BELIEFS ABOUT MATHEMATICS AND MATHEMATICS EDUCATION

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Problem solving is recognised as an essential goal in mathematics education. The performance of primary pre-service teachers, however, appears to be adversely affected by anxiety and other negative emotional and social factors. A previous study by Southwell(1990) indicated that some mature-aged students hold beliefs which prevent them from tackling certain kinds of problems and from being successful in others.

It is possible that if pre-service primary teachers hold beliefs to the effect that mathematics is a very difficult subject, that they are not good mathematicians and that mathematics has limited appeal and use, their teaching will reflect these beliefs and each new generation of learners will be locked into similar beliefs and negative attitudes.

Ball (1988) lists a number of "hunches" she has about what prospective teachers believe about mathematics. They include the following:

> Mathematics does not have much relationship to the real world and most mathematical ideas cannot be represented any way other than abstractly, with symbols. Knowing mathematics means 'knowing how to do it'. Teaching mathematics involves telling (or showing) the students how to do different kinds of problems. Teachers ask questions to elicit right answers; if a teacher questions your answer, it means you made a mistake. Learning mathematics is scary. Good teachers make mathematics fun for students. Elementary school mathematics teaching does not require much knowledge of math - everyone who can add, subtract, multiply and divide knows enough mathematics to teach little kids. Learning to teach, therefore, is mainly a matter of acquiring techniques. Love of children, not knowledge of subject matter, is the basis of elementary school teaching. Young children are eager to learn and trusting, but are not yet capable of thinking about complicated mathematical ideas or solving real problems.
>
> (Ball, 1988)

Several of these "hunches" are supported by studies conducted by Schoenfeld (1989), Thompson (1984) and Cockcroft (1981). Schoenfeld found three beliefs directly related to mathematics learning.

1. The processes of formal mathematics ... have little or nothing to do with discovery or invention,

2. Students who understand the subject matter can solve assigned mathematics problems in five minutes or less.

3. Only geniuses are capable of discovering, creating, or really understanding mathematics.

The Cockcroft Committee commissioned a study of the uses of mathematics in daily life. The results of this study reinforced the belief that it is permissible to not be able to do mathematics whereas very few were willing to admit they could not read. Furthermore the committee contended that the apparent dislike of the subject was attributed to some single event in the past, such as the over-expectations of parents, change of teachers, emphasis on examinations.

These findings led the authors to undertake a study into the beliefs of students and teachers concerning mathematics and themselves as learners and teachers of mathematics. If prospective teachers hold certain beliefs about mathematics and themselves which mitigate against them teaching mathematics with enthusiasm and real understanding then it is the responsibility of the institution preparing these students for their teaching role to undertake procedures to break the cycle which has developed. While there is considerable evidence that a person's beliefs about mathematics, about themselves and about the teaching of mathematics are interrelated and affect performance in mathematical tasks, the authors set out to explore whether these same phenomena exist in the western suburbs of Sydney and whether they persist across different age levels.

The questions the authors raised for study were:

1. What do students and teachers believe about mathematics?
2. Do beliefs about mathematics alter as students progress through the school system?
3. Do beliefs change when a person assumes a teaching, as distinct from a purely learning, role?
4. Do beliefs about ability to learn mathematics affect the learning and teaching of mathematics?
5. To what do students attribute their success or failure in mathematics?
6. What are the implications of teachers' reactions to students' responses to questions?
7. How do students perceive differences between mathematics learning and learning in English and science?
8. What contextual considerations are important in learning mathematics?
9. What is the motivation of students to learn mathematics?
10. What are students' perceptions of their own mathematical ability?

THE SURVEY

Survey instruments were constructed using as a basis the instrument reported by Schoenfeld (1989). Some additonal items were included on the respondents' perceptions of collaborative learning taken from a study by Way (1990). Three similar documents were prepared in order to make them suitable for administration to samples of primary and high school students and teachers. Each survey contained a number of sections each covering a part or all of one of the research questions. The differences between the three surveys were necessary to make the questions and ideas more relevant for the age level and role for which it was intended.

The participants were asked to respond to each item on a four part Likert scale ranging from "1 = very true" to "4 = not at all true".

The sections set out in the survey were as follows:

1.	Beliefs about achieving good grades in mathematics
2.	Beliefs about bad grades in mathematics
3.	Beliefs about the nature of school mathematics
4, 5.	Beliefs about teachers' questioning in mathematics
6,7.	General beliefs about mathematics, people's ability in mathematics, comparisons with English and science, good teaching in mathematics and problem solving in mathematics
P8, S11, T10	Reasons for trying to learn mathematics (P = Primary, S = Secondary, T = Teachers)
	The High School survey also included questions related to geometry.
P9, S12, T11	Grade levels, self-perceptions of ability in mathematics, perceptions of ability and beliefs of parents, and ethnic origin.

The remaining section included some open-ended questions to which the students were asked to provide any other additional comments. This was designed to extract information about beliefs on a less structured basis.

THE SAMPLE

The sample was selected on the basis of availability and convenience. The teachers in the study were fourth year students in the BEd program at the University of Western Sydney, Nepean. Responses were received from a sample of 75 of these teachers which was approximately 80% of the enrolment. The primary students were students in Years 4-6 classes of the teachers in the study. Responses were received from 185 of these students. Because of this situation, it could be said that the sample was biassed towards the positive beliefs since the students were in classes of teachers obviously wishing to upgrade their qualifications. This may be so and needs to be kept in mind when interpreting the data as any negative results may reflect worse general beliefs.

The high school sample came from an independent girls' school in a middle class area of the western suburbs of Sydney. The initial motivation to carry out the study came from a consideration of the affective aspects involved in the problem solving behaviour of mature-aged women. The data collected from a girls' school readily accessible to the researchers were considered to be relevant to the general population. The respondents from this school numbered 310 students in Years 7-10.

TIME

The surveys were administered to the high school students in November, 1990. The other surveys were completed in April, 1991.

RESULTS

1. From an examination of Table 1, a general belief exists that good grades in mathematics were the result of hard work and not because of any element of luck or teacher attitudes. The teachers reported that liking the pupils (2.5) was more likely to influence the pupils' results compared with the pupils' perceptions which indicated these are not related at all.

Table 1: Reasons for Good Grades

ITEM No	ITEM	PRIMARY PUPILS	SECONDARY PUPILS	PRIMARY TEACHERS
		MEANS	MEANS	MEANS
1	Worked hard	1.6	1.6	1.5
2	Teacher liked me	3.5	3.7	2.5
3	Luck	2.6	2.8	2.7
4	Good at maths	2.2	2.8	2.0
5	never knew	2.9	3.0	2.8

2. In both the secondary and teacher responses, the perception is that lack of hard work contributed to poor grades. No relationship between teacher attitude to students and grades was found as far as primary pupils were concerned. The results were not so definitive as far as teachers were concerned.

   For all respondents, we found that careless mistakes contribute to poor grades. This was more evident in the responses of the high school students and the teachers. It is probably the result of complicated procedures which require several steps. Mistakes can occur at any stage of the operations. (Table 2)

Table 2: Reasons for Bad Grades

ITEM No	ITEM	PRIMARY PUPILS	SECONDARY PUPILS	PRIMARY TEACHERS
		MEANS	MEANS	MEANS
6	Lack of hard study	2.3	1.7	1.8
7	Teacher didn't like	3.6	3.7	2.8
8	Bad luck	2.5	3.1	2.7
9	No good at maths	2.8	2.7	2.6
10	Careless mistakes	2.1	1.7	1.7

3. All respondents generally perceive that the mathematics children learn in school consists mainly of facts and procedures that have to be memorised but that mathematics is thought provoking.

A general belief appears to exist that students have to think hard to provide answers to questions and that occasionally there would be a number of answers. However, there appeared to be agreement that questions do have right answers and the students who understand the work require less time to answer questions. (Table 3)

Table 3: Perceptions of the Nature of Mathematics Learned

ITEM No	ITEM	PRIMARY PUPILS	SECONDARY PUPILS	PRIMARY TEACHERS
		MEANS	MEANS	MEANS
11	Facts and procedures	1.7	1.9	2.2
12	Though provoking	1.6	1.9	1.7
13	Space, numbers and problems	2.3	2.4	1.8
14	Remember right answer	2.6	2.4	2.3
15	Lots of right answers	2.5	2.7	2.1
16	Think hard	2.3	2.5	1.8
17	Few seconds for those who understand	1.9	1.9	2.0

4. There appears to be general agreement by the three groups about the nature of classroom interactions. When teachers ask questions pupils cannot answer, they try to keep the lesson moving by asking someone else. Respondents indicated that an attempt is made to allow a "short" period of time for pupils to answer then the teacher moves on. All respondents generally agreed the teacher tries not to answer all the questions. (Table 4)

Table 4: Possible Alternatives when Students Cannot Answer Questions

ITEM No	ITEM	PRIMARY PUPILS	SECONDARY PUPILS	PRIMARY TEACHERS
		MEANS	MEANS	MEANS
18	Someone else asked	2.4	2.6	2.2
19	Teacher will answer	3.1	3.0	2.8
20	Everyone waits	2.3	2.3	2.3

5. Students generally believe that people are just good at mathematics and that there are correct procedures to follow in order to get the right answers.

The perception was just as valid for English and for science but slightly fewer students believe that answers in science and English are either right or wrong. (Table 5)

Table 5: Perceptions of the Nature of Maths Compared to Other Subjects

ITEM No	ITEM	PRIMARY PUPILS	SECONDARY PUPILS	PRIMARY TEACHERS
		MEANS	MEANS	MEANS
21	Some are good at maths	1.4	1.6	2.0
22	Right or wrong	1.4	1.7	2.4
23	Good teachers - different ways	1.4	1.7	1.3
24	Good teachers - exact way	1.9	2.0	2.8
25	Good at English	1.5	1.7	2.1
26	English right - wrong	1.8	2.9	3.1
27	Good English teachers - different ways	1.8	1.8	1.5
28	Good English teachers - exact way	1.9	2.4	2.9
29	Good at Science	1.6	1.7	2.3
30	Science right - wrong	1.7	2.1	2.7
31	Good Science teachers - different ways	1.9	1.9	1.4
32	Good Science teachers - exact way	1.9	2.2	2.8

All respondents indicated that teachers try not to show students exactly what they have to do in order to answer the question. This perception was stronger amongst teachers than students. In addition, teachers believed more so than the students that in mathematics you can be creative and discover things.

Some evidence exists to suggest that students' perceptions of good teachers were related to being shown how to solve problems. Teachers on the other hand did not think this way.

Primary and secondary students appeared to seek the teachers' guidance to obtain solutions. Both groups felt that "good" teachers showed their students the exact procedures to solve problems.

This belief was not supported by the teachers who appeared to indicate that students should not be shown the exact procedures but should be encouraged to explore different ways of solving problems. This is supported by the teachers' response to (T, 34).

There were some differences in the way the respondents perceived the solving of problems. Generally, all respondents felt there could be a number of ways to solve the problem, but primary and secondary students emphasised the remembering of the rules much more so than the teachers. All respondents felt that common sense played a role in problem solving. (Table 6)

Table 6: Perceptions of Learning Strategies Associated with Maths

ITEM No	ITEM	PRIMARY PUPILS MEANS	SECONDARY PUPILS MEANS	PRIMARY TEACHERS MEANS
32	Everything important is already known	na	2.1	3.2
33	In maths you can be creative	1.7	2.1	1.4
34	Maths problems done	2.6	2.9	3.4
35	Solve by common sense	1.9	2.4	2.3
36	Taught the right method	2.1	2.1	2.8
37	Remember all rules	1.6	1.8	2.8
38	Maths - everyday life	1.8	1.8	1.2
39	Work in groups	1.6	1.9	1.4

All respondents also felt that mathematics was important for everyday life.

6. Secondary students appeared to reflect the conventional teaching approach which required students to check their answer with the answer in the back of the textbook and if there was a difference the student was more likely to be wrong. When students got the wrong answer they generally "started" again. (Table 7)

Table 7: Possible Courses of Action when the Answer is Perceived to be Wrong

ITEM No	ITEM	PRIMARY PUPILS MEANS	SECONDARY PUPILS MEANS
42	Wrong - no argument	2.4	2.7
43	Different to back of book	2.1	3.1
44	Start again	1.3	2.4
45	Mathematician already verified it	1.8	2.4
46	Statements/reasons in proper form	1.6	2.4
47	Better understanding maths thinking	2.0	1.8
48	Can't remember next step	2.8	3.1
49	Discover things about geometry	2.2	1.7
50	Nothing to do with real world	2.8	3.1
51	Doing something useful	2.0	1.5
52	Constructions	2.3	na
53	Memorise	1.9	na
54	Not related	2.5	na
55	Easy to figure	2.5	na

Responses to questions 45 - 55 indicated that the girls in the secondary school generally had a slightly negative attitude to mathematics. Mathematics was not easy to figure and had nothing to do with real life although the latter perception is not as evident (mean 2.8). Some discrepancy exists about this - e.g.

doing something useful	2.0
not related	2.5
easy to figure	2.5

7. Reasons for doing mathematics included the following:

Students generally wanted to do well in mathematics even though some reported they were only doing mathematics because they have to.

They did not appear to be overconcerned with "feeling stupid", "looking dumb" or "trying to make the teacher think they were good."

There was general agreement about this issue among the three groups. (Table 8)

Table 8: Reasons for Learning Maths

ITEM No	ITEM	PRIMARY PUPILS	SECONDARY PUPILS	PRIMARY TEACHERS
		MEANS	MEANS	MEANS
56	Help to think clearly	1.7	2.0	1.3
57	I have to	2.0	1.8	2.3
58	Want to do well	1.5	1.5	2.1
59	Was interesting	2.0	2.4	1.5
60	Get into trouble	2.7	2.8	2.4
61	Feel stupid	2.1	2.3	2.5
62	Don't want to look dumb	2.1	2.3	2.5
63	Make teacher think I was good	2.7	3.1	3.0

DISCUSSION

1. The belief that good grades are the result of hard work is in keeping with other studies on attribution theory (Barnes, et al, 1984). In these studies, females were found to attribute their success to hard work rather than luck or ability. As all the subjects in the secondary sample in this study were female, as was also the majority of teachers in the sample (78.5%), this result was to be expected. The inference can be made, however, that at the primary level, the male-female attributions of success are not yet very strongly developed. It is at this early stage that work needs to be carried out to obviate the danger of later attributions. The prevalence of this belief among teachers is viewed with concern, particularly when one realises that the subjects in the study were all graduates of a teacher preparation course and were aspiring to complete a BEd (Primary) a degree. A further consideration is that 40.5% of the teacher sample perceived their mathematical effort in school to have been above average compared to their effort in other subjects and 48.1% perceived it as average, leaving only a small percentage (11.4%) perceiving it as below average. Contrasting with these percentages, 38% perceived their actual ability as a mathematician to be above average, while 51.9% considered themselves average. This downward trend continues with only 27.8% seeing themselves as above average in teaching mathematics and 60.8% see themselves as average. These results need to be viewed cautiously as 63% of the teacher sample have been teaching for less than five years.

   The discrepancy between the perceptions of the primary pupils and the teachers on the effect of the teacher liking the pupil implies an emotional response to the teachers' attitudes reflected in mathematical achievement may be expected on the part of the teachers. An investigation of the interactions within a classroom and the effects on student learning at different levels is needed as the secondary students also appeared to share the perceptions of the teachers.

2. Again, the two predominantly female groups in the sample believe that lack of hard work results in poor grades, while no similar relationship was found amongst the primary pupils.

3. The belief that mathematics learnt in schools is mainly facts and procedures to be memorised is an alarming result in view of the many statements of a much more inclusive nature that have been issued in recent times (*National Statement on Mathematics for Australian Schools, NSW K-12 Statement of Principles for Mathematics in K-6 Syllabus*). The one heartening feature about this is that the teacher sample viewed mathematics in this way marginally less than the primary and secondary students.

   This belief that mathematics is mostly facts and procedures implies that it is being associated with arithmetic only. This is a view which has been very prevalent in the past with most syllabi in primary mathematics emphasising the number aspect of mathematics rather than geometry and other branches of the subject. An attempt to overcome this was made in the *NSW K-6 Mathematics Syllabus* by placing the Space strand at the beginning of the syllabus.

   There was a general belief that mathematics is thought provoking but one wonders whether this is because it is viewed as difficult or because it is a subject to be seriously considered. Unfortunately, the former of these views appears from other responses in the survey to be the more applicable one.

   That mathematics is a subject in which one has to think hard does not seem to be linked in the minds of the primary and secondary students with the idea that mathematics is thought provoking. This seems to indicate that mathematics is a subject where effort is necessary. Teachers on the other hand indicate a belief that one can do mathematics with less effort, implying that there could be greater emphasis on structure, making connections and processes.

   An obsession with 'the right answer' is indicated on the part of all subjects. There is also, however, some indication that all the subjects recognise the possibility of more than one answer to a question. The emphasis on remembering the right answer is particularly alarming when there is so much emphasis in modern curricula on processes. This aspect of mathematics education is particularly relevant for assessing student learning. If memory is to be the chief determinant of success in mathematics then the affective implications are horrific. Under stress as in test situations, students' memories may be very unreliable.

4. That teachers do not attempt to answer all the questions asked by students may relate to the way in which teachers have been 'trained' by 'redirecting' questions to other pupils. Trying to involve the total group is indicated by the fairly consistent response by the three groups in the sample, all of whom reported that the teacher does not usually answer the question. (3.1,3.0, 2.8). The Cockcroft Report makes a comment on what has come to be called 'teacher lust' where teachers give students more than prompts or clues either by telling them the method to be followed or the answer to a question. Lovitt and Clarke (1988) also discuss the issue of 'wait time' and stress the importance of allowing students time to focus on a question and think through it.

5. The belief that mathematics is a 'cut-and-dried' subject comes through again in beliefs that people are just good at mathematics and there are certain procedures which must be followed in order to get the right answer. The belief that in mathematics something is either right or wrong raises an number of issues, not least of all the effect on one's emotions of always being wrong, or of believing that one is not good at mathematics and can never be any better.

   Similar beliefs in connection with English and science are evident though these do not appear to be as strong as for mathematics. This reinforces the public perception that mathematics is the most difficult and narrowest subject students encounter.

   The importance of the teacher showing students different ways to look at the same question is seen to be greater in mathematics than in English or science. This may be because when students have difficulty with a particular question, the teacher explains another method is possible. This situation may not occur as often in English and science. Despite this, there still seems to be quite an emphasis on teachers showing students the 'exact procedure' to obtain an answer.

   For the primary and secondary samples, remembering rules is considered the most important thing required in order to do well in mathematics. This supports a previous observation.

   The belief that one can be creative in mathematics as indicated by the primary sample and the teachers and less so by the secondary sample may be negated by the examination system which exists. When one is constrained by the demands of external examinations and set syllabi there could develop the belief that mathematics is only what fits into these categories. This means that secondary students are denied the opportunity of exploring mathematical situations and making discoveries.

6. Attitudes of secondary students to getting 'wrong' answers are interesting from the point of view of the implications which can be drawn from them. That they accept the decision they are wrong without argument could mean one of two or three things. It could be that the student has already detected an error in her working and the teacher is simply confirming this or the student believes that her ability is low, therefore the teacher must know better. A third possibility is that other emotional factors prohibit the students from debating the answer. The tendency to start the question again rather than to consider the incorrect effort and amend it reinforces the view that the second of these theories is more likely to be the relevant one.

7. Reasons for learning mathematics differ slightly between the school students and the teachers. The primary and secondary students tended to learn mathematics because they wanted to do well, whereas teachers leaned more to the benefit of thinking clearly. This could be because the teachers consider themselves to have already done well and were now striving to improve their mathematical thinking. The existence of some of the rather negative reasons for learning mathematics - because they have to - calls into question the levels at which mathematics should cease to be compulsory. This also relates to beliefs about the usefulness of mathematics in everyday life. As reported before, most respondents agreed that mathematics is very important in everyday life. That being so, some greater attempt may need to be made to incorporate real life situations into mathematics or to at least help students make the connections between mathematics and the real world.

IMPLICATIONS FOR MATHEMATICAL PROBLEM SOLVING

Certain beliefs about mathematics are shared by students and teachers alike. When these are restricted, narrow and unimaginative, the way in which mathematics is taught and assessed will also be restricted, narrow and unimaginative. This kind of approach is entirely opposed to the view that considers problem solving as the key to mathematics. In mathematical problem solving emphasis is placed on thinking skills, the use of both inductive and deductive reasoning, on being creative and adventurous in approach to the mathematical situation.

Some of the beliefs thus held appear to be the following:

1. You are either good at mathematics or not.

2. Answers in mathematics are either right or wrong.

3. If you do not get the answer, you just start again.

4. Mathematics is important for everyday life.

5. Memorising facts and procedures is the way to learn mathematics.

6. Mathematics is arithmetic.

These beliefs, with the exception of Number 4, are likely to lead to failure in mathematics education where mathematics is not viewed in the way specified in the *National Statement on Mathematics for Australian Schools*. They are reinforced by the methods which have in the past been used to assess student learning in mathematics.

Greater efforts need to be made to enlarge the students' concept of mathematics. While this requires a general public education program since certain beliefs are acquired long before children get to school, some things can be done on a local level. One is to ensure that spatial and measurement concepts are given equal importance as number concepts in planning and teaching mathematics. Another is to ensure that varied teaching styles are used with considerable emphasis on the role of language and concrete materials.

Problem solving and mathematical investigations can play a significant role in this regard. Both problem solving and mathematical investigations require a reflective approach if they are to be effective in facilitating mathematics learning. Because the problems and the situations to be investigated can be focussed on geometry or some other branch of mathematics, emphasis on them should help students to see mathematics as far more than arithmetic and far more than rules and procedures. Such processes as specialising, generalising, enumerating, conjecturing and testing conjectures all form an important part of mathematics and help the student recognise the great scope of the subject.

Methods of assessment which emphasise reflective procedures for students should also be used. These could involve the preparation and implementing of personal checklists, practical tasks, the keeping of mathematics journals, preparing written test items, oral tests/interviews, projects and other written reports.

While not wanting to imply that hard work is not necessary, some emphasis should be put on willingness to tackle problems and on the importance of thinking rather than remembering rules. Again problem solving and mathematical investigations are good ways in which to make this emphasis.

Just as considerable emphasis has been placed on the desirability of matching teaching styles to the students' learning styles, so greater effort needs to be made in matching affective considerations to teaching styles. For this purpose some assessment procedures should ensure that students' attitudes and beliefs are known to the teacher and that the teacher has the skills to bring about change where necessary. Assessment procedures which have a reflective component are best suited for this purpose.

Reflective procedures are ones which allow the student and the teacher to return to their previous experience, eliminate negative feelings, emphasise positive ones and integrate new knowledge and understanding with their existing understandings. This type of cycle can do much to obviate the negative aspects of assessment and enhance the students' opportunity to learn mathematics effectively and happily.

While there are no great differences between the three groups on any of the items, there are several in which slight differences indicate certain trends. The perception that the lack of hard work and careless errors contribute to poor results does not appear to be as strong with primary students as it is with secondary students and the teachers.

There are some differences in the way the respondents perceive the solving of problems. Primary and secondary students emphasise the remembering of rules much more than the teachers.

While this study does not have the capacity to indicate that beliefs about mathematics affect mathematics learning, there are some related issues to be considered. When a student holds a belief such as that one is either good at mathematics or one is not and then decide on the basis of a single failure or difficulty to understand what is going on that he or she is no good at mathematics, then there is little if any, motivation to try the mathematics presented to the class. Also, if one convinces oneself that one cannot do mathematics, this will become a self-fulfilling prophecy.

Motivation is a critical issue in learning and its role in mathematics learning cannot be underestimated. The emphasis on investigating mathematical situations or solving problems, especially if they are ones which are relevant for the students, could well be the key to motivation in mathematics. If students are encouraged to pose their own problems and find ways of solving them, they will have a sense of achievement which will be invaluable in developing positive and enthusiastic approaches to mathematics.

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