Mathematical Beliefs and Achievement of Pre-service Primary Teachers

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Pre-service primary teachers in their first mathematics pedagogy subject at the University of Western Sydney completed three surveys: an achievement test of the mathematics they would be expected to teach; a survey of their beliefs about mathematics, mathematics teaching and mathematics learning; and a survey of their attitudes towards mathematics This paper reports the data from the achievement test and the beliefs survey, and investigates the relationships between these

A cursory examination of the research literature into beliefs quickly reveals that it is an area of considerable complexity Pajares (1992) was able to list over twenty ways of defining belief Early research generally accepted that behaviour was linked to belief even though there were a number of studies that reported inconsistencies between the two Agyris and Schon (1974, 1989) provided an explanation for this inconsistency proposing that people possessed theories that were differing collections of beliefs Thus theories of action were based upon beliefs that influenced behaviour whereas espoused theories were based on espoused beliefs although the two were not totally mutually exclusive To add to the complexity, researchers disagree over whether beliefs are expressions of knowledge or opinion and whether beliefs belong to the cognitive or the affective domain (Schuck & Grootenboer, 2004) Because of this complexity, a researcher who wishes to study beliefs has a duty to the readers to clearly position the research within the range of available options In this current study, beliefs are seen as what participants provided as suitable responses to open 'I believe' statements The importance of this type of study lies in the exposure of espoused beliefs and their relationships with other outcomes

Beliefs and Academic Achievement

A summary of the findings from research into pre-service teachers' beliefs, it is claimed, have reached a consensus on several issues (Kane, Sandretto & Heath, 2002):

- students enter teacher education programs with pre-existing beliefs based on their experience of school;
- these beliefs are robust and resistant to change;
- these beliefs act as filters to new knowledge, accepting what is compatible with current beliefs; and
- beliefs exist in a tacit or implicit form and are difficult to articulate

Studies that investigate the relationship between beliefs and achievement in mathematics tend to categorise beliefs as: beliefs about the nature of mathematics and mathematical tasks including its usefulness; beliefs about mathematics teaching; and beliefs about learning mathematics

The importance of pre-existing beliefs resulting from school experiences was examined by Schoenfeld (1985) who asserted that mathematical beliefs help constitute a mathematical ‘world view’ Stipek (1984) noted that Grade two students begin to appreciate that some children learn more quickly than others and that not everyone will be high achievers in school Kloosterman and Gorman (1990) suggest that with the formation of these beliefs can come a notion that affects achievement in mathematics: the notion that it makes little sense to put forth effort when it does not produce results that are considered desirable

In earlier studies, Fennema and Sherman (1977, 1978) reported that middle school and high school students who achieved higher scores on tests of mathematical achievement perceived mathematics to be more useful than lower-achieving students Schreiber (2002) studied attributions associated with successful achievement and found the more a student believed that success in mathematics was caused by natural ability, the higher the test score Stage and Kloosterman (1995) reported that secondary school females who had more positive beliefs about their own ability and about the nature of mathematics were more likely to succeed Earlier Boswell (1985) had found a relationship between elementary school girls’ stereotyping of mathematics and their achievement in mathematics While earlier studies reported mathematics being seen as a male domain, Forgasz and Leder (2000) provide evidence that stereotyping within mathematics is lessening

Several researchers (Amarto & Watson, 2003; Chick, 2002; Morris, 2001) have reported that preservice teachers do not always have the conceptual understanding of the mathematics content they will be expected to teach Rech, Hartzell and Stephens (1993) reported the mathematical competency of American university students enrolled in elementary education majors was significantly lower than the established norms of the general population

Recent studies testing the robustness of existing beliefs of pre-service teachers reported evidence of belief change, although the sample sizes were not large Aldridge and Bobis (2001) tentatively reported a change in beliefs about mathematics towards a more utilitarian and problem solving perspective as a result of a university education program Similarly Beswick and Dole (2001) also reported a change of mathematical beliefs of pre-service teachers undertaking an education degree subject Among South African pre-service teachers examined by Hobden (2001) personal beliefs about the nature of mathematics were found to be incompatible with the theoretical underpinning of the school curriculum Schuck and Grootenboer, (2004, p 58) stated research "on the beliefs of student teachers has found that prospective primary school teachers generally hold beliefs about mathematics that prevent them from teaching mathematics that empower children" Perry, Vistro-Yu, Howard, Wong and Fong (2002) found distinct differences between various primary teacher groups in their beliefs about mathematics and its learning, which led to speculation about the impact of these beliefs upon student achievement It is this speculation that has become the key issue for the current study which considers the relationship between achievement in mathematics and pre-service teachers’ beliefs about the nature of mathematics, mathematics teaching, and mathematics learning

Methodology

A total of 83 primary Bachelor of Education student teachers undertaking their first mathematics pedagogy subject at the University of Western Sydney provided responses for this study The ages of the student teachers ranged from 18 to 53 years, with 40% of them 20 years or less, another 34% between 21 and 30 years inclusive and 26% over 30 years old This distribution of ages is typical of the University of Western Sydney primary teacher education intakes with high proportions of “non-recent school leavers” All but

12% of the respondents had studied mathematics at the Higher School Certificate level (that is, until the end of high school) The 83 participants were located on two different campuses

Three surveys were administered during class time at the conclusion of the participants' first mathematics pedagogy subject in 2004 A survey methodology was considered most appropriate for this study McMillan (2004, p 195) describes surveys as popular because of their "versatility, efficiency and generalizability" Their versatility lies in their ability to "address a wide range of problems or questions, especially when the purpose is to describe the attitudes, perspectives and beliefs of the respondents" Their limitation, according to Mertler and Charles (2005), is that they do not allow the researcher to probe further as would be possible in an interview In this current study, the 23 questions used in the mathematical achievement survey were designed to ascertain whether the participants had the necessary mathematical knowledge on topics they were expected to teach Both the beliefs and the attitudes survey had been used in previous research, (Relich, Way, & Martin, 1994; Perry, et al, 2002) All three surveys were trialled with a smaller sample of students earlier in the year and amended as necessary The mathematical achievement survey consisted of 23 items which were linked in groups, covering the areas of basic concepts, numeration, basic facts, four operations, order of common fractions, operations with common, fraction, decimal fractions, percentages, measurement, order of operations, and word problems The level of ability required was lower secondary The other two surveys employed Likert scales The belief survey consisted of 18 items to which the participants were asked to respond Disagree, Undecided, or Agree The attitude survey consisted of 20 items to which the respondents were asked to respond on an eight point scale ranging from "Definitely False" to Definitely True" Another response: "Not applicable to me" was also available

Results and Analysis

In this paper, comparisons are made between measures of the espoused beliefs of the teacher education students and their total scores in the mathematics achievement test Later papers will deal with similar comparisons between the responses to attitude statements and these same total scores as well as links between attitudes and beliefs

Espoused Beliefs

All 83 respondents completed the 18 item beliefs survey The frequencies for these responses are given in Table 1 Exploratory principal components factor analysis using a scree plot resulted in the identification of five possible beliefs factors Four of the 18 items (numbers 4, 8, 9, 10) loaded across these factors and were removed for subsequent analysis Using the remaining 14 items, and the Varimax rotation procedure, five interpretable factors—student respect, computation, transmission, development, and decision making—were determined The loading of the beliefs items onto these factors is shown in Table 2 The five factors account for 38% of the item variance

Mathematics achievement scores

Seventy-eight of the student teachers completed the 23 item mathematics achievement test Responses were allocated a mark if the answer was correct and no marks for an incorrect answer Total marks ranged from 10 to 21 with mean 16 09 and standard deviation 3 21 (see Table 3)

Table 1
Responses to Beliefs Survey (n = 83)

Belief statement	Disagree (%)	Undecided (%)	Agree(%)
1 Mathematics is computation	18	31	51
2 Mathematics problems given to students should be quickly solvable in a few steps	63	24	13
3 Mathematics is the dynamic searching for order and pattern in the learner’s environment	0	26	74
4 Mathematics is a beautiful, creative and useful human endeavour that is both a way of knowing and a way of thinking	11	25	64
5 Right answers are much more important in mathematics than the ways in which you get them	95	4	1
6 Mathematics knowledge is the result of the learner interpreting and organising the information gained from experiences	5	16	80
7 Students are rational decision makers capable of determining for themselves what is right and wrong	22	40	39
8 Mathematics learning is being able to get the right answers quickly	90	9	1
9 Periods of uncertainty, conflict, confusion, surprise are a significant part of the mathematics learning process	5	12	83
10 Young students are capable of much higher levels of mathematical thought than has been suggested traditionally	4	23	74
11 Being able to memorise facts is critical in mathematics learning	23	41	36
12 Mathematics learning is enhanced by activities which build upon and respect students’ experiences	2	5	93
13 Mathematics learning is enhanced by challenge within a supportive environment	0	2	98
14 Teachers should provide instructional activities which result in problematic situations for learners	11	29	60
15 Teachers or the textbook - not the student - are the authorities for what is right or wrong	70	27	4
16 The role of the mathematics teacher is to transmit mathematical knowledge and to verify that learners have received this knowledge	36	28	36
17 Teachers should recognise that what seem like errors and confusions from an adult point of view are students’ expressions of their current understanding	2	14	83
18 Teachers should negotiate social norms with the students in order to develop a co-operative learning environment in which students can construct their knowledge	1	15	84

Table 2
Item Loadings onto Five Interpretable Factors for Espoused Beliefs

Item number	Student respect	Computation	Transmission	Development	Decision making
1	09	**45**	- 09	- 02	- 35
2	- 17	**83**	19	- 03	24
3	06	14	- 14	**42**	- 03
5	- 18	26	- 08	- 48	17
6	**43**	- 02	- 05	05	05
7	09	03	06	- 11	**54**
11	- 05	- 04	**37**	- 03	- 44
12	**48**	- 21	- 16	11	17
13	**85**	02	14	13	- 05
14	06	- 12	04	**45**	- 16
15	- 01	- 07	**75**	00	02
16	- 03	15	**30**	- 03	- 01
17	08	05	- 05	**48**	25
18	**39**	18	- 35	19	- 05

Table 3
Total Mathematics Achievement Scores (n = 78)

Score	10	11	12	13	14	15	16	17	18	19	20	21
Percentage	9	4	4	8	5	8	8	18	8	18	6	5

The student teachers were grouped into three age groups: 20 years or less; 21 to 30 years; over 30 years A one-way analysis of variance was conducted to evaluate whether there is a relationship between these age groups and the total mathematics test score That is, we were interested in seeing whether the different age groups of students achieved differently No statistically significant differences were found As can be seen in Table 4, the means and standard deviations in the total mathematics test score varied little between the groups

Table 4
Means and Standard Deviations in Total Mathematics Test Score Across Age Groups

Age group	Mean	Standard deviation
20 years or less	16 86	3 06
21 to 30 years	15 57	3 28
More than 30 years	15 81	3 34

Correlations

Correlation coefficients were computed between the total mathematics achievement scores and both the individual beliefs item scores and the factor scores resulting from the factor analysis on the beliefs items

Only four individual beliefs items provided statistically significant correlations with the total achievement scores Three of these yielded relatively small negative correlations:

Item 2 *Mathematics problems given to students should be quickly solvable in a few steps*

r = -0 24, p<0 05;

Item 3 *Mathematics is the dynamic searching for order and pattern in the learner's environment*

r = -0 29, p<0 01;

Item 5 *Right answers are much more important in mathematics than the ways in which you get them*

r = -0 25, p<0 05;

while the fourth yielded a small positive correlation:

Item 13 *Mathematics learning is enhanced by challenge within a supportive environment*

r = 0 23, p<0 05

When correlation coefficients were calculated between the total test scores and five factors scores calculated for each respondent, two factors provided statistically significant results The student respect factor was positively correlated to the total test score (*r* = 0 27, p<0 05) while the computation factor was negatively correlated to the total test score (*r* = -0 32, p<0 01)

Discussion

Examination of Table 1 reveals a strong tendency in positive responses towards constructivist approaches to mathematics learning and teaching This is a much stronger tendency than has been detected using the same instrument in previous studies in different contexts (e g , Perry, Howard & Tracey, 1999; Perry, Wong & Howard, in press) Perhaps the fact that these student teachers were just completing a mathematics pedagogy subject in their degrees, firmly oriented towards such approaches that underpin the school syllabus, explains this tendency Despite this tendency, there is evidence of some remaining indecision See, for example, the strong agreement with constructivist-based statements of Items 6, 13, and 18, and the more evenly distributed beliefs in other statements, such as Items 7, 11, and 16 These findings are consistent with recent research suggesting that changes in beliefs about learning and teaching mathematics can occur during teacher education courses (Aldridge & Bobis, 2001; Beswick & Dole, 2001)

Also apparent in Table 1, are some seemingly contradictory beliefs regarding the nature of mathematics For example, almost all respondents are definite about what mathematics is *not* about (Item 5), but fewer are sure about what mathematics *is* about (Items 1, 3, 4, 6) Again, this could be interpreted as an indication of at least the questioning of previous beliefs and, therefore, is somewhat reassuring, considering the concerns expressed in other research findings about the quality of teaching when personal beliefs are incompatible with the theoretical underpinnings of the school syllabus (Hobden, 2001; Schuck & Grootenboer, 2004)

Overall the performance on the achievement test was quite poor, but not really surprising according to other research (Amarto & Watson, 2003; Chick, 2002; Morris, 2001) Though the connections between beliefs and achievement were not striking, of interest is the consistency of the negative correlation of beliefs about the nature of mathematics (Items 2 & 5) to achievement test scores That is, the stronger the belief in the importance of computation and correct answers, the lower the achievement performance On the other hand, Item 13 was positively correlated to higher scores in the achievement test Item 13 had a high loading in the factor of 'Student Respect', and students who rated the key items (6, 12, 13, 18) highly showed a positive tendency towards achievement It is not possible to determine the direction of any cause and effect in these relationships, but perhaps there is a self-esteem element at work There is a need to consider the attitudes data gathered in the third component of this study to understand the students' perceptions of themselves as mathematics learners

Conclusion

This study has highlighted some interesting conundrums when considering the relationships between pre-service teachers' beliefs about mathematics, mathematics teaching and mathematics learning and their achievement on a test of the mathematics they will be expected to teach Further analysis of these data, along with those on the pre-service teachers' attitudes to mathematics should shed more light on possible links across these three domains

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