A THEMATIC APPROACH TO INTEGRATING MATHS AND SCIENCE FOR PRE-SERVICE PRIMARY TEACHERS VIA SUSTAINABILITY

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Abstract

Efforts to improve mathematics and science content knowledge have in many institutions required redefining teacher education through new teaching and learning. See, for example, Peard & Pumadevi (2007) for an account of one such attempt involving the development of a Foundations Unit, Scientific and Quantitative Literacy. This unit is core for all first year pre-service primary teacher education students at Queensland University of Technology (QUT) and two Education Institutes in Malaysia, Institute Perguruan Raja Melewar (IPRM), and Institute Perguruan Teknik (IPT) Kuala Lumpur. Since then, QUT has modified the unit to adopt a thematic approach to the same content. An aim of the unit rewrite was the development of a positive attitude and disposition to the teaching and learning of mathematics and science, with a curiosity and willingness to speculate about and explore the world. Numeracy was specifically identified within the mathematics encountered and appropriately embedded in the science learning area. The importance of the ability to engage in communication of and about mathematics and science was considered crucial to the development of pre-service primary teachers. Cognisance was given to the appropriate selection and use of technology to enhance learning - digital technologies were embedded in the teaching, learning and assessment of the unit to avoid being considered as an optional extra. This was achieved around the theme of "*the sustainable school*". This 'sustainability' theme was selected due to its prominence in Australia's futures-oriented National Curriculum which will be implemented in 2011. This paper outlines the approach taken to the implementation of the unit and discusses early indicators of its effectiveness.

Introduction

Bransford, Brown, and Cocking contend "Much of what constitutes the typical approach to formal teacher professional development is antithetical to what promotes teacher learning" (1999, p. 240). Not only do teachers need the knowledge and skills of their craft, they need to be learners in the classroom. They need to be able to improve their teaching through reflection and evaluation (Darling-Hammond & Bransford, 2005). Research regarding how blended course design can prepare teachers for professional collaboration, problem solving, and evaluation is needed. Blended instruction is an emerging delivery method in Australian teacher education programs. It combines face-to face instruction with online instruction (Bonk & Graham, 2005). Blended learning is in contrast to traditional face to face instruction which is led by the lecturer and only has person-to-person interactions. Blended instruction and learning is the preferred delivery mode as it encourages asynchronous learning. This allows the student:

- More time to complete a task;
- To employ their own preferred learning style, and
- Maintains the quality of lecturer-student interaction in the classroom (Lin, 2008).

It should be noted that the learning effectiveness of blended learning is simply based on sound instructional design principles and practices, and the strategic implementation of the principles and practices (Russell, 1999). In this paper, we present a model for blended learning to enhance good practice in pre-service primary teacher education.

That many students begin teacher education displaying negative attitudes towards mathematics and science is a continuing concern (see, for example, Grootenboer & Lowrie, 2002). Furthermore, as Aubrey (1997) notes, it is fundamental that a teacher understands the subject content they teach if they are to be effective teachers. Ma (1999) categorised teachers' mathematical content knowledge as thorough understanding of mathematics having breadth, depth, connectedness and thoroughness. Ball, Thames & Phelps (2008) referred to this as *specified content knowledge* and is what teachers need in their teaching to identify a range of solutions and connections. Most pre-service primary teacher education programs in Australia only allow a limited time for the teaching of mathematical and scientific content. It is therefore important to make the most efficient use of the limited time available to improve the general mathematical and scientific competencies of pre-service primary teachers.

Purpose of the Study

The research was guided by the following question: How did course design in mathematics and science education promote collaboration, reflection, and learning from one student to another?

Conceptual Model

The conceptual model for this study was the *How People Learn* (HPL) framework, a synthesis of the scientific basis of learning published in several National Academy of Sciences reports (Bransford, Brown, & Cocking, 1999; National Research Council, 2000). The HPL framework focuses on the learning environment and indicates that effective learning takes place to the extent that the learning environment is:

- *learner-centred;* taken into account is the "knowledge, skills, belief, perceptions, misconceptions, and learning styles of the students" (Cox, 2009, 2). The learners need to use existing knowledge in order to construct new knowledge. Thus, what a student knows, and who they are impacts upon how a student interprets the new knowledge. The implications for a teacher or course designer is that they must develop an awareness of the learning differences of their students (Dole & Bloom, 2009).
- *knowledge-centred;* cognisance is given to promoting learning with understanding by organising content around core concepts and an understanding of when to apply these concepts (Cox, 2009). Concepts are presented so they link students' existing knowledge to new understandings and build higher level thinking skills. In a knowledge-centred perspective, thinking about curriculum design is essential; teachers have to think carefully about what they teach and why they teach it (Dole & Bloom, 2009).
- *assessment-centred;* this allows the students to make their thinking and learning visible, and to revise this thinking through feedback techniques (Cox, 2009). Teachers use a suite of assessment strategies and give students feedback to improve their achievement. "Formative assessments are important because they give students the

opportunity to revise their work and help them learn how to self-assess their own progress" (Dole & Bloom, 2009, 3).

- *community-centred;* encourages students to share a belief in the importance of learning and achieving high standards (Cox, 2009). Thus, instructors need to create safe learning environments in which communities of learners can thrive. Teachers need to structure collaborative activities based on common behavioural practices that promote a sense of community (Dole & Bloom, 2009). From a school perspective, collaboration with other teachers can further increase the professional status of teaching (Clark, Hong, & Schoeppach, 1996). Teachers today are more likely to be expected to be active participants in decisions that affect the entire school. No longer are teachers relegated to their individual classrooms, isolated from their colleagues, and disengaged from school-based management.

Unit Design

The unit is a core foundation undergraduate unit which integrates mathematics and science content. The unit is required for registration as a primary school teacher in Queensland, Australia. The unit was designed using the principles of the *How People Learn* (HPL) framework which is inquiry-based and presented as a "learning cycle," with the learner progressing through a series of phases in exploring a multifaceted challenge (Dole & Bloom, 2009). To design a unit, the unit needs to be divided into modules, with each module having a challenge based on an important mathematics and or scientific concept relevant to the context. This modular design is to help the Lecturers prioritize the concepts and skills of the unit, set objectives for what the students should understand by the end of the unit, and arrange activities to help develop the students' understanding (Brophy, 2000). In each module, the students progress through all phases of the learning cycle. Brophy describes the six phases of the learning cycle as follows:

- *The Challenge* - A statement or scenario is presented which poses a complex objective for the students. The challenge should be related to a major concept of the course that students should come to understand in order to meet the objective. In the case of the present unit, the challenge was to design a sustainable school.
- *Generate Ideas* - Students are provided with an outlet for showing what they know about the challenge. It can serve as a baseline or pre-assessment. In the case of the present unit, an online blog for weekly reflections was provided.
- *Multiple Perspectives* - provide insights on the challenge. These statements or comments from experts do not provide a solution but should help the students see the many dimensions to the challenge. In the case of the present unit, additional tutors and guest lecturers provided expertise.
- *Research and Revise* - engages students in learning activities linked to the challenge. These can be readings, homework problems, simulations, or other activities. In the case of the present unit, technical notes, and specifically designed science investigations were provided.
- *Test Your Mettle* - application of what students have learned and evaluation of what they need to know more about. This step helps students reflect on and synthesize what they know. They may have to go back to the *Research and Revise* phase if they find that they need to learn more. In the case of the present unit, class time was allocated for students to share their learnings prior to a teaching presentation.
- *Go Public* - provides students an outlet to demonstrate what they know at the end of the module. In the case of the present unit, each student presented a seminar.

Methodology

Research Design

A qualitative case study approach was used for the design of the study. Merriam (1998) defines a qualitative case study as "a thing, a single entity, a unit around which there are boundaries" (p. 27). Case studies are particularly relevant when the researcher is interested in process, as in this study. A qualitative case study should give the researcher and reader a feel for the context of the issue and the purpose of the inquiry.

Participants

There were 255 students enrolled in the unit. The students taking the unit were predominantly school-leavers in their first semester of university study. The cohort self-allocated into ten tutorial groups. The data used in this paper is drawn from five of these ten tutorial groups. Each student completed a weekly reflective journal in the form of an online blog, as well as presenting a 10-15 minute colloquium. Student artefacts used in the colloquia were also considered.

The unit

The unit, MDB001 Foundation: Scientific & Quantitative Literacy, is the initial mathematics and science learning experience in the sequence of units required for graduation and registration as a primary school teacher in Queensland, Australia. The following aim is given in the unit outline: "*This foundation unit aims to increase your awareness of the role of mathematics, science, and technology in society. Your confidence in working with mathematics, science, and technology will also be enhanced. You will participate in knowledge creation of core mathematical and scientific concepts, principles, and processes, and develop problem-solving competencies, higher-order thinking skills, and mathematical and scientific reasoning processes. The development of elementary pedagogical skills in lesson planning, implementation, and evaluation (critical reflection skills) are also key aims. The unit will encourage your use of ICT's in learning*." The unit was designed as five modules, each module based around the six phases of Brophy's (2000) learning cycle. The challenge of the Lego robotics module was to programme a Lego robot to complete two challenges: 1) to bury carbon dioxide, and 2) to elevate a house (These were challenges from *The First Lego League* international competition which had a 2008 theme of "Climate Connections" (See: http://firstlegoleague.org/community/TabbedPage.aspx?id=1002)). Subsequent modules dealt with important concepts specific to the unit context of *The Sustainable School*. Table 1 contains a summary of the key ideas for each module.

Table 1. Modules and their content.

Modules	Key Ideas and learnings
1. School Automation	Lego Robotics challenges with sustainability themes - Problem Solving, Working Scientifically, Thinking and Reasoning.
2. Built Environment	Considered the location and positioning of the school. Insulation requirements and furnishings - Measurement, Metric Units, Scales, Latitude, Longitude, Time Zones, Derived Units, Geometry, Angles, Perspectives
3. Energy	Links Built and Natural Environment – Energy, Electricity, Solar Power
4. Natural Environment	Water supply and usage in the school, edible school yard - Symmetry, Crystals, Soil, pH, Microscopes, Measuring Microscales, BioGeoChemical Cycles, Energy, Carbon, Water, Wind
5. Carbon footprint	Mathematical and Scientific Modelling, Carbon Footprint

Data Analysis

Qualitative data was collected from the data sources. Reading and re-reading of reflections facilitated a coding of the information, where categories and themes were identified. The categories were compared to form major themes. Video analysis of the colloquia involved transcriptions, coding, and category then theme generation.

Findings

The resultant themes from the data analysis aligned with aspects of the HPL framework. The integration of mathematics and science, through a context relating to the design and building of a sustainable school appears to have had a positive impact on the learning of the pre-service teachers. The results are presented below in relation to the School Automation - Lego Robotics module which had the underlying aims of problem solving, working scientifically, thinking and reasoning as well as school automation in the sustainable school. Four themes are presented. Identifiers of students are S1, S2 and so on.

Theme 1: *Constructivism*

The Constructivism theme aligns with both the *learner-centred* and *knowledge-centred* components of the HPL framework. Numerous students made reference to using past knowledge to form new knowledge. The formation of this new knowledge was often described as *better knowledge (S1), more informed learning (S2),* and in one case *what I think is a higher level of understanding (S3).* How this new and improved knowledge came to the awareness of so many students is through the *activity being of interest to us (S1),* and as one student (S4) wrote:

> *I think we learnt so much more because we were engaged, the activity was picked because they [the Lecturers] knew what we would like. It was like wow! 1st day at university and we get to play with Lego. I had my doubts, but very soon I was convinced this was for me. The activity suited me, the context suited me, and importantly I was meeting new people who will hopefully be my friends for years to come.*

The notion of motivation was made explicit by a number of students. S5 clearly understood the need for engagement:

> *While undergoing these activities I also looked around the room and I noticed how motivated everyone was to completing the task. I realised then that I myself felt this way because I was able to experience the activity. It was a hand on lesson and I wanted to be involved. This shows that hand on activities are a great way to learn.*

The importance of hands-on learning was also stressed by many students. The Lego Robotics activity proved very popular for the refreshing of terminology and basic skills in mathematics. The following student did not see the activity as a one-off single learning exercise to fill a 2 hour tutorial. The student (S6) saw the activity as a means of providing an educational platform on which to build further learning:

> *The use of the Lego robotics assisted in providing students with hands-on opportunities to construct and carry out multiple operations which incorporated the use of guess and check in order for the robots to fulfil the required tasks. The incorporation of basic maths and scientific terminology provided students with the tools to express the activities actions and functions in an educational manner, thus constructing a bank of terminology that can be use in later activities.*

Theme 2: *Attitudinal change*

The Attitudinal change theme aligns with the *community-centred* component of the HPL framework. Numerous students made reference to being initially fearful about having to undertake a university mathematics and science unit in their first semester at university. Beginning university was very daunting, but exciting, for most students, and many were dreading undertaking maths. However, by designing the unit around an integrated conceptual theme, and beginning the unit with a Lego robotics module, many of these fears were allayed as described by the following two insightful students:

> *What I believe to be important is what I learnt about myself and the way I think and learn. I came to realise that I have, to some extent, a fear of mathematics and science. Reflecting on this fear now, I don't think this is because I believe I am bad at these subjects. I think the idea that scared me off was an impression that these subjects have only one correct answer, and only one way of getting to this correct answer. This made me feel that if you do not have an understanding of a particular algorithm, for example, you could not do well in that topic. I have now come to realise that this assumption I had cemented into my brain may not necessarily be true. (S7)*

> *I learnt that mathematics does not have to be difficult. As a student teacher, I can't afford to find it boring or hard; this may impact how my future students will feel about mathematics, which is not a good thing. (S8)*

Theme 3: *Group work*

The Group work theme aligns with both the *knowledge-centred* and *community-centred* components of the HPL framework. Students made mention of opportunities to work with

other, in small groups. *I particularly like the way we were expected to keep in the same group each week, Not change around each time. Security is important, and it made the maths less threatening (S9).* The processes of the group work and the implications for learning are clear in the following insightful reflection:

> *Maths has never been my strongest subject and I was sure that the activities required of us would prove a difficult challenge. I had never imagined that one day I would be sitting in a tutorial programming a Lego robot by putting into practice some of the math theories I thought I would never consider using. It helped that we were working in groups and I valued my peer's suggestions in this problem solving matter. During one activity we were asked to find the distance of one wheel revolution. We achieved this by pooling our knowledge on the subject and presuming that if the circumference is equal to the diameter of the wheel multiplied by 3.14 (pi) we would find the distance of one wheel rotation. With this information we then found the distance of one rotation which we could use to find how many rotations the wheel makes in a given distance (S10).*

Theme 4: *Problem solving*

The Problem solving theme aligns with both the *learner-centred* and *knowledge-centred* components of the HPL framework. The problem solving theme was the most prevalent for this particular module. Approximately 80% of students made reference to the problem solving that occurred between peers. Although there is overlap with the Collaboration theme, the notion of problem solving is also clearly evident. The following reflection from one student shows this overlap, but the essence of this somewhat descriptive reflection is problem solving.

> *When carrying out the tasks, we found ourselves working through Polya's strategy without being conscious of doing so. We looked at the problem, we discussed what we interpreted the problem to be, we suggested solutions and discussed our thoughts, we drew diagrams to assist us with calculating the mathematics, and we experimented to conclude if our solution was correct with our calculations. The majority of the time, we used deductive reasoning to help solve the tasks by having a theory then experimenting to confirm our hypothesis.(S11)*

Of interest in the above reflection is also the link the student is making to Brophy's (2000) "learning cycle". The learning cycle requires a challenge for the overall unit, as well as a challenge in each module. While not explicit, S11 describes the challenge of programming the Lego robot. By working scientifically, the group were able to use visualise the problem, pose a hypothesis, test and retest calculations in order to finally solve the challenge. Another student elaborated on how the kinaesthetic nature of Lego robotics enhanced their mathematical learning:

> *The mathematics made more sense and seemed much clearer when we had something physical in front of us than if we had the same problem in a text book. It gave us a visual understanding of the problem and provided us results that we could see, which in actual fact, showed us that our calculations were incorrect and we needed to go back over our workings. (S12)*

As previously indicated, the student statements used in this paper have been selected from the online blog they were required to write at the conclusion of the Lego robotics module, to enable them to reflect on their learning. The purpose of this requirement was to detect 'at risk' students, as well as providing early course feedback to the students on their progress. Although the nature of the reflection was to explore their thinking and learning, a number of students commented that they appreciated this early 'check' on their progress:

> *I like learning maths and science this way, It is interesting being given a problem and having toys to solve it. It doesn't seem to matter if we get it wrong – this is something I am yet to understand, because we can look on internet for help, we can ask others, and now we get this blog thing to do to see if we are coping. This is good to know so early on. It is a different way to do maths, I am looking forward to being able to do the teaching presentation at the end of semester. That's what I am here for. I don't get to teach in other units so this will be fun. (S13)*

S13 was personalising the requirements for the unit. She was appreciating the assessment-centred component of the HPL Framework in terms of both the early check on progress and the final assessment task of a teaching colloquium. She also made reference to the multiple perspectives component of Brophy's (2000) 'learning cycle' where she had more sources to draw upon, than just herself, to solve a problem, or meet the requirements of a challenge. S13 was looking beyond the immediate nature of the task, as was another rather astute student who made the following reflection:

> *I have also learnt that the purpose of these activities is not the data or facts gained at the conclusion of the activity, but the knowledge and understanding gained through process itself. When it came to applying the mathematical theories that I had learnt in school, I had forgotten them, as they were taught to me as rules, rather than demonstrated in real-world models. I now view technology as a method of understanding that is realised through real-world problem solving which creates curiosity and passion for learning, the facilitation of self-learning, and the confidence and ability for self-application. I can now take these principles and implement them into my future lessons as a teacher. (S14)*

Summary and Conclusion

The purpose of the paper was to explore how the course design for a foundational unit in mathematics and science education could promote collaboration, reflection, and learning. By considering students written reflections we have concluded that the design of a unit following a HPL framework can promote collaboration, reflection at varying degrees of depth, and learning. Through using a modular approach, small challenges were able to be enjoyed by the students, along with the overarching challenge of designing a sustainable school. The use of a blended learning approach enabled students to be autonomous learners and provided lecturers with the opportunity to monitor student progress in respect to the online blog reflections. The culminating activity of a teaching colloquium provided the students with the opportunity to 'go public' with their learnings in relation to the overarching challenge. Figure 1 was used by one student (S15) to demonstrate his understandings of scale.

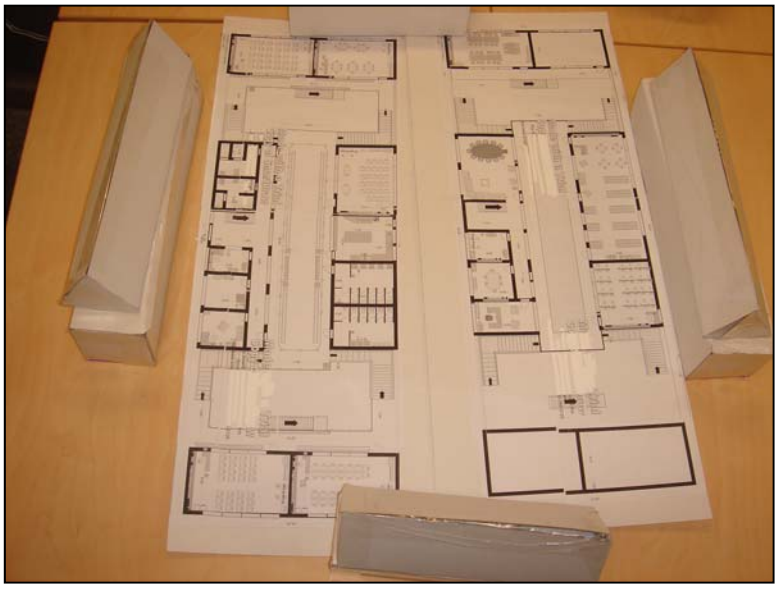

Figure 1. The Sustainable School floor plan used by S15 in his teaching colloquium.

He set himself the challenge of drawing a floor plan for his sustainable school. To do this he had to make accurate measurements and convert them to scale representations of the life-sized item. He then used a computer program to draw the school. It should be noted that prior to this challenge, the student had no prior experiences in the construction and design of floor plans and buildings. The following statement by S15 during his teaching colloquium provides us with a nice conclusion to this paper:

> *That's the school there. So it's gone from the 2D plan, to the 3D model, to the 3D concept. It wasn't easy to do, but I really enjoyed the challenge, and the maths that I learned about area and space and ratio was really staggering. I've never had to measure a toilet before … or think about children needing … different sized desks … So everywhere I turned there was new maths to be done.*

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