# Building new partnerships through a common concern with the teaching of mathematics: The Australian-Welsh connection

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## Abstract

This paper describes research being undertaken to address the urgent need to break the cycle in which student teachers with poor understandings of basic mathematical concepts and procedures and low selfefficacies in relation to mathematics pass on the same misunderstandings and low selfefficacies to their students when they enter the teaching profession. The Mathematics for Initial Teacher Education Students (MITES) project began in an Australian context in its preliminary stages before a partnership was formed with a Welsh university at the 1995 AARE conference in Tasmania. The implications of the nature of this partnership and the two contexts in which the research is taking place are examined. In particular the implications for the research design and methods as well as the refinement of the tests of achievement and self efficacy are discussed. The paper will also address the effects of context on the co-operative learning

strategies employed.

The Mathematics for Initial Teacher Education Students (MITES) project began in 1995 at a regional Australian university in response to concerns about the low incoming levels of mathematics achievement and selfefficacy that had characterised inservice teacher education (primary) student groups in previous years. The students often demonstrated a dislike for mathematics on their entry to university, they did not expect to enjoy studying mathematics and they did not seem to have much confidence in their mathematical abilities. These observations were serious enough to begin research into assessing more objectively the nature and extent of the problem and identifying and implementing teachinglearning practices to address the problem. One of the main concerns was that, if attitudes towards mathematics did not change while these students were at university, then their future students in primary schools would be at risk of adopting the same attitudes and also have achievement levels in mathematics suffer.

The concerns which led to the start of the MITES project were consistent with the available literature, demonstrating that similar problems had already been identified by others. Research into mathematics education indicates that more effort needs to be directed to exploring interventions which may lead to the development of higher levels of selfefficacy in mathematics (Pajares & Miller, 1994; Williams, 1994). Studies which explore the nature of pedagogical interventions and which could lead to an enhancement of the mathematics selfefficacies of teacher education students is much needed. The eventual goal of the present study is to unlock the key to breaking the cycle whereby teachers with low levels of selfefficacy in mathematics pass on their attitudes to their students.

The goal of this research has its theoretical basis in Bandura's (1977, 1986) work on selfefficacy and more recent research into the connection between selfefficacy and achievement (Moriarty, Douglas, Hattie & Punch, 1995; Randhawa, Beamer & Lundberg, 1993). Selfefficacy is considered to be a pivotal force in relation to achievement because it affects the effort and persistence with which people approach tasks (Bandura, 1986). Applying this theory, those students who have high levels of selfefficacy in relation to mathematics are likely to believe that their efforts will be rewarded by success. Their continued efforts are then likely to lead to higher achievement. The important point is that students need to experience success on a regular basis for this happen. Research into learning environments strongly shows that the cooperative learning environment more than any other, is likely to lead to success for a greater number of students.

A key element of teachers' knowledge of mathematics is their knowledge about the nature of mathematics (Sanders, 1994). Pupils' images of mathematics are built up, at least in part, by the images presented by their teachers (Keane, 1988). Evidence exists that mathematically able pupils demonstrate a versatility of approach (Krutestkii, 1976). This is an area that has not been addressed in many mathematics courses and is underresearched. It is a theoretical underpinning of the mathematics programme at Swansea, however, and so it so was decided to ask students to reflect on their beliefs about the nature of mathematics at the beginning of their training year.

The focus for the remainder of this paper is on the design of the study. Particular emphasis is given to the methods and the implications of the partnership, in particular the influence that the partnership had on the tests which were developed. Consideration is also given to the different contexts, that is, the Australian and Welsh situations, and the effects of context on the teaching strategies employed.

## Methods

This research project is ongoing, with each stage in the research making a contribution both methodologically and conceptually. A brief overview of the outline of the first two stages of the research is given below.

### Stage 1.

Tests of selfefficacy and achievement based on the primary school mathematics curriculum in Queensland were constructed and administered to incoming first year teacher education students at a regional Australian university. The reliabilities of the tests were established, together with a determination of the levels of performance on these measures by the students at the beginning of the academic year.

The students on one campus of a regional university were then invited to participate in mathematics classes which had a distinctly cooperative learning basis. Participation was entirely voluntary. The classes were not part of their course for that year and performances did not affect grades for units in which the students were formally enrolled. Twenty one hour classes were offered throughout the year and tests of selfefficacy and achievement parallel to the pretests were given at the end of the period.

### Stage 2.

Several changes occurred in stage 2 of the study. One was that a mathematics curriculum unit, which had until two years previously been part of the first year teacher education course at the Australian university, was now taken from the second year of the course and reintroduced into first year. This provided a much more stable situation for conducting the research and had more meaning and immediate benefit for the participants. The new students were given pretests of selfefficacy and achievement in mathematics, taught for a semester using cooperative learning strategies and given parallel posttests at the end of the semester. The tests were revised versions of those given in Stage 1, as explained below.

One of the outcomes of the Australian part of this stage of the research has been the production of a professional videotape to introduce teachers in schools and universities as well as student teachers or other groups of people who need to work together to cooperative learning. Next year, notes to accompany the video will be written as an added dimension to this resource.

In stage 2 of the study, a short, 20item questionnaire was also developed to be administered with the other tests at the end of semester. This questionnaire asks students to rate the frequency of behaviours in their mathematics classes which relate to the degree of cooperative learning structures present in the class from their perspectives. None of the currently available questionnaires were appropriate as they do not include items which relate to the current definitions of cooperative learning available in the literature.

The most important change that occurred in the second stage of the study was the formation of the partnership between the Australian university and a university in Wales. This partnership began at the 1995 AARE conference in Tasmania, in which the two colleagues met for the first time through their common interest and concern about mathematics education. Pretesting began in September, 1996 in Wales to coincide with the start of the first semester of study in the northern hemisphere. The same tests of selfefficacy and achievement in mathematics are being used in the Australian and Welsh contexts for Stage 2 of the study.

Implications of the Partnership

This partnership which was formed between the colleagues at the two universities, had implications for both methods and theory. In particular, it involved a refinement and extension of the tests which were administered to participants and a broadening of the conceptual framework with the blending of complementary theoretical positions.

The refinement and extension of the tests.

The tests developed in the first stage of the study were used as the basis for tests of selfefficacy and achievement in the second stage. Improvements were made to items and an extra section on probability and statistics was added to reflect the Welsh and English National Curriculum. After careful analysis of the Australian and WelshEnglish curricula, the final tests were appropriate to each culture, both in terms of content and language usage. The tests to be administered at the end of the course of study were constructed to parallel the pretests.

Strictly speaking, as Wales is a bilingual country, the tests also need to be made available to Welsh speakers in their own language. This is one of the planned extensions to the research for next year. (See Appendix for examples of items from the different tests).

The broadening of the conceptual framework.

This more international perspective was also reflected in the blending of two complementary theoretical approaches which gave the conceptual framework of the study more depth. One approach, which had informed the first stage of the study in the Australian context, supported the proposition that selfefficacy and achievement are optimised under cooperative learning conditions. The Welsh contribution to the theoretical framework was also developed from previous work undertaken by the researcher from Wales. Fundamental to this approach was the proposition that teachers' beliefs about the nature of mathematics should underpin their work and that a multiplistic view of mathematics has beneficial effects. It is therefore important to assess students' beliefs about the nature of mathematics, as these may also need to be addressed. This latter position resulted in the development of further items included in the testing which sought information from students about their views on mathematics. These items were to be given to both the Australian and Welsh students at each testing in the second stage of the study. (See Appendix).

The Australian and Welsh contexts

Australia is in the process of developing a national curriculum for mathematics and also procedures for determining whether school students meet national standards of performance. There has been much debate in Australia in recent years about this direction and progress has depended to some extent on changing government policies.

One of the most important and farreaching changes in Queensland schools has been the ways in which teachers are required to observe and record (Student Performance Standards or SPS) progress in mathematics. The mathematics curriculum and pedagogy course which the students at the Australian university study in their first year, concentrates on strategies for teaching mathematics. One perceived benefit to students involved in the research is that they learn at first hand a wide range of cooperative learning strategies which they can then use to teach mathematics, and other subject areas, in schools. In the first year of their teacher education course, these students spend a total of 20 days in primary schools and have the opportunity to put into practice some of what they have learned about cooperative learning at university. They also begin to see how teachers observe and record the progress of their pupils in line with the reporting procedures for the Student Performance Standards.

In Wales, the National Curriculum is much more firmly established, having had their system for longer. The government lays down strict controls over the number of hours that student teachers must study mathematics (150 in a 38 week course, of which 50 hours has to be arithmetic). They also stipulate that 50% of the total time (about 18 weeks) must be spent in schools. This makes it impossible to deliver all 150 hours in the university so schools have to be responsible for some of the curriculum. It is important that lecturers know which content areas students tend to be competent in so that the university can suggest that schools have the student teachers work on the these areas with pupils. Schools then do not have to worry about whether student teachers 'know the maths'.

The Australian students involved in the research are first year university students, mostly straight from school or one year out of school by the time that they start their teacher education course. In 1996, most students came from the surrounding region of the state. The main participants in the study were the total cohort of about 20 teacher education students on the regional campus at which the research was instigated. Job prospects for these students look very bright, as it has been for students with a teacher education degree in the region in recent years.

The Welsh students are all graduates and approximately 40% have had jobs and are over 25 years of age. As with the Australian students in the 1995 stage of the study, the 1996 Welsh students were given the opportunity of joining the mathematics classes as an additional option to their course. About 10% of the students chose to attend. Also in line with the Australian situation in 1995, these classes are held at the end of the normal taught day and this may have influenced participation choices.

One difference in approach to the pretesting in the Welsh situation was that the students were permitted to selfassess their papers, although the papers were also remarked for the official analysis. All papers are anonymous with code numbers for retesting. The decision to give students the opportunity to selfassess their papers was made because of the maturity of the students and their degreestatus background. On reflection, there appears to be no reason why this could not also be done with the Australian students in the next stage of the study. These students simply completed the tests and were provided with individual feedback about their performances on the achievement scales.

The Welsh students have an age 16 mathematics qualification (General Certificate of Secondary Education at Grade A, B or C). It was anticipated that they would have retained this knowledge but the results so far indicate that they forgot or did not know a great deal. The situation is similar with the Australian students, although previous observations did not lead to such an optimistic prediction.

One of the advantages of a working partnership involving researchers in the northern and southern hemispheres for this type of research is that the different timing of the academic years permits two applications of the same stage of the research in the one year, with details of methods, techniques and procedures able to be refined twice in that time. Even though it was necessary to take account of the different curricula and cultures, having a two researchers instead of one who were at different points in the research at the same time, facilitated a more speedy coverage of the preparatory work. This was further supported by the use of modern technologies such as email. Even the time difference between the two sites on a day by day basis has an advantage in that it is possible for one person to do some work, send it through to the other, then go home while the other one continues. In some ways, it was almost like two shift workers sharing an office but never meeting each other face to face.

Effects of context on co-operative learning strategies employed

The decision to use cooperative learning strategies to help increase students' levels of achievement in mathematics is strongly embedded in a theoretical position. This position is based on the results of research into learning environments which began in the 1920's, was subject to metaanalysis in 1981 (Johnson, Maruyama, Johnson, Nelson & Skon) and on more recent research which has found a connection between selfefficacy development and cooperative learning (Moriarty, Douglas, Hattie & Punch, 1995).

It is appropriate to have teacher education students learn mathematics in a cooperative learning environment for several reasons. One reason is that these students are likely to have increased levels of selfefficacy and achievement in mathemcatics because of this involvement. Another reason is that these students will be able to make their own decisions about the value of cooperative learning by having experienced it at first hand. They will then have at their disposal a range of cooperative learning techniques which they can then use when planning mathematics lessons for their own students. This is more likely to be the case if these students have had these experiences themselves rather just having had the strategies explained to them.

Another advantage to having all these students work through the content of the mathematics curriculum in cooperative learning groups, is that those students who had misconceptions or poor understandings of the basic mathematical concepts involved would be working through these concepts, able to discuss those concepts and clarify their understandings in the same way as all other students. There would be no reason, therefore, for students to feel inadequate. In addition, even students who claimed to be quite confident in the beginning were found to need some misconceptions explained, and the cooperative learning approach allowed for this.

By building into the lessons individual accountability, with all students having to demonstrate understanding and grasp of concepts, as well as reflections on the processes involved, students were introduced to the most important elements of cooperative learning. Where cooperative learning has not worked adequately in classrooms or in research situations, these elements have most often been omitted.

The unsolicited comments made by students on the video which was produced this year and incidentally throughout the period, support the view that students enjoyed working cooperatively and intend to use these strategies when they are teaching. Other observations are also consistent with this view. For example, in their mathematics classes and in other university classes in which some of the participants also had the opportunity to use cooperative learning, it was noted that students would automatically rearrange chairs and desks if these were not in groups when they entered the classroom.

Where to from Here?

The Welsh students are currently undertaking mathematics classes using cooperative learning. They will then have their posttests. Data from the Australian part of the second stage of the study are currently being analysed. This will be followed by the analysis of the Welsh data when those students have finished their semester. The two bodies of results will then need to be examined together.

Next year, activities will be written to accompany the video produced in Australia. The target audience will be groups of people, for example university lecturers, school teachers, teacher education students and other groups interested in using cooperative learning or interested in learning about techniques to work together successfully. The suggested activities will be designed using a cooperative learning approach, so that participants can experience cooperative learning at first hand while they work through the material.

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Appendix

Examples of items from the selfefficacy, University Class Description Questionnaire, knowledge about mathematics and achievement tests.

1.Selfefficacy

* 1 = Not very confident at all 2 = Only just confident 3 = Reasonably confident
4 = Very confident 5 = Extra confident 6 = Super confident

1. How confident do you feel working with whole numbers, including: *
12 3456

addition
multiplication
subtraction
division
expanding numbers
factors
exponents (powers, indices)
estimation

University Class Description Questionnaire

For each of the statements below, please circle ONE of the descriptors on the right to indicate how you believe that your mathematics classes operate at university. Please ensure that all questions are answered. There are no right or wrong answers; it is what you think that is important.

AlmostSeldomSomeOftenVery
nevertimesoften

1.The students talk to each other about their work.12345
2.Groups of students work together towards common goals.12345
3.The lecturer imparts the knowledge while the students are expected to listen.12345
4.The students in our class feel comfortable about doing maths.12345

3.Knowledge about mathematics

Please circle the numeral from 1 (strongly agree) to 6 (strongly

disagree) that best represents your belief in each of the following statements about maths.

Strongly Strongly

agree disagree
16
1.Mathematics was devised by human beings
to explain natural phenomena.123456
2.Everything in mathematics can be proved.123456
3.There is still mathematics to be discovered.123456
4.Achievement

WHOLE NUMBERS
1.Define the following terms and give an example to show the meaning of each:
(a)prime number
(b)multiple
2.What is 10 fewer than 37 505?
3.What is 100 times more than 1000?

MEASUREMENT
1.Define the term hectare.

2. Write the formula for calculating:
(i)the area of a circle
(ii)the volume of a cube
(iii)the perimeter of a rectangle
(iv)the area of a triangle

3.The perimeter of a square is 20cm. What is the area of the square?

FRACTIONS
1.What fraction should replace in this sequence?
1, , 3/4, 5/8, 1/2

2.Arrange these fractions in order from greatest to least:
1/4,38%,0.3,1:3
3.Circle the fractions that are equivalent to 45%:

9/20,46/100,0.4,45 hundredths,20:9, 0.045,0.45

SPACE
1.Define the following terms and draw a diagram of each one.
(a)obtuse angle
(b)isosceles triangle
(c)parallelogram

2.A prism has a base the shape of a hexagon. How many faces would this solid have?

3.A triangular based pyramid has:
(a) faces(b) edges(c) vertices

STATISTICS

3.In five innings a cricketer made the following scores:8467921
Calculate the mean.
5.What is the probability of throwing two fives if throwing 2 dice?