IMPROVING SELF-CONFIDENCE AND ABILITIES: A PROBLEM-BASED LEARNING APPROACH FOR BEGINNING MATHEMATICS TEACHERS

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This paper draws from a pilot study about a teacher education program that focused on building preservice primary teachers' confidence and abilities in teaching and learning mathematics. The cohort involved on-campus [*n*=82] and off-campus [*n*=420] participants. The qualitative study was based on developing three aspects of mathematics teacher education: (1) Content knowledge; (2) Pedagogical knowledge; and (3) Knowledge of the learner. A problem-based learning environment was created to build students' self-efficacy and to encourage the beginning teachers' willingness to engage in the unit content by providing authentic teaching contexts, and to develop a richer conceptual and procedural understanding of mathematics.

Introduction

For many preservice primary teachers, learning to teach mathematics can be a challenging and, at times, a fearful undertaking. Many researchers (Black, 2007; Jorgensen, Grootenboer, & Sullivan, 2010) have discussed the nature of preservice mathematics education, and in particular, how a social constructivist approach can enhance a productive disposition and willingness to engage in learning mathematics. Student-centred learning offers a pedagogical approach for mathematics education in the 21st century where the educational paradigm shifts from traditional, teacher and textbook-centred approaches, to situations where the learner is personally challenged and engaged in a social construction of knowledge.

This paper describes an ongoing project that seeks to investigate a productive learning environment for first-year preservice primary teachers taking an initial mathematics education unit of study. During the first stage of the project, the focus was on the plausibility of a problem-based learning (PBL) approach for enhancing productive dispositions with preservice teachers to teaching and learning mathematics.

Background

Many preservice primary teachers have demonstrated negative feelings and attitudes to learning mathematics (Cady & Rearden, 2007). In addition to poor attitudes, mathematics educators are often faced with teaching students with low mathematical content knowledge and a history of mathematical experiences that are predominantly teacher-centred (Tobias, Serow, & Schmude, 2010). To complicate the situation further, it has recently become necessary to broaden the scope of tertiary teaching and move beyond lecture-plus-tutorial and 9-to-5 approaches, as well deliver units online and via mixed modes. Whilst face-to-face and even mixed mode strategies enable real-time contextual experiences in social situations, replicating this is in an online environment where the preservice teacher experiences the multiple facets of student-centred teaching, is a hurdle that many tertiary educators are facing as we move to a more global classroom environment.

Teachers' work is often described as working within the union of different domains of knowledge. Lappan and Theule-Lubienski (1992) provide a visual model for teacher education that defines at least three kinds of knowledge that a teacher must have in order to teach effectively. These domains are represented visually in Figure 1.

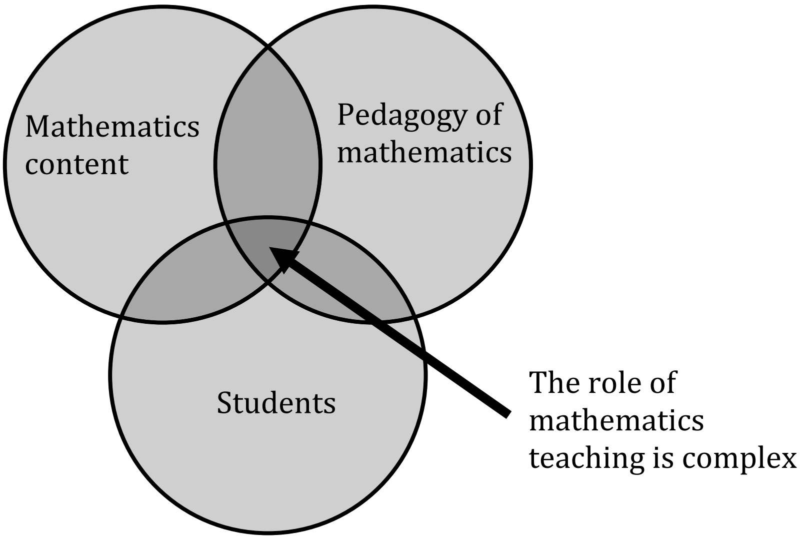

Figure 1. Knowledge domain framework for mathematics teacher education (Lappan & Theule-Lubienski, 1992, p. 253).

It has been previously said that many teacher education programs only teach students these domains of knowledge in isolation from each other (Lappan & Theule-Lubienski, 1992). The lack of integration between these three key areas of knowledge can create divisions between these different aspects of teacher education, and leaves the student without the appropriate experiences and skills needed to reason and analyse their teaching and students (Lappan & Theule-Lubienski, 1992).

Figure 1 depicts effective teaching as the intersection of these three domains of knowledge and identifies the inherent complexity in good teaching. Cooney (1994) appreciated the value of this mathematics education framework and that the task for the teacher was more than imparting knowledge about content and processes. However, Cooney also recognised the complexity of the task for effective teacher education. "The problem is that these different domains are neither mutually exclusive nor clearly defined, thereby making the nature of teacher education anything but a well-defined process" (p. 609). While this paper does not seek to clarify or clearly define these domains of knowledge, it does recognise the benefit that the Lappan & Theule-Lubienski (1992) framework offers, by illustrating the interplay of the different types of knowledge needed for effective mathematics teaching. However, the intention of the research study is to enunciate how the three domains of knowledge interact and are utilized as a model for "effortful" mathematics teaching. It is argued that if we want our preservice teachers to have a positive attitude and enhanced teaching practices when they graduate, then it seems essential that, during their tertiary studies, they need to have authentic and engaging experiences that incorporate the complex nature of mathematics education.

One approach that lends itself to working closely with many interrelationships in domains of knowledge is problem-based learning. This pedagogical approach has been identified over many decades as a successful way to educate students in medical education (Azer, 2007). Since its extensive use in the education of medical students at McMaster University in Ontario, Canada, which began in the 1960s, problem-based learning has spread to many other fields of education including law, engineering, psychology, and architecture (Gijbels, Dobchy, Bossche & Segers, 2005; Peters, 2006).

However, problem-based learning has not been used extensively, thus far, in teacher education. As the problem-based learning approach is designed to use and promote student-centred learning, it appears to have the potential to embrace and place the preservice teachers in the complexity that is inherent in teaching by providing authentic, ill-defined problems that need resolution.

The early pioneers of problem-based learning were Howard S. Barrows and Robyn M. Tamblyn. Barrows and Tamblyn (1980) observed that medical students, who had passed a number of courses in basic medical knowledge, using a non-problem-based learning approach, were not able to sufficiently transfer their knowledge when applying it to the assessment of a patient's condition. This was evident when Barrows and Bennett (cited in Barrows & Tamblyn) investigated medical students as they performed an inquiry on a simulated patient. For the most part, the students would gather data procedurally and try to combine it together later, or make a diagnosis based on a single symptom or sign, without looking deeper for other possibilities.

Barrows and Tamblyn (1980) felt at this time that the current use of problems in the curriculum was misplaced. Problems were often given to students to solve only after they had been given the facts, concepts and principles, either as an example to highlight the importance of the knowledge they had just been given, or as an opportunity to apply this knowledge. However, Barrows and Tamblyn believed a complex problem should be introduced before the facts were known, as a focus for the study to be carried out. Problem-based learning has certain broad characteristics with the central one being that "the problem is encountered first in the learning process" (Barrows & Tamblyn, 1980). They believed that the application of this knowledge helps enthuse students, teach problem solving skills, and aid in retention, and assert that knowledge used is better remembered.

It is important to note from the outset, as does Savin-Baden (2000), that not all learning that involves some kind of problem is problem-based learning. Eng (2000) mentions that with the "explosion" of interest in problem-based learning, concern has arisen that the concepts of problem-based learning will be confused with any educational approach that uses the word "problem", which may then be seen as applying a problem-based learning model. This concern has given rise to the question of what actually qualifies as problem-based learning. Many have asked what characteristics does the learning process need to have in order to be considered a genuine problem-based learning approach. To what extent does the use of problem-solving have to be included in a course to have a genuine problem-based learning status?

Many researchers (Eng, 2000; Savin-Baden, 2000) agree that the characteristics of problem-based learning laid out by Boud (1985) are key features. These are:

- the presentation of a problem occurs at the beginning of the learning process, and that this process is in response to the problem;
- an emphasis on students taking the initiative and responsibility for their own learning;
- more scope for the crossing of boundaries between disciplines;
- a focus on processes rather than products of knowledge attainment;
- a more collaborative relationship between students and teachers;
- an appreciation and accommodation of a student's knowledge and experience at the beginning of the learning process;
- a greater attention to the communication and interpersonal skills so that students understand that in order to relate their knowledge, they require skills to communicate with others; and
- tutors/lecturers are not used as significant sources of content, but rather as facilitators of the learning process, achieved through guiding and questioning.

Whilst it appears in theory that problem-based learning has much to offer mathematics preservice teacher education, the approach has had little investigation using the key features outlined by Boud. This paper reports on the findings of a pilot study that required a four-week problem-based learning intervention as a precursor to assist in the development of a semester long problem-based learning unit in mathematics education. The pilot program implemented is described in the following methodology.

Research questions

The following research questions were used to guide the pilot study and to establish whether a student-centred approach could positively influence preservice mathematics teachers' dispositions to learning and teaching mathematics:

- How do preservice teachers respond to a problem-based learning approach to learning?
- What are some of the implications of applying a problem-based learning approach in teacher education?

Methodology

The problem-based learning approach was undertaken in the initial stages of Semester Two 2010, with 82 (67 female, 15 male) first-year primary preservice teachers, undertaking the Bachelor of Education course at The University of New England in Armidale, NSW. The preservice teachers were enrolled in a first-year, semester-length mathematics education unit of study. All participants are described as continuing students who arrive at university immediately or within a few years of completing secondary school education. This intervention is a pilot study to inform a larger project investigating problem-based learning in the mathematics education context.

The problem-based learning program

The problem-based learning program was conducted over a 4-week duration at the commencement of a semester-long unit (11 weeks). The intervention focussed on early Number using the Count Me In Too framework (NSW Department of Education and Training, 2002). Each week involved a 2-hour tutorial, followed by a 1-hour content lecture. The tutorials were broken into two parts: The Open and The Close.

The Open involved preservice students being presented with a scenario of a student engaged in mathematical tasks, and involved opportunities to determine the student's level of understanding. The scenario was typically divided into two or three packets of information that were released throughout the tutorial time. These packets would often describe the context of the scenario and student work samples in varied forms, such as paper artefact, a description, or video of the student doing a task. The pre-service teachers were expected to discuss, analyse, and critique the information, as well as hypothesise possible educational implications. Once the information had been exhausted, another packet of information was provided. This new information was usually more comprehensive and revealed further detail about the scenario's context and insight into the student's mathematical situation. It was expected that while preservice students were working through the scenario they would identify areas where they believed their knowledge was inadequate to deal with the situation if they were the teacher. These items of need were called Learning Targets. Each person in the group was assigned a Learning Target to study, and asked to report the findings back to the group at the beginning of the next tutorial.

The Close began with students sharing what they had found about their Learning Target. This was usually followed by a whole group discussion to bring the scenario to a conclusion.

At the conclusion of the 4-week PBL intervention, participants were invited to complete an online questionnaire concerning their experiences of learning in a problem-based learning environment. From the sample of 82 participants, 48 participants elected to complete the post PBL survey. The questionnaire comprised of multiple-choice responses and open-ended responses. The goal of the survey was to collect the participants' subjective feedback, as well as their practical experiences of learning mathematics education in a problem-based learning environment. Examples of questions relating to their experiences were "What three things have you most valued about learning through a problem-based learning?" and "What has been challenging about learning using the problem-based learning approach?" The responses to the online survey were analysed qualitatively to identify emerging themes (Miles & Huberman, 1994).

Results

The following results report on the responses to three questions from the online questionnaire. The data highlight some interesting themes from the first-year cohort's reflections of their experiences during the problem-based learning section of the unit. These are presented in tabular form and are a result of a thematic content analysis of the qualitative responses received in the questionnaire.

Table 1 includes the themes identified in the students' qualitative responses when asked "What three things have you most valued about learning through a problem-based learning (PBL) approach?" Table 2 shows the themes of the students' qualitative responses when asked, "What has been challenging about learning using the PBL approach?" Table 3 shows the themes from the student responses when asked, "What could be improved to assist learning using the PBL approach?"

Table 1. Students' most valued aspect about the PBL experience.

Theme	Frequency
Real life/practical	29
Group work	24
Learned teaching strategies	23
Independence/self-directed/own responsibility	14
Structure of the PBL (tutorial/scenario first, then lecture)	11
Creating own learning targets	10
Lectures	8
Discovering resources	3
Logical sequence of unit content	1
Problem solving	1

Table 2. Students' themes of the most challenging aspects of the PBL experience.

Theme	Frequency
Group members not doing work	15
Finding relevant information/knowing what to look for	14
Being inexperienced 1st years	10
Didn't know the answers	8
Group dysfunction	7
Content	2
Repetitive scenarios	2
Lecture spoiled Close (gave the answers)	2

Table 3. Students' advice of what could be improved in the PBL experience.

Theme	Frequency
The Close (in general)	17
The Close (need for tutor/class summary)	13
Accountability	12
Need for more direction, such as question/goals	7
Create a final product/presentation/portfolio	7
Nothing	6
Better explained Close	6
Provide more resources	4
Not every week/too repetitive	3
Glossary/terminology	2
Have lecture first, before tutorial	1
Smaller groups	1
More PBL (pilot too short)	1

Discussion

The results from the post-intervention questionnaire revealed a number of aspects of the problem-based learning experience that the students clearly valued. These highly-regarded attributes can be closely aligned to the general features of student-centred learning, such as collaboration, autonomy in their learning and working on authentic tasks that are relevant to the students. This is an encouraging sign, because experiencing and valuing student-centred learning is one of the goals the researchers set out to achieve. It is hoped that this will assist the students to reform their view of pedagogy from a teacher-centred approach to a student-centred approach.

The most highly valued aspect was the authentic or "real-life" nature of the scenarios. The majority of the cohort appreciated this element of their problem-based learning experience. An example of this appreciation can be seen in the following student's comment.

> It was really good seeing real-life situations. Seeing how things don't work out all of the time … Like we've watched videos in Drama, and everything works out perfectly. The class did everything correctly. But with these [scenarios], you are working on problems, which is what teachers do, they have to work out problems.

The students generally appeared to value the actual goals of the scenarios, such as analysing the mathematical work of the student. They engaged in exploring strategies and ideas that could help develop the student's understanding of mathematics.

> [I valued] how to improve students learning by being able to recognise where the students are having difficulties and as a teacher, what steps to take to help the students succeed.

> By using real-life problems and seeing them occur, it makes it much easier to understand and learn how to fix the problems rather than just being taught about different approaches.

Autonomy and self-directed learning was also seen as a positive aspect to the problem-based learning experience.

> I like how it is a peer-directed option but still have the tutor there to help out, and how we feel in more control of our learning.

> I like the idea of having a problem and having time to locate the answer for ourselves, then being able to check our ideas with the lecturer.

Approximately half the cohort mentioned that they valued the group work and collaboration. Interestingly, group work was also mentioned as one of the greatest challenges they faced while working in the problem-based learning environment.

> [I valued] discussion with group members, to bounce ideas off each other and come up with ideas you would not normally have thought of.

There were, however, areas that need to be significantly improved in order to implement a successful problem-based learning unit. A clear weakness of the pilot program identified by students was the second part of the tutorials, The Close. Many students saw it as ineffective for a variety of reasons. Partly this dissatisfaction with the Close was attributed to the students' belief that it was lacking a clearly defined structure and had limited direction. This was evident in student responses that offered advice on what could be done to improve the problem-based learning experience.

> The Close part of the PBL might need to be more organised and structured, possibly to get more out of it and to come to a final conclusion about the strategies that should be put into place, to help the students.

The Close was also seen as ineffective by a number of students, owing to the lack of contribution by a few group members. It was revealed that some students believed members of their group were not contributing sufficiently, which was due to a lack of accountability, and this resulted in dysfunction within the group.

> It would be good if there was someone to ensure that all group members were doing their share of the work, as it was really focused on everyone being involved. Everyone in the group relied on others to learn certain areas and when they wouldn't do it and you spent a lot of time doing yours, it gets quite irritating.

Group dysfunction has been identified as a very common cause of impeded learning in a problem-based learning environment. However, if the facilitator is only working with a single group, this dysfunction can usually be resolved (Azer, 2007). This raises a challenge that needs to be addressed when a single lecturer is working with multiple groups in a problem-based learning environment, as was the case in this pilot study.

With respect to the inherent complexity of teaching described in the Lappan and Theule-Lubienski framework (1992) and offered in a problem-based learning environment, a small number of students commented that they appreciated the complexity and challenge of the scenarios.

> I personally liked being chucked in the deep end, because then you have to sink or swim. Because then you know that if this happens to me in real life, I know I can do it. Whereas I'd rather have the choice to sink or swim now, than be in a job and don't have a choice.

The results of the questionnaire reveal a number of implications for incorporating a problem-based learning approach in mathematics teacher education. Barrows and Tamblyn (1980) mention that problem-based learning was originally designed specifically for use in medical education. This raises a number of issues for educators wanting to incorporate this approach in areas such as teacher education, which has significantly less resources, and if it is to be used in other modes of education, such as distance learning. Problem-based learning was designed for face-to-face learning with a facilitator for each group of eight students. This is a significant use of resources that are simply not available in current times in teacher education, resulting in a number of practical implications evidenced in this pilot study.

Conclusions

This paper reported on a pilot study used to inform and assist in the development of a much larger main study, which is to be undertaken in Semester 2, 2011. A significant development in the main study will be the inclusion of approximately 400 online students as well as a cohort of 100 on-campus students. Consequently, this significantly broader environment will provide a larger collection of data, including pre- and post-tests looking at attitudinal and pedagogical change of the preservice mathematics teachers. It is anticipated that the main study research evidence will lead to teacher educators gaining greater insight into how preservice mathematics teachers construct their pedagogical understandings in an interactive and technologically rich environment.

Problem-based learning has been an effective pedagogical approach in medicine, architecture and engineering for over forty years. There has been a surge in popularity in the last few decades and it has been used in many other areas of education to enable students to develop their skills and understandings in an authentic and personally meaningful manner. Curiously, the PBL approach is yet to be used extensively in teacher education and is rarely reported in mathematics teacher education. This ongoing investigation offers a potentially powerful means of modelling with preservice teachers an effective student-centred approach for an inherently complex and challenging mathematics education environment.

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