MATHEMATICS AND MATHEMATICS TEACHING: CHANGES IN PRE-SERVICE STUDENT-TEACHERS' BELIEFS AND ATTITUDES

CAROL MAYERS
Auckland College of Education

This paper reports on a study which sought to determine whether changes could be induced in primary student-teachers' beliefs about and attitudes towards mathematics and mathematics teaching through their participation in a mathematics education course which adopted constructivism as its theoretical framework. The course was designed to facilitate the development of positive attitudes towards mathematics and mathematics teaching and to facilitate the development of beliefs about mathematics and mathematics teaching which are consistent with a constructivist perspective. Two beliefs scales and three attitude scales were used to measure changes in beliefs and attitudes. These were completed by subjects prior to the commencement of the course and again following its completion. There was a significant shift towards a constructivist perspective in students' beliefs about mathematics and in their beliefs about teaching mathematics. There was also a significant reduction in mathematics anxiety and a corresponding increase in mathematics self-concepts for those students who had completed four or less years of secondary school mathematics. Interview data identified several constructivist teaching practices as having been significant in contributing to changes in students' beliefs. The results are discussed in terms of their implications with respect to the instructional practices which students might adopt in their mathematics teaching and in terms of their implications for pre-service teacher education.

In recent years a number of writers and researchers have focussed attention upon primary teachers' and student-teachers' beliefs about and attitudes towards mathematics and mathematics teaching. Teacher's beliefs about mathematics have been shown to be particularly important in terms of the instructional practices they adopt. Studies have shown that teachers' instructional practices are closely related to their beliefs about mathematics (Lerman, 1983; Thompson, 1984). Lerman argues that the choice between teaching perspectives "is not a question of pedagogical method in the first instance, but of the logical consequence of a theory of knowledge" (p.63). Studies have also shown that teachers' instructional practices affect their pupils' perceptions of mathematics as a discipline (Schoenfeld, 1988). The relationship between teachers' beliefs about mathematics teaching and their instructional practices is not as strong as that between their beliefs about mathematics and their instructional practices (Thompson, 1992); a number of constraints, such as the need to conform to school norms (Sullivan, 1989) and inadequate mathematical knowledge on the part of the teacher (Maher & Davis, 1990) are known to account for inconsistencies in teachers' professed beliefs and their instructional practices. Other studies have shown that teachers' attitudes affect their instructional practices (Ball,

1988) and that these in turn affect the attitudes and achievement of their pupils (Buerk, 1985).

Beliefs: A traditional view of mathematics is known to predominate amongst teachers (Thompson, 1992) and pre-service student-teachers (Southwell & Khamis, 1993). They are known to regard mathematics either as a body of absolute truths which exists independently of the learner (the absolutist view) or as a set of tools, comprising facts, rules and skills (the instrumentalist view). A traditional view of mathematics tends to lead to a 'transmission' model of teaching characterised by exposition, practice, and memorisation, known as instrumental teaching (Lerman, 1983; Thompson, 1984). Recent curriculum reforms which are based upon constructivism require for many teachers and student-teachers a change in their perceptions of mathematics, of the nature of learning and of the teacher's role in the classroom (Cobb et al., 1991; Simon & Schifter, 1991). Constructivism, which is based upon the notion that learners actively construct their own understanding as opposed to discovering an objective reality, implies a view of mathematics as "fallible, changing and like any other body of knowledge, the product of human invention" (Ernest, 1991, p. xi) and thus as a process of inquiry. This view, known as the fallibilist view is clearly incompatible with traditional notions of mathematical knowledge and furthermore, implies a pedagogy which is not consistent with a traditional view of mathematics (von Glasersfeld, 1990). Constructivism argues for a learner-centred, problem-solving view of mathematics teaching, in which the teacher is a facilitator of learning whose task it is to provide for students, opportunities to engage in meaningful mathematical problem-solving in order that opportunities for them to construct mathematical understanding are maximised.

Given that a traditional view of mathematics is known to predominate amongst primary student-teachers, it is likely that their beliefs about mathematics teaching would be consistent with instruction that is characterised by exposition and practice (Lerman, 1983; Thompson, 1984). Furthermore, since their own personal experiences of learning mathematics are known to be the most significant influence on pre-service students' beliefs about mathematics teaching (Sullivan, 1987) and since instrumental teaching has predominated in mathematics teaching (Straker, 1988), it seems is likely that their beliefs about mathematics teaching would be consistent with instrumental teaching. If student-teachers are to adopt the instructional practices recommended by the recent curriculum reforms, it is clearly essential that pre-service mathematics education courses induce changes in their beliefs about what constitutes mathematics, in their beliefs about what constitutes effective teaching and in their beliefs about the role of the teacher.

Attitudes: In addition to the findings that student-teachers hold a view of mathematics that is not consistent with constructivism, a number of studies (eg. Sullivan, 1987) have reported high numbers of pre-service student-teachers entering teacher education courses with negative attitudes about mathematics. Whilst a study by Nisbet (1991) found that, although many primary student-teachers had negative attitudes towards mathematics as a subject, they responded positively to questions related to confidence in and enjoyment of teaching mathematics, other studies (eg. Ball, 1988) which have shown that teachers who experience mathematics anxiety or who lack confidence in their own mathematical ability are more likely to adopt an instrumental teaching style and are less likely to teach for conceptual understanding or adopt constructivist instructional practices give rise to concern. Relich and Way (1992) recognise the importance of attitude towards mathematics as a subject as well as attitude towards teaching mathematics. To enable student-teachers to adopt constructivist classroom practices it is clearly important that mathematics education courses facilitate the development of positive attitudes towards mathematics and mathematics teaching as well as the development of beliefs about mathematics and mathematics teaching that are consistent with constructivism.

A number of studies (Carpenter et al., 1989; Cobb et al., 1991; Simon & Schifter, 1991) have evaluated in-service teacher development programmes designed to promote constructivist classroom practices. These studies found that programmes which adopted a constructivist approach to teachers' learning and which provided opportunities for teachers to engage in mathematical problem-solving at their own level of understanding, and experience mathematics instruction which modelled constructivist pedagogy, were generally successful in facilitating changes not only in teachers' classroom practices, but also in their beliefs about and attitudes towards mathematics and mathematics teaching. A number of researchers (Kelly & Tomhave, 1985; Larson, 1983; Tobias, 1980) have found that certain practices, all of which are consistent with constructivism, alleviate mathematics anxiety in students and result in more positive attitudes towards mathematics and mathematics teaching. These include providing opportunities for student-teachers, to work in collaborative groups, to explore different problem-solving approaches and to focus upon conceptual understanding. These findings suggest that constructivist teaching practices can lead to a reduction in mathematics anxiety and to more positive attitudes.

The present study sought to determine whether a pre-service mathematics education course, which adopted an approach similar to that of the teacher development programmes cited above (Carpenter et al., 1989; Cobb et al., 1991; Simon & Schifter, 1991), could facilitate shifts towards a constructivist perspective in student-teachers' beliefs about mathematics and mathematics teaching, and also facilitate the development of positive

attitudes towards mathematics and mathematics teaching. The course was designed to facilitate the development of a fallibilist view of mathematics; a 'learner-focussed' view of mathematics teaching; and positive attitudes towards mathematics and mathematics teaching. Within the context of learning how to teach, students engaged in mathematical problem-solving in collaborative groups. The purpose of this mathematical exploration was to challenge the students' conceptions of mathematics and of the nature of learning and to deepen their mathematical understanding. Small-group and whole-class discussion focussed on the mathematics which emerged and the teacher's role within a constructivist pedagogy.

METHOD

Subjects

The subjects were 449 first-year students enrolled in Primary Teacher Education programmes at two New Zealand tertiary institutions. The experimental group comprised 285 students enrolled in the first institution who participated in a 1-semester mathematics education course based upon constructivist principles, which was designed to facilitate the development of beliefs which are consistent with constructivism and of positive attitudes towards mathematics and mathematics teaching. The second institution provided two distinct control groups. Students in Control Group 1 (N=76) participated in a 1-semester mathematics education course which, although its underlying philosophical framework was constructivist, was different in nature from the intervention. The focus of the course was on the preparation of students for school-based work with young children. Whereas, in the Control Group 1 course the mathematics 'content' was confined to an examination of early numberwork and measurement activities, the experimental course focussed upon providing students with opportunities to engage in mathematical problem-solving situations designed to challenge them at their own level of understanding and with opportunities to experience first-hand mathematics instruction that modelled constructivist pedagogy. Students in the second control group (N=88) participated in a 1-semester science education course.

Design and Procedure

The study employed a pretest-posttest design. A survey comprising five questionnaires was administered to all subjects prior to the commencement of their Primary Teacher Education programme and again upon the completion of their first semester in the programme. The survey included two beliefs questionnaires developed by the author.

These were the Beliefs About Mathematics Questionnaire and the Beliefs About Teaching Mathematics Questionnaire. They were designed to assess the degree to which students' beliefs about mathematics as a subject and their beliefs about teaching mathematics were consistent with constructivism. Three attitude scales were included in the survey. These were Betz' (1978) Mathematics Anxiety Questionnaire; Gourgey's (1982) Mathematics Self-Concept Questionnaire; and Nisbet's (1991) Attitude Towards Teaching Mathematics Questionnaire. Each questionnaire comprised a number of statements to which subjects were asked to indicate their degree of agreement or disagreement. Item responses for each questionnaire were based on a 5-point Likert scale, ranging from 'strongly agree' to 'strongly disagree'. With the exception of the Mathematics Anxiety scale an increase in scores represents a shift towards a more positive attitude or a shift towards a more constructivist perspective. In the case of the Mathematics Anxiety scale, a reduction in scores represents a shift towards a more positive attitude.

Following analysis of the survey results, a multiple regression analysis was carried out on the pretest and posttest scores of students in the experimental group for each of the two beliefs scales. Predicted posttest scores for each of the two scales were calculated for each student. These were based upon a student's pretest score and the correlation of pretest and posttest scores for all the experimental group students. Standardised residual scores were then calculated. Five students were randomly selected from a group denoted as 'Big-Shifters', identified as having made greater than expected shifts in their beliefs about mathematics and mathematics teaching; five students were randomly selected from a group denoted as 'Middle-Shifters', identified as having made shifts in their beliefs close to those expected; and five students were randomly selected from a group denoted as 'Small-Shifters', identified as having made less than expected shifts in their beliefs. This sub-group (N=15) of the experimental group were subsequently interviewed in order to ascertain their perceptions of any changes that might have occurred in their beliefs about mathematics and about mathematics teaching and to identify the factors to which the students attributed such changes.

RESULTS AND DISCUSSION

There were no significant differences between the three groups in scores on either of the two beliefs scales or in scores on any of the three attitude scales at the time of the pretest.

Beliefs: There was a significant increase in scores on the Beliefs About Mathematics scale for students in the two groups which had participated in a mathematics education course (ie. the experimental group and Control Group 1). However, whilst there were significant increases in scores for both groups, the posttest scores for students in the experimental group were significantly higher ($p < .05$) than those of students in Control Group 1. These findings suggest that shifts are unlikely to occur in students' beliefs about mathematics unless they participate in a mathematics or a mathematics education course and that a course which focusses on students engaging in mathematical problem-solving at their own level of understanding and which models constructivist pedagogy is likely to result in greater shifts in beliefs about the nature of mathematics than one which focusses primarily on preparing students for school-based work with children. Twelve of the 15 students interviewed stated that their ideas about what constitutes mathematics had changed. Interview responses reflected shifts in their views away from a traditional or absolutist perspective towards a process-orientated, fallibilist perspective. Each of the 'Big-Shifters' perceived that significant changes had occurred in their beliefs about mathematics and were able to articulate readily the nature of the perceived changes and the factors to which they attributed such changes. Two of the 'Middle-Shifters' and one of the 'Small-Shifters' were unsure whether their ideas about mathematics had changed. Two of these described a view of mathematics that was consistent with constructivism. When those students who believed that their ideas about mathematics had changed were asked to identify the factors that they thought had contributed to the changes in their beliefs, the following factors were included in five or more of the 12 responses: the modelling of a different approach by their lecturer; experiences of engaging in mathematics or of being placed in the role of the learner; the 'hands-on' nature of the course; and the exploration of a variety of approaches in solving problems.

There was a significant increase in scores on the Beliefs About Teaching Mathematics scale for students in all three groups. The increase in scores on this scale across all three groups (including Control Group 2 which did not participate in a mathematics education course) suggests that this scale may be measuring beliefs about teaching generally and not about mathematics teaching in particular. However, whilst there were significant increases in scores on this scale for all three groups, the posttest scores for students in the experimental group were significantly higher than those of students in both control groups. This finding suggests that the intervention resulted in greater shifts in students' beliefs about mathematics teaching towards a constructivist perspective than did either the Control Group 1 mathematics education course or the

Control Group 2 science education course or a Primary Teacher Education programme in general. With the exception of two 'Small-Shifters', all of the 15 students interviewed said that their ideas about what constituted effective mathematics teaching had changed. Interview responses reflected shifts in their views from a belief that good teaching was 'teacher-directed' and involved clear explanation/demonstration to a view that good teaching should be 'child-orientated' and allow for exploration of mathematical ideas and should focus upon conceptual understanding. Each of the 'Big-Shifters' were again able to articulate readily the nature of the perceived changes and the factors to which they attributed such changes. Of the two 'Small-Shifters' who thought their ideas about mathematics teaching had remained unchanged, one expressed beliefs about effective mathematics teaching that were consistent with a 'child-orientated' approach and the other described a traditional approach to mathematics teaching. When those students who believed that their ideas about mathematics teaching had changed were asked to identify the factors that they thought had contributed to the changes in their beliefs, the following factors were included in five or more of the 13 responses: the modelling of a different approach by their lecturer; experiences of engaging in mathematics or of being placed in the role of the learner; the 'hands-on' nature of the course; the importance of groupwork and discussion; and the exploration of a variety of approaches in solving problems.

Attitudes: There were significant shifts in attitudes for students in the two groups which had participated in a mathematics education course, but only for students who had completed four or less years of secondary school mathematics.

There was a significant reduction in Mathematics Anxiety scores and a significant increase in Mathematics Self-Concept scores for students in the experimental group who had studied four or less years of secondary mathematics. These results suggest that the intervention was more successful in facilitating the development of positive attitudes towards mathematics as a subject than was the Control Group 1 course or a teacher-education course generally. Given the difficulties that student-teachers with an inadequate mathematics background are likely to experience in implementing constructivist teaching practices (Maher & Davis, 1990), particularly if they also exhibit mathematics anxiety or have a low mathematics self-concept (Ball, 1988) it would appear that the intervention was successful in facilitating the development of positive attitudes towards mathematics as a subject for an 'at risk' group.

There was a significant increase in Attitude Towards Teaching Mathematics scores for students in Control Group 1 who had studied four or less years of secondary mathematics. This result suggests that the Control Group 1 course which focussed

primarily on the preparation of students for school-based work with children was more successful in facilitating the development of positive attitudes towards mathematics teaching than the intervention. However, without a concomitant change in attitudes towards mathematics as a subject, an increase in confidence in or enjoyment of teaching mathematics is unlikely on its own to result in students being able to teach for conceptual understanding or adopt constructivist teaching practices.

CONCLUSIONS

The results of this study indicate that a pre-service mathematics education course which adopts constructivism as a framework for learning, and in which students experience mathematics instruction which models constructivist pedagogy, will facilitate the development of beliefs about mathematics and mathematics teaching which are consistent with constructivism and will also facilitate the development of positive attitudes towards mathematics and mathematics teaching. The interview data support the conclusion that a number of constructivist teaching practices contributed directly to changes in students' beliefs, both about the nature of mathematics and about mathematics teaching. The results of this study are consistent with the findings of other studies (Cobb et al., 1991; Kelly & Tomhave, 1985; Larson, 1983; Simon & Schifter, 1991; Tobias, 1980). Because of the close relationship known to exist between teachers' conceptions of mathematics and their instructional practices (Lerman, 1983; Thompson, 1984), the findings that significant shifts in the experimental group students' beliefs about what constitutes mathematics is encouraging. It seems likely that these students will be more able to teach for conceptual understanding and be more able to adopt constructivist teaching practices. The findings that significant shifts in the experimental group students' beliefs about effective mathematics teaching also seem encouraging. Whilst the relationship between teachers' beliefs about mathematics teaching and their instructional practices is not as strong as that between their beliefs about mathematics and their instructional practices (Thompson, 1992) it seems clear that student-teachers will be unlikely to adopt constructivist teaching practices unless they hold beliefs which are consistent with a 'learner-focussed' view of mathematics teaching. The positive shifts in attitudes towards mathematics as a subject in the case of students in the experimental group is also encouraging. Without such a shift, students are likely to resort to instrumental teaching and unlikely to teach for conceptual understanding.

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