Engaging primary children and pre-service teachers in a whole school 'Design and Make Day': The evaluation of a creative science and technology collaboration

Kimberley Pressick-Kilborn and Anne Prescott, University of Technology Sydney (UTS)

Corresponding author: kimberley.pressick-kilborn@uts.edu.au; (02) 9514 5330

Short bios:

Dr Kimberley Pressick-Kilborn is a Senior Lecturer at UTS, with a focus in her teaching and research in primary science and technology education.

Associate Professor Anne Prescott coordinates the Master of Teaching program at UTS and conducts research in STEM education.

Acknowledgements

UTS Vice Chancellor's Learning and Teaching grants in 2012 and 2013 have supported developments in this project and research assistance from Margie Christowski was invaluable. We also thank UTS colleagues Ruth Fentie, Cathy Stokes, Peter Aubusson and Matthew Kearney, and the staff and children at the partner primary school. We especially appreciate the permission of UTS pre-service teachers, Hayley Carnell, Eric Lau, Bethany Luke, Linda Ham, Esther Lim, Kerrie Hatfield, Veronica Xiao and Thanh-Thy Nguyen, to feature the Design and Make Day activities that they devised in this article.

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Abstract

A pedagogical innovation was collaboratively designed, implemented and evaluated in the context of a school-university partnership. The innovation had a dual purpose: 1) to provide an opportunity for primary pre-service teachers to develop their understanding and experience of teaching *design and produce* processes (*Working Technologically*), and 2) to involve primary children in a highly engaging, meaningful learning experience with high visibility in the school's community. We decided that this could best take the form of an annual whole school 'Design and Make Day' ('DM Day'). In this article, we describe the context of the DM Day, spotlight three of the tasks, and share the key findings from the project evaluation.

Introduction and rationale for the project

In the NSW context, the *Science K-10* syllabus (BOSTES NSW, 2012) incorporates a focus on science as well as technology education in the primary school years. The emphasis is thus on creating learning experiences which support children to develop their skills both in *Working Scientifically* and *Working Technologically* (BOSTES NSW, 2012). While numerous studies of effective teaching of science have been conducted, there are fewer studies of the effective teaching of primary design and technology (Aubusson, Schuck, Ng, Burke, & Pressick-Kilborn, 2015). Previous research has shown, however, that pre-service teachers' confidence and enthusiasm for teaching can be positively developed through design and technology partnership activities with primary school children (Mettas & Constantinou, 2007). The issue identified by Bailey (2012) is that opportunities to focus and reflect on design and technology activities with children are rare for primary education pre-service teachers. While school-university partnerships have been investigated and reported in the research literature more widely (for example, Brady 2002; Kruger, Davies, Eckersley, Newell & Cherednichenko, 2009), it is more difficult to locate published research specifically focused on partnership initiatives in primary technology education.

How to successfully prepare pre-service teachers for supporting primary children in *Working Technologically* (BOSTES NSW, 2012) was the focus of the pedagogical innovation, a 'Design and Make Day' ('DM Day') that we developed. All Australian pre-service primary teachers engage in professional experience placements in schools in the course of their undergraduate degrees. However it is problematic that some generalist primary teachers do not feel confident in teaching science and technology, possibly based on their lack of background knowledge, their own lack of personal identification with science or negative experiences in their own science learning at school. This situation is not dissimilar to that of secondary teachers teaching out of field as identified by Hobbs (2012) who stressed the need for flamboyance in their teaching and stories to illustrate concepts in order to engage and interest children. Mansfield and Woods-McConney (2012), who focused on how to enhance primary teacher efficacy for science teaching, emphasise the importance of opportunities for collaboration and successful participation in science teaching practice. Our DM Day project provides pre-service teachers with a targeted professional experience that blends their on-campus learning with implementation and evaluation of an extended, face-to-face design and technology activity in a partner primary school.

Research questions

With such previous research in mind, we created an opportunity for pre-service teacher learning which emphasised how to plan for and guide processes of designing and making for children in a primary school-based science and technology context.

Our guiding research questions were:

1. What are the affordances and constraints of a collaborative project where pre-service teachers work with primary children in a science-based design and technology day?
2. What were the outcomes for the professional learning of the pre-service teachers?
3. What were the outcomes for the primary children?

The context for the pedagogical innovation and the evaluation

Professional experience placements for pre-service teachers are generally arranged in a two or three week period within a school term. At our own university, the University of Technology Sydney (UTS), we have noticed that it has become increasingly common in our primary partner schools to have the curriculum organised so that class programs have science and technology

taught in two terms of the school year and studies of society and environment in the alternate two terms. This results in some pre-service teachers not seeing science and technology taught during their professional experience placement, let alone having opportunities to teach such lessons themselves. In campus-based workshops, the majority of pre-service teachers indicate that they have never seen children engaged in designing and making processes while on practicum. To create an opportunity for pre-service teachers to engage in planning, implementing and evaluating a design and make activity with embedded investigation, teacher educators at UTS approached a primary school to develop a partnership project.

The partner primary school context

The science and technology program in the partner school is based on *Primary Connections* (Australian Academy of Science, nd)[1], with teachers using the resource as the starting point for children's learning experiences. The school staff developed a two-year scope and sequence based on *Primary Connections*. This has helped to support and strengthen the school's teaching of science through emphasising inquiry and investigation, with inclusion of opportunities for hands-on learning (Tytler, 2007; Aubusson et al, 2015). One of the issues identified by the teachers, however, has been that while the learning process of working scientifically is strongly supported within the *Primary Connections* focus units, there is weaker emphasis on working technologically. As a result, some of the teachers have developed and embedded relevant design and make activities in their science and technology units, however this was not the case for all staff.

Features of the collaborative project between the school and the university

In consultation with teachers at the school, we decided that the project could best take the form of a whole school DM Day, which would be led and facilitated by pre-service teachers working with every class from Kindergarten to Year 6. From the University's perspective, the key purpose of the project was to promote a discipline-specific form of professional experience for primary pre-service teachers, embedded in a campus-based third year science and technology education subject. This was the second of two science and technology subjects and a new professional experience context for these pre-service teachers enrolled in a Bachelor of Education (Primary) degree. In preparation for the day, the pre-service teachers engaged in a design and make sequence in their own workshops on campus, and teacher educators provided

[1] *Primary Connections* units can be accessed by Australian educators at http://www.scootle.edu.au/

them with a variety of frameworks and proformas for planning and scaffolding children's learning prior to developing their own activities. As well as focusing on the process of working technologically, the sequence of teaching and learning activities that the pre-service teachers collaboratively devised for the day aimed to promote creative and critical thinking, as a general capability in the *Australian Curriculum* (ACARA, nd).

The specific science-based contexts for the DM day were the various *Primary Connections* science units that each class at the partner school was engaged in learning. In teams of two or three, pre-service teachers were allocated a particular class at the partner school and they became familiar with the corresponding *Primary Connections* unit by doing some of the suggested activities in their on-campus workshops. Pre-service teachers developed their own understandings of the relevant key science concepts and located other resources related to the content focus of the *Primary Connections* unit.

In the process of the pre-service teachers developing a design brief and associated design and make task that complemented the children's learning through their lessons based on a *Primary Connections* unit, there were three distinctive features. First, the school sent copies of children's curiosity questions from the early weeks in the unit, so that these could inform the pre-service teachers' design and make task development. Secondly, a video-conference was arranged. Children were selected from each grade and a teacher at the school asked them questions about their learning in the science unit. Pre-service teachers then had the opportunity to ask the children and teacher further questions. Finally, the pre-service teachers had small-group face-to-face meetings with their science and technology education lecturer, in a style that simulated a professional conversation between a 'Stage team leader' and colleague teachers who were sharing their class program. These conversations took place in a meeting room on campus, and allowed for focused feedback on the lesson plans and clarification of science understandings in advance of the DM Day, in a similar approach to that taken by Mettas and Constantinou (2007).

The Design and Make Day activities: A spotlight on 3 tasks

On the DM Day, each pre-service teacher group was allocated to a small group (numbering 6-10) of children, with whom they worked throughout the day (9:30am until 3:00pm, with breaks for morning tea and lunch). Most groups worked in a space in the classroom, while some groups worked in withdrawal rooms, shared 'wet areas' or the school's library. The pre-service teachers

needed to provide all of the materials and equipment that were needed for the tasks that they had planned. This promoted the use of readily available, inexpensive and recycled materials. For any special equipment, such as globes of the Earth, there was a loan system from the University's primary science and technology storeroom established. In 2014, the school also made available the class sets of mobile tablet devices, if requested by the pre-service teachers in advance. In most cases, however, given that the children were in small groups, the pre-service teachers brought along their own tablet devices with the applications that they wanted to use already downloaded.

We have selected three activity sequences to illustrate the variety and creativity in the engaging learning experiences designed and implemented. In each activity sequence, the 90 minutes before morning tea were focused on engaging the children, introducing the design brief, embedded investigation, and design. The 90 minutes between morning tea and lunch were dedicated to making (producing or creating) and evaluating. Pre-service teachers also used this time to support the children to plan a short presentation of the specific brief, the process and design solution or product to class peers. The 60 minutes after the lunch break were allocated to sharing presentations, which was a celebration of the diversity of learning throughout the day.

Each of the three DM Day activity sequences takes the *Primary Connections* unit that was being taught in the partner school into consideration. The activity sequences thus were designed by the pre-service teachers to draw on and build from the science learning that the children engaged in during the unit. The embedded investigations and design and make tasks spotlighted here extend beyond the content of *Primary Connections* lessons. As such, the design briefs were created by the pre-service teachers and were not lessons in the *Primary Connections* units.

Marble runs **(Foundation/Kindergarten -** ***Primary Connections*** **unit:** ***On the Move*****)**
Design brief: The children were asked to work in a pair or group of 3 to design and make a vertical race track to race a marble through. Each race track had to include 1) a textured surface, 2) a tunnel, and 3) a minimum of 5 slopes.

Embedded investigations: Children were divided into two small groups, to undertake two investigations that involved 1) changing the gradient of a slope (ramp) to observe the effect on

the speed of a rolling ball, and 2) changing the surface texture at the bottom of a ramp to see the effect on a moving ball. For each task, the children were asked to predict what might happen and explain why, before undertaking exploration. The pre-service teachers also engaged the children in discussion about how they would keep their testing fair and how they would record their observations using a table.

Stages in the design and make process: After being given time to peruse the available materials for construction, each smaller group of children worked with guidance from a pre-service teacher to draw a labelled design of a marble race track that met the criteria. Once the designs were refined and agreed upon, the groups engaged in making their tracks. The children then raced their marble through the different tracks, to see which track was fastest or slowest, with discussion of why this was the case, focusing on the gradients, textures and other characteristics (number, length) of slopes in each track. The pre-service teachers developed rubrics to record their assessments of children's conceptual understanding, use of the design process and their collaboration and communication skills.

<Insert photograph 1 *Caption* Children were given time for testing their ideas>

The Ant-Hillton: Habitats for ants or snails **(Year 1 -** ***Primary Connections*** **unit:** ***Schoolyard Safari*****)**

Design brief: The design brief was presented to the children by the pre-service teachers, who were in-role and dressed up as The Ant-Hillton Hotel Manager, Charlotte Swebb and Project Manager, Katy Pillar. The children's task was to work in pairs to design and make a model of a 'hotel' in which ants and snails can co-exist, considering the characteristics, features and needs of each animal (eg. snails can eat through paper.)

Embedded investigations: Initially, children's knowledge and understanding of ants and snails (as gained in previous weeks of learning activities in the *Primary Connections* unit) were elicited through a brainstorming activity, with further information then shared using the iPad app, *Project Noah* (Networked Organisms, 2011). Subsequent investigation focused on a group 'safari' in the school's playground, to identify habitats suited to ants or snails. The children were given iPads to photograph areas of the playground, with subsequent discussion of the features of these habitats stimulated by the photographs on return to the classroom.

Stages in the design and make process: Children were given time to look through the available construction materials prior to designing their hotels. Once they had created labelled drawings or plans of their hotel, the children created their models. Polaroid photographs were taken of the finished products for children to keep. The children reflected on differences between their designs and final products through conversations with the pre-service teachers, with encouragement to discuss reasons why changes were made. In their presentations, the children highlighted specific features of their models which were designed to meet the needs of the ants and snails.

Solar system tourists **(Year 6 -** ***Primary Connections*** **unit:** ***Earth's Place in Space*****)**

Design brief: The children initially were asked whether they had been on holiday before, and to describe what they needed to pack, especially to wear, depending on the conditions of the destination. They were then told that they were about to become tourists of a different kind, and needed to prepare for a trip to a planet of their choice in our Solar System. The specific task was to work in a group of 3 to design and make 1) at least one piece of clothing, 2) a source of oxygen, and 3) something for entertainment or communication, to take to their chosen planet. They were asked to be logical and creative, and were told that they needed to be able to justify their use of particular materials. Children were given a proforma on which to record their planning and reflection, based on Wray and Lewis (1999).

Embedded investigations: Once the smaller groups had chosen their destination planet, they were then given iPads with some bookmarked websites so that they could undertake research about conditions on that planet. Guiding research questions provided by the pre-service teachers scaffolded the children's inquiry, with a particular focus on climate, surface conditions, gravity, length of day and night, and size. The information located subsequently informed the children's designs.

Stages in the design and make process: Each smaller group of children was given a pack, with a variety of materials such as aluminium foil, bubble wrap, plastic bottles, labels, tubing, and rope, along with scissors, sticky-tape and a planning sheet. In addition, there was a large pile of shared materials such as cardboard boxes and fabric, that all groups could access. Each group worked with a guiding pre-service teacher, and following the creation of labelled designs,

engaged in making their equipment. The smaller groups then came together and shared their creations on a cat-walk, with children in other groups having to guess what had been made and for which planet the equipment had been designed. The children explained their designs to one another, asked one another questions and provided feedback. The final discussion focused on the reasons why other planets cannot sustain life.

Evaluation methodology and analysis

In each of the three years of the project's implementation, there have been 11 primary classes at the school, with a corresponding number of class teachers and an average of 75 UTS pre-service teachers. Both inservice class teachers and pre-service teachers were asked three broad questions in a written reflective evaluation at the end of the DM Day in each of the years: (1) What do you consider the most successful aspects of the day? (2) Did anything surprise you? (3) What would you change if we partnered to have a similar activity in the future? In addition, in 2013 there were two pre-service teacher focus groups, which provide additional data. Teacher educators also had reflective evaluative conversations amongst themselves following the DM day, where written notes were taken. While we did not gather any data directly from the children, both pre-service and inservice teachers' reflective evaluations gave insights into the primary children's experiences and their perceptions of the children's learning.

Pre-service and inservice teachers' perceptions and experiences of the day were documented in their reflective evaluations. The qualitative approach taken to analysing these reflections was based on multiple, repeated readings by each of us, with codes generated and agreed upon (O'Toole & Beckett, 2010). We then systematically looked for similar themes in the focus group transcripts and notes from the teacher educator conversations, as well as interrogating these additional data sources for divergent themes. Through this process, three key themes emerged across the data sources:

1. children's engagement, creativity and risk-taking,
2. children's prior knowledge, the need for task differentiation and pre-service teachers developing the ability to teach responsively and flexibly, and
3. pre-service teacher confidence and the positive experience gained through an opportunity to team-teach science and technology.

Discussion of each of these themes follows, with direct quotes selected from reflective evaluations written by participating pre-service, inservice teachers and teacher educators.

Findings of the evaluation

Children's engagement, creativity and risk-taking

Overwhelmingly, both pre-service and inservice teachers regarded the most successful part of the day as the engagement of the children. "The design and make part of the lesson was very interactive and got the children very involved and interested as it gave them ownership of their work" and involved "the class in an authentic and inclusive learning experience" (pre-service teachers). For some pre-service teachers it was also the most surprising part of the day - perhaps because their prior experiences of a primary science and technology lesson were limited. "Hands-on work really got the children engaged and thinking. I recommend that" (pre-service teacher).

A number of pre-service teachers also commented that a successful and surprising part of the day was "how creative and excited the children were". They commented on the willingness of the children to modify their products, when their designs did not go according to plan during the making phase in the sequence. Equally, the inservice teachers commented on the creativity of the pre-service teachers, particularly noting those who dressed up and ran the session using a 'teacher-in-role' educational drama strategy. The teacher educators also reflected on the importance of the variety of materials available to the children to enable the design and creation of creative products. They noted that the creativity of the children was supported by an enticing display of varied resources and materials for 'making', that promoted a sense of possibility for the children in designing their products.

<Insert photograph 2: *Caption* A range of thoughtfully selected and attractively presented materials for making>

Children's prior knowledge, the need for task differentiation and developing the ability to teach responsively and flexibly

Many pre-service teachers were surprised by the children's high degrees of prior knowledge. One inservice teacher also commented on her appreciation of the opportunity to observe how much the children in her class had learnt over the term, as they engaged in the activities with the pre-service teachers on the DM Day. A few pre-service teachers were surprised, however,

at the lack of prior knowledge; the reflection that “[children] knew so much already” contrasts with another observation that “the [children] didn’t remember what they learnt previously”. In their own classroom, of course, they would be responsible for developing the prior knowledge of the children ahead of a design and make task, and would also know the capabilities of the children. The teacher educators also reflected on the importance of the pre-service teachers’ own content knowledge being sufficiently deep and broad, to enable them to suitably extend the children.

Pre-service teachers often find it difficult to pitch the lesson at an appropriate level so they can find themselves with either too much or too little material, or with material in the lesson that is not appropriate for the class. One of the inservice teachers noted that, “Activities perhaps were a little young for my kids, but they enjoyed it. I just feel they could have been stretched a bit more.” Some pre-service teachers realised that as, “the [children] finished things early - we needed more back-up”, and that “[children] didn’t seem very challenged by the lesson. It could have included more complex terms / ideas”. Such reflective comments from a number of the pre-service teachers indicated that their experiences on the DM Day renewed an appreciation of the need to plan extension activities, and the importance of responsive and flexible approaches to teaching.

Teaching smaller groups of children on the DM Day meant a greater focus on individuals’ learning needs was possible, which highlighted not only the need for differentiation but provided an opportunity to put specific pedagogical strategies into practice. The teacher educators observed that engagement with the children was most effective when the pre-service teachers were focused on posing questions. Such questions were aimed at promoting deeper thinking about the focus science concepts, greater consideration of decisions being made during the design process, and promoting children’s reasoning as they planned their presentations. On the flip side, some pre-service teachers believed that the student-teacher ratio may have been a little overwhelming for the participating Kindergarten to Year 6 children. This belief was not necessarily one shared by all, however, as reflected by an inservice teacher who commented that “my class benefited greatly from the small group environment so that all children were guaranteed success!”

<Insert photograph 3 *Caption* Children worked in small groups with pre-service teachers to design and make their products>

On reflection, several pre-service teachers commented that they would have liked a way of knowing of any particular needs of children in advance, to enable them to better plan for the day. Some inservice teachers also commented on the potential for more collaboration before the DM Day, to ensure both children and pre-service teachers were prepared. As one of the teacher educators reflected, “I’ve always pitched it to them as a casual teaching day - you only know the grade in advance, you do not know the children in the class and you have to make a quick assessment at the beginning of the day and adjust your plans accordingly - but this might be expecting too much of 3rd year student teachers? Something to think about for next year, perhaps.”

Pre-service teacher confidence and the benefits gained from a positive team-teaching experience

The pre-service teachers were overwhelmingly positive about the experience of the DM Day. Their reflections indicated that their confidence in teaching a science and technology lesson increased, having had the opportunity to collaboratively plan and successfully teach a sequence of tasks on the DM Day. Pre-service teachers commented on “how successful the activity was - the students achieved!”, and that “seeing the children present their final product was very successful”. It also was “good to see how peers teach” (pre-service teacher) and there was a sense of security provided through team-teaching, in that there was collective responsibility for professional problem-solving in situ.

A number of carefully planned factors contributed to the positive nature of the experience. The pre-service teachers were supported by their peers in teaching teams, by the class teachers who worked with the children to enable them to have the prior knowledge of the science content, and the university-based teacher educators and inservice teachers who were available during the DM Day to provide ‘just-in-time’ assistance if needed. These factors in concert created a scaffolded experience for the pre-service teachers that greatly increased the likelihood of success, which in turn promoted their sense of efficacy (Mansfield & Woods-McConney, 2012).

Discussion and conclusion

The key strength of this project for the pre-service teachers is that it is 'real'; they develop a lesson sequence that is embedded in a science and technology unit in which the children are currently engaged, and receive feedback on their planning from the teacher educators. The lesson sequence is then actually implemented with a small group of primary children, using a collaborative, team-teaching approach that provides opportunities for reciprocal peer observation amongst the pre-service teachers. "You can learn so much in a lecture but to put that into practice in a real teaching scenario was really great" (pre-service teacher). The associated assessment for the pre-service teachers also is contextualised, engaging them in collaboratively evaluating their teaching and learning. The process itself is designed to be supportive, from team-teaching a small group of children to receiving lecturer guidance and input at each stage.

It is also important to acknowledge the professional learning element of the project for the inservice teachers at the school. The DM Day provides an opportunity for them to learn from the pre-service teachers about a range of possible tasks that could be incorporated in the class program in future. Having the DM Day implemented by the pre-service teachers also enables the class teachers to step back and closely observe the learning and engagement of individual children. Additionally, it is evident that the children also look forward to the DM Day from the excitement they share as they approach the pre-service teachers in the school playground as they arrive in the morning at the school to set-up. The nature of the activity, organised as a dedicated day for designing and making, with the usual lessons set aside, contributes to it being a memorable learning experience. The teacher educators had conversations with children throughout the day, who could share exactly what they did in the previous two years on the DM Days, and name the peers with whom they worked. Since initiating the project with the original partner school in 2012, we have now established similar projects with two other primary schools.

Finally, in the words of a UTS pre-service teacher, "In the same way that the children were passionately engaged by our scenarios, I really felt that this project was so exciting and captivating. It was easy to be engaged and interested. I found myself so motivated to put something exciting on for the kids. Love, love, loved it!!!"

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