any discarded materials. Jenny had indicated to the students before the visit that they would be searching for materials to make their percussion instruments. This meant that the students were aware of the purpose for the materials, and so they gathered the materials with percussion instruments in mind.

Figure 2. Farm materials on classroom display

When they returned to school, the materials were displayed in the classroom. The students could see what was available for them to use. Jenny also supplemented these materials with others, such as cardboard, string, rope and plastic. These were also displayed for viewing (Figure 2).

The students examined the materials and Jenny led a class discussion followed by group discussions about their possible use (Figure 3). Jenny probed student reasoning about how the materials could be used and

Figure 3. Two students explaining to Jenny how they might use the materials

which materials might be more effective and why. Her aim was for the students to become more analytic and reflective about the properties of the materials and their possible use.

The students examined real percussion instruments to work out their essential features and construction methods. Jenny guided them to focus their attention on these aspects. The students then designed their own percussion instruments and created a blueprint for how they were going to make them. They knew what was available for them to use and how the materials could be used. They knew the essential components of percussion instruments and the attachment and construction techniques. They therefore designed with these ideas in mind.

< Students could also include other materials from home if they so wished (again they were encouraged to recycle). This meant there was some freedom in material choice and therefore for design.

Questions for you

- How could you help your students to work out a suitable plan of action that included quantities of materials, manufacturing issues and a timescale?
- What kind of feedback could you give your students to help them refine their design focus to account for appropriate materials and structures?

What could you do?

- You might find it useful to help your students analyse materials in a more formal way before they begin designing. You could give your students a selection of materials and ask them to fill out a materials-analysis form to indicate, for example, the type of material, its malleability, brittleness, durability, weightiness, permeability, ability to retain its shape etc. Of course, the selection of materials and the focus for analysis would depend on the design problem at hand.

Using design drawings to guide making

Students are able to use their design drawings as blueprints for making if they are cued to do so and when they know at the design stage their drawings are to serve this purpose. Teachers need to help students think ahead to making and to think about what to pay attention to when selecting materials. For instance, when they come to making, young students often select materials because of their appeal rather than their workable properties, even when appropriate materials are specified on their plans. Teachers therefore need to pay attention to what is happening when the students use their plans for making.

Ellie and her Years 3–4 class

Ellie's students had produced design drawings of the masks they were going to make for their school production. The plans they created were design drawings with added labels. These annotated design plans met the agreed specifications and included the steps for construction and the materials they would use. Before they collected their materials, making tools and equipment, and before they began to make their masks according to their plans, Ellie reminded the students to get out their design plans. She asked them to put their plans beside them so they could serve as a reminder and a guide for their mask making. Ellie had previously provided her students with opportunities to examine real masks and photographs of masks to discern their essential features. They had also examined designs from various designers to see what real designs looked like. All these experiences influenced their thinking, and they therefore understood the requirement to produce design drawings of functional masks.

Though Ellie had focused the students on the relatively open task of constructing a mask, she had also honed in on the process of using a plan as a blueprint for constructing. This focus meant that the students were able to develop their understandings and skills for using a plan, yet at the same time they were encouraged to be creative and flexible.

Figure 4 shows Maeroa making his mask with his plan nearby. He was able to follow this plan to make his mask because he had clearly articulated what he was going to do and he was very sure about his design intentions—he was to make a real mask for the school production. Hence all his design drawings were aimed at producing a mask that worked. There was a sense of real purpose in all his activities.

Figure 4. Maeroa making a mask using his plan

Questions for you

- How could you structure your lessons and resource the activities and tasks so that all students can think through all the design and making processes?
- What steps would you take to encourage your students to use their design plans as blueprints for construction?
- How would you encourage your students to adapt the products/artefacts they were constructing if, when they were constructing, problems emerged that necessitated a change from their blueprint ideas? Would you get them to record the changes on their blueprints? Why, or why not?
- How could you develop a record of design ideas that students could access for future use? One suggestion might be a design scrapbook or electronic portfolio of digital photographs.

What could you do?

- You might find it useful to focus on more in-depth teaching of one process, such as generating design ideas, in each of your technology units. Your students can then build up their understandings and skills of various processes gradually over time.
- Invite a specialist designer in to class to show their work and talk about it.

Direct teaching of graphical drawing

Drawing is a learnt skill. Asking students to draw their design ideas and to represent a three-dimensional object in two-dimensional form is intellectually demanding. The ability to visualise objects in diagrammatic form and translate these images into line drawings is a sophisticated skill with its own conventions. Where teachers value student drawings and foster graphical ability through direct instruction, drawing becomes a powerful tool for students to demonstrate, explore and build their ideas and to make sense of the world. Teachers and students will then value graphical drawing as a tool for thinking, developing and expressing ideas.

Sometimes young students will not draw at all because they lack confidence. Often they think that their drawings should be aiming for the perfect end product: they rub out "mistakes" and alter their design drawings after they have constructed to better reflect their finished product. In fact, the development of ideas through and with drawing is essential and to be valued when the focus is on the extension of students' designerly thinking.

Glenis and her Years 4–5 class

In this story, Glenis engaged with her students' drawing problem as it occurred during the technology task. She demonstrated and discussed with the students one way to solve their three-dimensional drawing dilemma. Glenis's students had the task of designing and making mock-up models of lunch boxes that would reduce waste. They had previously completed a unit on reducing waste, and became concerned at the amount of rubbish they created each day with the food they brought to school. They set about to design lunch boxes that would reduce the amount of paper, cling film etc. they used, and then discarded, in their lunch boxes. They were working in groups and had to produce a blueprint plan for making their mock-up lunch box. This blueprint needed to show the dimensions of the lunch box, the materials and construction methods.

> They had already examined lunch boxes, surveyed the amount of unnecessary packaging they used, scrutinised the materials available and set their specifications. This meant that they were able to image with information.

As they were creating their blueprints, Glenis noticed that most of the students were going to make box-like lunch boxes, but that they were unable to draw in three dimensions. This meant that they were having trouble indicating the size of their lunch box on the blueprint. Glenis had not anticipated that her students would have this difficulty, and so she altered her planned teaching activities to provide immediate help.

> Often when students have technical difficulties that remain unresolved, they become "stuck" and their learning momentum stumbles. Teachers need to act to help resolve the problems directly by providing support for their students to learn the technical skill and then apply it to their current situation.

Glenis asked all the students to come to the mat. In the sequence of Figures 5 to 7 we see Glenis demonstrating one way to draw a three-dimensional object.

Glenis drew her three-dimensional model on white paper, which was later displayed on the class wall display as an accessible resource for the students. The students then attempted to draw their own three-dimensional lunch boxes. Some needed extra help, which Glenis provided. She talked and drew alongside the students and her discussions and demonstrations helped make more explicit the three-dimensional drawing and measuring skills required.

Figure 5. Glenis begins to draw a rectangular box

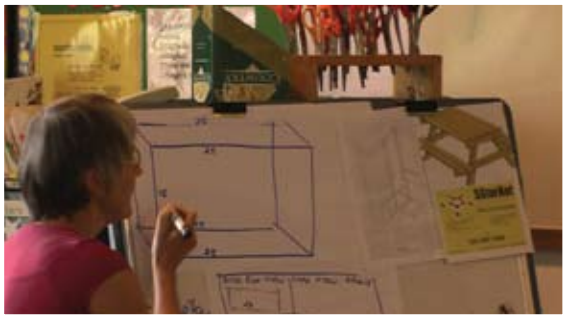

Figure 6. Glenis adds the proposed dimensions

Figure 7. Glenis demonstrates how her three-dimensional drawing looks like a real object

Questions for you

- Do you directly teach your students drawing conventions, such as cross-sectional drawings, architects' plans, exploded diagrams and rough sketches, to help them visualise and explore their thinking? If yes, what do you see as the benefit? What approaches have you found valuable for this? If not, why not?
- How would you encourage your students to think about the merits of different ways of drawing for different purposes?

What could you do?

- As part of your teaching resources you might find it useful to provide sketchpads, notebooks, annotated drawings, storyboards, orthographic drawings, architectural and engineering drawings as examples to foster student designerly thinking and behaviours.
- With very young students, you might get them to draw after making because this can help develop their drawing skills and ensure a better fit between their models and drawings. It can also allow them to demonstrate their understandings about material properties and dimensions in a different way.
- As a supportive strategy you might get your students to sketch everyday objects from various viewpoints. This can help them to develop confidence in using sketches and to represent three-dimensional objects in graphical forms.

Talking and drawing alongside students

Working alongside students as they are working through technology tasks allows teachers to identify opportunities for introducing new knowledge and skills to boost student progression. It is vital for students to be engaged in designing and making that is within or just beyond their reach. This challenges students to extend into new understandings in order to achieve success. New ideas and skills are best introduced to students at the point they need them to further pursue their designing and making.

Tanya and her Years 7–8 class

In the InSiTE project, drawing and talk together provided an important support for students to explore their thinking with their teacher. This was amply illustrated in a teacher–student drawing conversation between Tanya and three boys in her Years 7–8 class. The class task was to design and make percussion instruments for use in a school production. They had already examined real percussion instruments and gathered a range of appropriate materials, and were in the process of creating their musical score. Tanya had explained to her students that they needed to develop concise construction steps and include simple annotations in their design plan, as this plan was to be their blueprint for construction. In the example here,

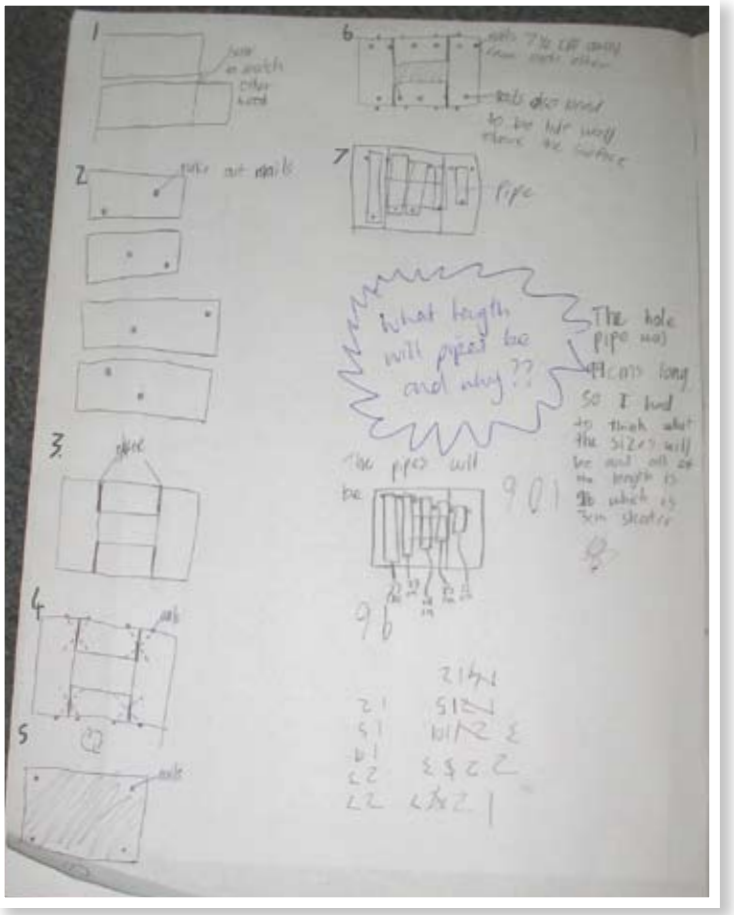

Figure 8. The boys' plan

the three boys under the spotlight were at the stage of planning out the steps for constructing a xylophone. The photograph shows the sequence of drawings they created showing how they were going to make a xylophone from recycled timber and plastic pipes in seven construction steps. The boys produced the drawings for the first three steps unassisted by Tanya (Figure 8).

The Step 1 drawing shows two rectangles of different sizes indicating the different sizes of the wood they were going to use for the xylophone's underlying wooden rack. The annotation "cut to match other end" and the dotted line indicates their intention to saw the two pieces of wood the same length.

The Step 2 drawing shows four rectangles, two smaller than the other two, depicting the four pieces of wood, now sized, for the xylophone rack. The dots on the rectangles depict the nails already in the wood. The annotation is "take out nails", showing the boys' intention to remove them.

Step 3 shows the boys' top-down view of the xylophone rack, their rectangular placement of the four pieces of wood, the label "glue" and lines leading from this label to thickened lines indicating the location of the glue. Tanya came to the boys when they had just completed drawing Step 3.

When she examined these three steps, she saw two things: first, that they had not included any detailed construction steps and second, that they had decided to only glue the joints of the wooden rack. The following dialogue ensued:

> Teacher: Remember you need to outline your equipment and your construction steps. Talk me through your steps bit by bit.
>
> Tim: First off we're going to cut this piece of wood, so it's the same size as that [points to Step 1 drawing].
>
> Teacher: Right, that's your first step.
>
> Garth: Then once it's like that, we're going to take out all the nails [points to Step 2 drawing].
>
> Teacher: So that's your second step—take out the nails … We're cutting the wood. We're taking out the nails; that's the second step.
>
> Tim: [Pointing to Step 3 drawing] Once it's like that, we're going to get a hot glue gun to join it.
>
> Teacher: A hot glue gun! Why a hot glue gun?
>
> David: We're going to ask Mr. T [specialist technology teacher] about what might be the best connection.
>
> Teacher: The best connection. Just one thing, what do you think makes the best connection for wood and wood?
>
> Garth: Nail the ends.
>
> Teacher: Nails.
>
> David: Oh, so we're going to put glue in there, as well as the nails.
>
> Tim: It's like so it will stick together better.
>
> Teacher: Make it stronger, robust, really strong, really robust.
>
> Tim: Yeah, we'll put in the glue; then nail it [the boys then drew Step 4 and annotated glue and nails on their plan].

In this example, the drawings were:

- a record of the boys' thinking in Tanya's absence
- an entry point into their thinking for Tanya when she came to talk with them.

Tanya was able to probe what would be "the best connection for wood and wood". The drawings then served as a tool that contributed to developing the meaning and implications of robustness, as this came to be taken-as-shared by Tanya and the boys. In this case it was associated with "glue plus nails" so that the wood "will stick together better".

The combination of talk, drawing and gesture were pivotal to Tanya and the boys coming to understand ideas about a robust joint being "more than glue". The drawing process provided a forum for the boys' discussion about how to proceed with the production of their xylophone.

This example illustrates the potential for drawing to anchor and augment talk to support the development of a shared understanding about the intent and potential limitations of a particular design. It also illustrates how student drawing can provide teachers with opportunities for meaningful (and useful) feedback about technology ideas that can then lead to the expansion of their students' technology approaches and solutions. The necessity for a conversation that involved more than talk is evident in this example. The interpretation and subsequent development of the boys' plan led to a more feasible design.

Questions for you

- How might a teacher focus on the use of multiple modes to enhance student learning?
- Why might the use of multiple modes enhance the learning of all students?
- How could you change the focus of interactions in your classroom to be "more than talk"?
- How do teacher conversations that focus on interpreting the technological aspects and implications of drawing assist in making valid judgements about student learning?

What could you do?

- Think about how to use talk with more purpose in conjunction with written text, drawing, gesture, demonstrative actions and the manipulation and production of objects and artefacts in your classroom.
- Plan to make more of drawing conversations as a means to focus on the technology ideas inherent in the task.

The take-home message

The production of technological artefacts involves the development of designerly thinking. Designerly thinking requires that students keep in mind the form and function of what they are designing. They need to consider appropriate materials and possible structures. They also need support to develop skills to represent their ideas so that these can become discussable with others as part of the process of developing and refining their ideas. Becoming competent in technology requires students to develop proficiency with a range of graphical techniques. Ideally in technology there is a direct link between the annotated design drawing and the process that students undertake to produce their technological outcomes. These aspects provide authentic contexts for teachers to develop pedagogies around the key competency of *using language, symbols and texts*.

A focus on direct instruction of graphical conventions coupled with discussion of students' design drawings emerged as a key feature of the InSiTE project. Attending to the ways students draw to develop their thinking provides a rich entry point for teachers to help students develop and explore ideas. Through interactions that include talk, drawing and artefacts, students and teachers were able to work together to negotiate shared understandings and teachers were able to provide targeted feedback related to students' designerly thinking.

In this resource, teachers' real names are used in the "Teachers Talking to Teachers" stories. Otherwise, names are pseudonyms.

The InSiTE research was undertaken between 2005 and 2007 when the revised curriculum (Ministry of Education, 2007) was not finalised. Therefore the teachers involved in this research based their work on the previous science and technology curriculum documents (Ministry of Education, 1993, 1995). However, given the changes indicated in The New Zealand Curriculum *(Ministry of Education, 2007), we have made links to it where possible without distorting the integrity of the findings themselves.*

References

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Technology is about more than just the practical skills to make things. Producing technological artefacts requires the development of designerly thinking.

This booklet looks at ways that the InSiTE teachers helped their students develop their design thinking—such as prompting them to consider how materials and form relate to function and using student drawings to discuss and problem solve design issues. It focuses on the key role of the design drawing in students thinking through and realising their design ideas.

This booklet outlines some findings related to teacher knowledge for primary teachers that were derived from a Teaching and Learning Research Initiative (TLRI) project, The Classroom InSiTE Project: Understanding Classroom Interactions to Enhance Teaching and Learning in Science and Technology in Years 1–8. The project involved working in classrooms over three years with Years 1–8 teachers when they taught science and technology to their students. The project aimed to identify, investigate and enhance ways of teaching science and technology.