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Viewing Mathematics in New Ways: Can Electronic Learning Communities Assist?

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Prospective primary school teachers often see mathematics as being a rigid, inaccessible subject. Their fixed ideas about the nature of mathematics and mathematics education can often impede their learning, and future teaching. This paper considers research literature which suggests that a learning community can be a powerful agent in helping students reflect on their own beliefs, and that computer-mediated conferencing tools can be effective in developing an electronic learning community. The paper goes on to investigate a web-based intervention that encouraged dialogue about mathematics between an international community of mathematics educators and the student teachers' local learning community. Data from two surveys and from the students' reflective journals show that this intervention encouraged them to examine and evaluate their own beliefs. In addition, some of the factors that inhibited the effects of the intervention are identified and discussed, in particular, the influence of the practicum on students' beliefs.

Introduction

This paper considers the beliefs that prospective primary school teachers hold about the nature of mathematics and mathematics education. It focuses on the characteristics of these beliefs and the constraints that the holding of such beliefs may entail. In the paper we describe an intervention in which an electronic learning community presents and debates a variety of alternative viewpoints on the nature of mathematics, together with the implications of these beliefs for classroom practice. The paper starts by describing some of the possible consequences that can occur if prospective teachers hold various beliefs about mathematics, and then discusses how learning communities and computer-mediated conferencing may be used in such a context to challenge these beliefs and offer alternative viewpoints.

The Problem

Prospective teachers of mathematics in the primary school have often had negative experiences in their own learning of mathematics (Pateman, 1989). Further, many have ideas about mathematics education that are at odds with the views espoused by a majority of mathematics educators interested in reforming the way mathematics is taught (Australian Education Council, 1991; National Council of Teachers of Mathematics, 1989). The literature in mathematics education shows that many primary school teachers and prospective primary school teachers see mathematics as a fixed and sequential body of knowledge which is most effectively learnt by rote, algorithmic and repetitive procedures (Foss & Kleinsasser, 1996; Mayers, 1994). These views lead to a vision of mathematics in which its relevance and power are not recognised except for use in low-level arithmetical operations, applied only to basic utilitarian situations. As a consequence, people who hold such views are unable to share a more liberating view of mathematics, one in which the subject is seen as offering flexibility in its methods, and connections to other areas, both mathematical and across other subjects. Indeed, Burton (1996) suggested that the teaching of "immutable mathematics" has led to widespread marginalisation and failure for its learners. She propounded the view that the very socio-cultural nature of mathematics has led to a differentiation amongst its learners of those who can engage with the traditional presentation of the subject and those who are unable to do so. Her views are shared by many mathematics educators (Dengate & Lerman, 1995; Ernest, 1991) and a reform movement in mathematics education has evolved with aims of making mathematics accessible to more people. The National Council of Teachers of Mathematics (1991, p. 3) has recommended that such reform should be supported by movement:

- toward classrooms as mathematical communities – away from classrooms as simply a collection of individuals;
- towards logic and mathematical evidence as verification – away from merely memorising procedures;
- towards conjecturing, inventing and problem solving – away from an emphasis on mechanistic answer-finding; and
- towards connecting mathematics, its ideas and its applications – away from treating mathematics as a body of isolated concepts and procedures.

In the teacher education context, it has been suggested (Crawford & Deer, 1993) that prospective primary school teachers' views of mathematics as instrumental might be modified "if opportunities for active and reflective participation in the learning process are provided" (p. 30) in the teacher education program. Intervention studies conducted in teacher education programs show some success (Schuck, 1997; Even & Lappan, 1994). However, many teachers still appear to begin their teaching careers with the views that they held when they started their teacher education preparation. The implications of teaching with the instrumentalist views described above are that primary school students are introduced to a conception of mathematics which accepts that access to the power of mathematics is available to only a few 'elite' students and denies others an entry into a world of mathematics that is culturally and socially relevant for them. If we wish more students to have access to the power and connectedness of mathematics, a different vision of mathematics needs to be presented to them from primary school days onwards. For this to happen, primary school teachers, and prospective primary school teachers, need to challenge their own views of mathematics so that they become open to visions of mathematics as a collaborative, creative and problem-solving discipline in which procedural methods are merely means to ends, rather than the ends themselves. In what follows, we will discuss an intervention in which such visions of mathematics are made accessible to prospective teachers through the mediation of a learning community.

Fostering a Learning Community

The paper is framed by the authors' beliefs that learning is a socio-cultural activity. A socio-cultural conception of learning is described as "a collective, participatory process of active knowledge construction emphasising context, interaction, and situatedness" (Salomon & Perkins, 1998). In this conception of learning, the sharing of knowledge and interaction within a learning community are central. Wilcox, Schram, Lappan and Lanier (1991) suggest that learning communities have the potential to help their members challenge their own views and construct more powerful views.

Sherin, Mendez and Louis (1997) advocate four pedagogical principles to help in fostering a community of learners (which they abbreviate as FCL): active participation by the learner in discussion; reflection and analysis by the learner on his or her own thinking; collaboration by learners in support of each other's learning; and community, where a class is not just a collection of individuals. These researchers found a high degree of commonality in the kind of mathematical learning promoted by these pedagogical principles and the educational reform advocated by The National Council of Teachers of Mathematics (1991). Sherin et al. report an intervention in which a middle school teacher implemented FCL pedagogy in his middle school classroom over a two year period. This teacher found that "a key image for mathematics was the building of a discourse community, and that through this, he could achieve the FCL principles" (p. 29).

Research has also been carried out in the teacher education context. Wilcox, Schram, Lappan and Lanier (1991) designed an intervention with prospective teachers which aimed to overcome limited, instrumentalist conceptions of mathematics by creating a community of scholars in which students and teachers engaged together in mathematical inquiry over a two year period. The learning environment allowed students to "take risks, to make conjectures, offer arguments in support of assertions, and assume the authority for deciding about the reasonableness of mathematical representations and solutions" (p. 26). The researchers found that the intervention produced significant change in prospective teachers' beliefs about mathematics and the teaching of mathematics. Schuck (1997) also carried out an intervention with prospective primary school teachers which involved the fostering of a community of learners. This intervention used a research simulation to make prospective teachers aware of the affective aspects of learning mathematics, and to make explicit the beliefs held by the prospective teachers about mathematics, together with the implications of these beliefs for classroom practice. An important feature of this research simulation was the dissemination phase, in which prospective teachers read papers by mathematics educators from Australia and other countries. Through reading, reflecting on, and discussing these papers, students "became aware that the feelings that they had and the views that they carried about mathematics were common to prospective primary school teachers from different countries and different cultures, and that many of these views were challenged by teacher educators all over the world" (p. 533).

It seems clear from the above research that learning communities can be effective in helping students reflect on their beliefs. In the intervention described in this paper, the principles advocated by Sherin et al. (1997) were incorporated into the design. Another aspect of this design was the use of computer mediated conferencing, which combines the benefits of the electronic age with the benefits of learning communities.

Computer-Mediated Conferencing

Research literature indicates that computer-mediated conferencing tools are especially well-suited for providing social arrangements that enable collaborative construction of knowledge (Blanton, Moorman, & Trathen, 1998). In their social constructivist review of research in this area, Blanton et al. suggest that such tools provide opportunities for prospective teachers to participate in learning experiences that encourage the integration of classroom practice and theoretical knowledge. Bonk, Appleman and Hay (1996), in describing how computer conferencing has increased the range of viewpoints available to students, suggest that we investigate how such "tools encourage learners to explore and accommodate alternative viewpoints". Blumenfeld, Marx, Soloway and Krajcik (1996, p. 39) describe how web-based conferencing "engages students in the construction of shared meaning".

A number of researchers have reported on the advantages of web-based conferencing where students have collaborated in learning tasks. Sherman (1995) describes the gains in students' critical thinking when they have to post regular reflections at a conferencing site, then react to their colleague students' postings. Windschitl (1998) considers the complementary aspect of computer-mediated conferencing: the production of material, by students, for others. He cites research that states that there are significant positive benefits in writing for others, both with e-mail and more conventional forms of composition. Reeves (1998, p. 6) draws attention to a "powerful sense of audience" in students who can share knowledge with others around the world. James (1995) develops this theme further: "Students see their own writing on the World Wide Web, impressed by the fact that their writings are in a real sense 'published' and available to millions of browsers. Students are in effect modeling the role of author, scholar, and scientist. They are thus awakened and introduced to intellectual citizenship."

Thus, it can be seen that computer-based conferencing presents a powerful way to develop an electronic learning community, although little has been written on its role in challenging beliefs of participants.

The Context of the Study

Students in an initial teacher education program for primary teachers at an Australian university have a sequence of four semesters of mathematics education which begins with Mathematics Education 1 in the second semester of their first year. In 1997, students in the Bachelor of Education program at the university enrolled for Mathematics Education 1. A major component of this subject was a substantial intervention aimed at challenging prospective teachers' beliefs about the nature of mathematics. The intervention was ongoing throughout the semester.

The study investigated whether the intervention, using web-based conferencing and an international community of learners, would encourage students to examine and challenge their beliefs about mathematics, and mathematics teaching and learning.

The Intervention

The characteristics of the intervention were that it encouraged collaborative learning, that students were given access to a large number of views about the nature of mathematics, and that the material was current, relevant and challenging of students' beliefs about mathematics.

In the first lecture students were required to give their responses to two focus statements, which formed the basis of the computer conference. The two statements given to the students were:

On the nature of mathematics:

"I'd describe maths as the calculation of certain things to do with numbers, and the use of certain formulas and methods, simplifying, counting and subtracting and things like that." (Maria, first year prospective primary school teacher)

On the cultural context of mathematics:

"Mathematics is universal, objective and unchanging. It is independent of social, cultural and political values."

The first statement had been made by a first year student teacher in a previous research study done by one of the researchers, and the second one was a compilation of comments made in that same study by a number of prospective teachers (Schuck, 1997).The students were then given the task of forming groups with five or six members and choosing one of the two focus statements for their study and response. They were introduced to the computer conferencing tool and the requirements of the task. Three types of material were made available to the students: (a) a selection of readings to be held in the library collection; (b) links to a number of Websites with relevant material; and (c) responses to the focus statements by a number of respected mathematics educators, which were placed at the discussion site of the conferencing tool.

The last set of materials was written specifically in response to the focus statements, by mathematics educators from a number of countries, including Fiji, New Zealand, the United Kingdom and Australia. These educators had been invited to respond to the statements by the researchers.

Students were required to read from each of the three sets of material, and then work collaboratively to formulate a group response to the chosen statement, based on their understandings of the material, and their ensuing discussion as a group. They were then required to post their response into the discussion site of the conferencing tool on the Web. Time was allowed in the subject for group meetings and collaboration. After the groups had all posted their initial responses to their chosen statement onto the conferencing tool (approximately halfway through the semester), they were required to read each others' responses to this statement, displayed in the discussion site, and then, in the same groups as before, formulate a second response to the statement that took other groups' points of view into account.

Towards the end of the semester, the entire first year cohort undertook a three week practicum and was required to teach a number of mathematics lessons during that time. Finally, in the second last week of semester, after students had posted their second response on the conferencing site, class discussions were held about the various responses to the given focus statements and the implications of these responses for teaching.

Methodology of the Study

Participants

One hundred and eighty-five students initially participated in the study. One hundred and sixty-five of them responded to a survey, which asked for some biographical and demographic data. Of the students responding to this survey, 101 were 18 to 20 years of age, the remaining participants being in a range from 21 to 47 years of age. One hundred and forty students were female, 25 were male. Fifty-one students had been in full-time employment before entering the course, and about two-thirds of the students lived in middle to high socio-economic areas. The two researchers were the academics responsible for the subject at that time.

Data Collection Methods

1. *Pre-intervention survey.* Students were surveyed in their first lecture about their beliefs about mathematics and mathematics education. The full set of beliefs statements in the survey is listed in Table 1. Examples are: 'mathematics does not change with time, only the ways of teaching it change' and 'mathematics is value free and objective'. Students were required to score each statement on a Likert scale, ranging from 1 – strongly disagree – to 5 – strongly agree. The survey was anonymous, with students being asked to supply code names so that each individual's survey results could be matched with the results of a later survey.

2. *Reflective journals.* Students were required to keep a reflective journal throughout the semester. They were given support in developing their journal writing skills by means of discussion in class on the value of reflective journals in mathematics education; readings on the use of reflective journals, placed in the library's special reserve; and material on the value of reflection developed by a literacy specialist within the Education Faculty, placed in the discussion site of the conferencing tool.

During the first lecture, students were given the two focus statements that formed the basis of the Web-mediated discussion and asked to write down in their journals their first thoughts in response to these statements. The computer-mediated intervention was then carried out over the semester and students were requested to keep journal entries on the group process, the meanings they had derived from reading the available material, and their thoughts about mathematics. At the end of the semester the journals were collected by the lecturers and permission gained to use them as data. Together with the journals, students were asked to submit summaries of the journal notes, documenting any critical incidents or new learning that had occurred during the semester. The journals were ungraded to encourage students to reflect upon their learning without being concerned about what the lecturers wanted to see.

3. *Post-intervention survey.* In the second last week of the semester, the students were given another survey which included the same set of questions about beliefs as had been asked at the beginning of the semester, adjusted for tense where necessary. They were asked to use the code name chosen at the beginning of the semester.

Analysis

Researchers read the journals and found that four broad categories covered all themes discussed in the journals. These four categories were not exclusive: material often appeared in more than one category. The first category was called *Beliefs*. This category contained any material that gave information about the students' beliefs about mathematics and mathematics teaching and learning. The other categories were: Technology (material discussing the value of the conferencing tool, or any issues relating to this technology), *Evaluation* (material evaluating any aspect of the subject), and *Workshops* (material relating to a sequence of workshops on measurement topics undertaken by students in another component of the subject). Foley and Schuck (1998) critically evaluated the pedagogical benefits and constraints of web-based conferencing which emerged in this intervention by examining the results from the Technology category. The present paper focuses on the data placed in the first category, *Beliefs*.

Extracts from a few reflective journals which expressed a view that appeared representative of a majority view were selected to be copied, and all those extracts that expressed a view that was substantially different in any way from other views were also copied. Two journals were read by both researchers to ensure that they were being categorised in the same way. The researchers then categorised all the selected journals. The contents that had been marked as Beliefs were then used to supply data for this paper.

The two sets of surveys were also analysed for the information they supplied about beliefs. A mean and standard deviation for the group, on each statement about beliefs, were calculated. Each item was then tested for significance using a t-test on the means on each survey for that item. A t-test for paired samples for means was also used on the group of 18 belief statements, to test for an overall change between means for the pre- and post-intervention surveys. As only 51 students had put their code names on both surveys, all statistics were calculated for that subgroup ($n = 51$) of the whole cohort, to ensure that the groups were paired.

Results

The Survey

For each individual item about beliefs, the change in mean values on the two surveys is small, and only four of the 18 changes are statistically significant with $p < 0.05$ (items 7, 8, 10 and 14 in Table 1). This result could have arisen because these items were more directly related to the discussion topics than some of the other items. In two cases, responses do not show change in the direction of a more liberating view of mathematics (items 9 and 17). However, the change is not statistically significant. In all other cases the change is in the direction anticipated by the researchers, but again the reader is reminded that the changes are not statistically significant. Reasons for this lack of change could be variability in understanding of the scale items, or lack of engagement with the survey. Nevertheless, a strong finding for the study emerges from the survey results when the entire group of beliefs statements is considered using a t-test for paired samples for means. When the whole group of statements is considered, there is a clear trend in the direction of change of beliefs towards a more liberating view of mathematics ($t = 3.7, p < 0.01$).

Journal Entries

Students' journal entries offer more detailed information about the intervention and other factors influencing students' beliefs. Many students commented in their reflective summary, written at the end of semester, on how limited their thinking had been about mathematics when they initially responded to the two statements. For example, the following text from one student's journal and summary show this kind of development. Jenny's[1] initial response to the first focus statement was as follows:

> I agree with Maria's statement. My views on maths are similar. My thoughts on maths are basically just different ways of applying figures and numbers together in order to get an answer. I think this is due to the way I was taught in maths, from a young age, through to a teenager, I found maths to be a very passive learning experience, I was told what to do and how to do it and that was the end of it. I kept on thinking this is not relevant to life, unless you wanted to become a mathematician which I had no intentions of becoming one [sic]. I don't understand or appreciate maths, therefore I can't see past the numbers, formulas, etc. Mathematics makes very little sense to me especially at the high school level – years 11 and 12.

At this point Jenny is showing the sort of thinking about mathematics that is limiting for her, and will prevent her from sharing a more dynamic view of the nature of mathematics with her primary school pupils when she starts teaching. The next extract of text is taken from Jenny's journal after she has started reading the material provided to challenge beliefs:

[1] Pseudonyms are used in all cases.

Table 1.
Surveys of Beliefs (Significant values asterisked, $p<0.05$)

	Survey Aug 97 Mean (SD)	Survey Nov 97 Mean (SD)	t by pairs
1. A person's cultural background will affect the way he/she learns maths	3.6 (0.7)	3.8 (0.5)	-1.64
2. People learn about maths by organising and interpreting information gained from experience	3.8 (0.3)	3.9 (0.5)	-1.21
3. Being able to memorise facts is critical in learning mathematics	-3.4 (0.8)	-3.3 (0.9)	-0.59
4. Challenges are an important part of learning mathematics	3.9 (0.3)	4.0 (0.4)	-1.41
5. Maths is value-free and objective	-2.7 (0.7)	-2.5 (0.8)	-1.33
6. Maths does not change with time, only the ways of teaching it change	-3.1 (1.4)	-2.8 (1.3)	-1.11
7. You need to be mathematically inclined to get anywhere in maths	-2.8 (0.7)	-2.4 (0.8)	-2.66*
8. Knowledge of mathematics is important for life	3.8 (0.4)	4.0 (0.7)	-1.75*
9. Maths is all about solving problems and finding patterns	3.0 (0.6)	2.9 (0.8)	0.71
10. Mathematics is all about learning rules and procedures	-3.0 (0.7)	-2.7 (0.7)	-2.14*
11. There is a basic foundation knowledge you need in order to be able to learn	-3.7 (0.5)	-3.5 (0.7)	-1.64
12. Mathematics is discovered, not invented	-3.5 (0.7)	-3.7 (0.7)	1.43
13. Mathematics is a sequential subject	3.5 (0.6)	3.7 (0.8)	-1.41
14. Different mathematics is developed in different societies	3.4 (0.7)	3.7 (0.8)	-2.00*
15. Right answers are much more important in mathematics than the ways in which you get them	-1.8 (0.6)	-1.8 (0.9)	0.00
16. Mathematics is a creative endeavour	3.1 (0.9)	3.2 (1.1)	-0.50
17. Maths is a way of thinking	3.9 (0.5)	3.8 (0.5)	1.00
18. Mathematics is about searching for order and pattern in our environment	3.4 (0.6)	3.6 (0.6)	-1.67

> After the completion of this article [NCTM, 1989], I discovered mathematics means so much more than just numbers. It showed me the importance of the process – discovery/journey of mathematics than to get the answers. It can also link to different KLAs [Key Learning Areas], while, prior to reading this article, I thought mathematics was an isolated subject on its own. Not forgetting maths should have relevance to life, therefore it is easier to understand. This article has given me a whole new approach of looking [at] and thinking [about] mathematics.

Finally, Jenny wrote in her summary about the new learning occurring during the semester:

> At the start of semester two I had a very narrow view of mathematics, thinking it was just boring numbers and formulas. My view was very similar to those [sic] of Maria's quote. However, as I progressed through this subject I found my views changing...
>
> The second group discussion gave me the opportunity to read other groups' responses which gave me an even broader knowledge on the meaning of mathematics.
>
> In conclusion, my views have completely changed. They are no longer limited. ...

So for Jenny, both the material supplied by the lecturers and the responses of her peers helped her to challenge her own beliefs. Another student also wrote enthusiastically about the value of the group discussion that was a central feature of the intervention. She wrote in her summary:

> To be honest I think that the maths discussion tested my beliefs and ideas about maths more than any test could.
>
> Thank you who ever reads this journal because I would never have thought of some of the points that came up through other people's readings and ideas, and also they really began to challenge my own.

Another example that illustrates the broadening of a student's views about mathematics comes from Thomas, who had shown some impatience with the way the subject had started, as indicated by his comments, written in his journal about the first class held for the subject:

> Right now I'm hoping that my attitude improves greatly because I'm thinking "When the h.. are we going to do mathematics?" ... I will try to understand why we are talking about everything but maths. I like maths and I want to do some.

He seemed to show some awareness that he had developed in his thinking a few weeks later: "Have realised by reading for the assignment that I've already started to change my thinking about mathematics. It's a lot more complex than suggested in the quote [Maria's statement]...". And in his summary he wrote:

> The mathematics readings, or one in particular, opened my eyes to something else. I didn't realise that different cultural backgrounds made a difference to people's concepts of mathematics. Obviously people living in a third world country with little access to education will not be as good at it as others who have access. But I thought this was only an educational deficit, but then to read about how playing particular games in India, girls become better at mathematics [an article from the Web: http://ms.mathscience.k12.va.us/ lessons/kolam.html], or hearing in the tutorials that Fijian children have little concept of mass [maths?] and number

> because they give and share everything [sic].[This last comment was sparked by a response from a Fijian mathematics educator to the statements on the conferencing tool.]
>
> I think it is a good idea to keep a diary, it makes one think about what they have done during the day and reading back over it I can see where my ideas have changed about the subject. For example I can remember telling you that I basically agreed with Maria's quote, but I thought it could have been written a little better. By the time I had finished the first reading I realised that Maria and I were totally wrong. If not wrong, narrow minded in our views of what mathematics is.

Some other students' journal extracts suggest that the collaborative aspect of the web-based conferencing led students to delve more deeply into the issues being discussed, than if they had been working individually. For example, Alison wrote:

> About four of our group members spent over fifteen hours just discussing the statement. We could have easily completed the task in an hour or two, however the concept of sharing ideas and opinions etc. became such a rewarding experience in itself that we got carried away.

A feature of the web-based conferencing tool that widened the collaboration was its ability to make all the postings available for viewing by all students. Anita wrote:

> It allowed us to share and discuss our ideas and beliefs through the readings and from different group responses we have learned a lot from each other [sic].

The same aspect was also commented on by Thanh, who also drew attention to the advantages of a wider collaboration with mathematics educators overseas:

> I was able to access the assignments of all the other groups and read what they thought on the subject. I think that this method of computer conference is very useful, because it allows a greater field of information and ideas. It also makes the world a great deal smaller when experts are able to comment on your ideas on the Internet.

Some Tensions Arising in the Study

There are many rich examples in the text of how prospective teachers felt that their original thinking about mathematics, as evidenced by their responses to the focus statements in the first lecture, was very limited, and how they felt they had changed their thinking to some extent as a result of the discussion and sharing of material in their mathematics education community. However, other aspects of the teacher education program worked against such change. A perennial problem experienced by many teacher education institutions is that when students go out on their field experiences, the links between campus and field learning are very variable. In this study there were a few examples showing that even while beliefs may have been challenged by the intervention, the experience on the practicum often led to some tension between the approaches used in the university subject and those used by the supervising teacher. Often, the supervising teacher saw mathematics as rigid and procedural, and saw the role of the teacher as being the transmitter of knowledge. In these cases, student teachers in their classrooms encountered a different set of beliefs from those that they had been developing through the intervention. The teacher's unquestioned authority in the classroom often led to ready adoption by the student teachers of the approaches and views of their supervising teacher. The following extract shows this sort of thinking.

Jake started his journal by writing about his goals for the subject:

> There are many goals I would like to reach by the end of Mathematics Education 1. ... It should be emphasised through lessons that the answer is NOT the most important aspect of maths, but the method from which it derived – this method or technique I wish to begin to understand, so I can teach mathematics successfully.

Later in the journal, Jake responded to an aspect of his group's discussion:

> Our conversation confirmed that attitudes are constructed through either positive or negative experiences in mathematics, the fact that, unfortunately, some teachers seek only correct responses.

But his notes on the practicum in his summary seemed to be expressing an opposite view to the above, and some dissatisfaction with the investigative workshop approach used in Mathematics Education 1:

> The greatest learning experience in the field of mathematics occurred during practice teaching. The class although challenging, allowed me to experience what it's really like to teach... Initially I made several errors, I took too long in marking the answers (should have been informed on how to mark work for optimum results) and not knowing how to answer certain questions, which I had to figure out myself.
>
> These failures set up successful maths lessons which were highly controlled in terms of explanation, modelling and exercises. The methods I used were from my assisting teacher, as she recommended that I mark the work fast, seek exercises that are challenging and to explain concepts thoroughly. These may not sound difficult, but we never discussed this in mathematics.

Discussion

The Problem

It would be ambitious to expect that beliefs held for many years could be changed in the space of one semester. However, there was sufficient indication in the data from the surveys and the journals to show that the intervention was successful in encouraging prospective teachers to become aware of their own beliefs, and that the process had begun to challenge their beliefs. Students showed that they had increased awareness of the influence of school students' cultural backgrounds on their learning of mathematics, the differing nature of mathematics in different cultures, the importance of process as well as solutions, and the possibilities of integration across the curriculum. In particular, it appeared that those areas addressed explicitly in the discussions had led to increased reflection about the nature of mathematics. However, it should be noted that the other components of the subject, which comprised workshops and readings based on the authors' beliefs about learning through community and participation, would also have been instrumental in starting to challenge students' views about the nature of mathematics teaching and learning and therefore it would be presumptuous to claim all change was due to the web-based intervention.

Learning Communities

It appears from the journal extracts, for example, Jenny's discussion above, that the learning community was effective in presenting alternative viewpoints and broadening students' ideas. Students indicated that their ideas were challenged as a result of being part of the learning community. Further, the mathematics educators who were invited to respond to the focus statements also became members of the learning community. Some of them read the materials provided by the other mathematics educators and indicated by electronic correspondence that they had found the other responses enlightening and interesting. One of the mathematics educators also responded to a contribution by one of the student groups and in this way entered the discussion with the students. Consequently, the mathematics educators played an active role in the learning communities formed, and were influential in challenging the beliefs of the students.

Further, it can be seen that the four pedagogical principles recommended by Sherin et al. (1997) were present in this intervention. The first principle was that of active participation by the learner in discussion – in this study the design of the intervention required students to actively contribute to the discussion within their groups. The second principle dealt with reflection and analysis by learners of their thinking – a reading of the journals indicated to the researchers that they had proved to be a successful vehicle for reflection on, and analysis of, students' own learning, as can be seen by the extracts provided. The third principle of collaboration by learners was demonstrated by the collaboration within the groups which supported the learning of the group members as shown in the extracts above. Finally, learning was also supported by the ability to read other groups' viewpoints, as indicated in journal extracts, suggesting that this learning community was more than "just a collection of individuals" (Sherin et al., 1997), Sherin et al.'s fourth principle for fostering a community of learners.

Computer Mediated Conferencing

It should be noted that the web-based conferencing tool was just that – a tool or device which was used as the medium for the intervention. In itself, it was not instrumental in changing beliefs. However, it provided a vehicle through which contact with the international community of mathematics educators, and with the local community of learners, could occur with immediate feedback. The use of web-based conferencing had many benefits such as allowing students access to each others' writing, and the ability to conduct debates asynchronously. It encouraged discussion in the whole learning community of the cohort, as opposed to dialogue between the group and the lecturer. Hence the use of the conferencing tool made access to material easier and more immediate. Having the responses placed on the Web also meant that students could use each other as the learning community and benefit from the careful thoughts of other groups. Students also commented that the knowledge that their response was going to be read by others encouraged them to think more carefully about the material they would submit. For a detailed discussion of the benefits and limitations of the conferencing tool, see Foley and Schuck (1998).

Tensions Arising in the Practicum

Finally, some comments from the student journals clearly show a tension between approaches used in the university based part of the subject, and the experiences occurring during the practicum. Where supervising school teachers saw mathematics differently from university academics, some conflict was evident in the beliefs of the student teacher over the two periods. This raises the question of how shifts in beliefs can be sustained when students' previously held beliefs are so prevalent in the teaching community. The implications for teacher educators wishing to challenge beliefs are that communication between university staff and school staff must be improved, so that school teachers are aware of the content and approaches of the university subjects, and academics are aware of the approaches, beliefs and constraints operating in the school classroom. With this knowledge, a better understanding of the role of the practicum can be negotiated. Further, with the current emphasis on partnerships between schools and teacher education programs, opportunities are arising for mathematics educators on campus and teachers in schools to negotiate and share their visions of mathematics education. An extension of the project discussed in this paper, in which teachers are invited to participate in such interventions as part of their professional development, might lead to a broadening and strengthening of the learning community in mathematics education. The nature of on-line interventions with their facilities to support asynchronous discussion make web-based tools ideal for development of thinking and reflection by practising teachers with demanding teaching loads as time and place of use can be totally flexible.

Conclusion

In the light of our experiences with this intervention, we found that student teachers beliefs can be challenged by exposure to alternative viewpoints and the support of a learning community. The use of the computer mediated discussion tool was effective in creating an international learning community, in which views of both mathematics educators and student teachers could be shared and debated. It was through membership of this electronic learning community that beliefs were made explicit and then challenged.

However, certain constraints reduced the effectiveness of the intervention. For example, moving out of the learning community into a more traditional context often interfered with the development of new beliefs. The question of sustainability of beliefs remains unresolved.

In general, then, the intervention was successful in challenging student teachers' beliefs, but more attention needs to be paid to the influence of the practicum on the learning occurring in the mathematics education class at university.

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