Adult innumeracy and the influence of negative mathematics attitudes, low self-efficacy beliefs, and mathematics anxiety in student primary teachers – an interventionist approach for better practice

Christopher M. Klinger
University of South Australia
chris.klinger@unisa.edu.au

The role of primary teachers in the relationship between adult innumeracy and mathematics anxiety is examined via a specific focus on the mathematics attitudes and competencies of pre-service (student) primary teachers commencing their first year of Bachelor of Education (Junior Primary and Primary) degree studies. First, the mathematics attitudes, self-efficacy beliefs, and mathematics anxiety of one cohort are reviewed to identify the students' perceptions of mathematics, including their own capabilities; second, the results of a short but comprehensive skills test administered to a different (but comparable) cohort are analysed to identify facets of the students' understanding of, and capacity to carry out, fundamental mathematical tasks; and third, this latter cohort's attitudes towards, and perceptions of, mathematics in the context of their experiences are examined from a qualitative perspective via an open questionnaire. The results confirm and expand upon previous findings by the author that student primary teachers tend to have pervasive and frequently severe negative attitudes, low mathematics self-efficacy beliefs, and anxiety of mathematics that are more extreme than those of any other undergraduate student group. However, there is evidence for the effectiveness of appropriate interventions during teacher preparation programs for pre-service primary teachers.

Introduction

Adult innumeracy is found in most Western societies (and elsewhere, no doubt, although 'numeracy' is a particularly Western construct). As reported previously (Klinger, 2009), the connection between adult innumeracy and mathematics anxiety is that the origin of both tends to be located in the area of primary education, with a particular focus for the role of primary teachers, especially in the middle to late years of primary education. Here I will concentrate on two problematic areas relating specifically to characteristics of teachers. These are:

- teachers' expertise and preparedness to teach mathematics effectively; and
- the attitudes and anxieties of teachers and prospective teachers.

Student teachers will ultimately carry their attitudes and perceptions into primary school classrooms (a somewhat self-evident observation in as much as one accepts that attitudes and perceptions are defining character attributes). If these are profoundly negative, there are deep implications for the perpetuation of poor early mathematics learning experiences which must ultimately translate to future adult numeracy concerns; Schuck and Grootenboer (Perry *et al*, 2005, p. 626) put it succinctly, stating that the negative beliefs about mathematics generally held by student primary teachers 'prevent them from teaching mathematics that empower children'.

The role of primary teachers in the relationship between adult innumeracy and mathematics anxiety is examined here via a specific focus on the mathematics attitudes and competencies of pre-service (student) primary teachers commencing their first year of Bachelor of Education (Junior Primary and Primary) degree studies. First, the mathematics attitudes, self-efficacy beliefs, and mathematics anxiety of one cohort, surveyed in an earlier study using the *Inventory of maths attitude, experience, and self-awareness* (IMAES) instrument developed by the author, are reviewed to identify the students' perceptions of mathematics, including their own capabilities. The existence of severe negative affective influences among pre-service primary teachers is again identified and it is postulated that these might reasonably be expected to manifest as a deficit of functional numeracy skills. Second, the results of a short but comprehensive diagnostic skills test, administered to a different (but comparable) cohort, are analysed to identify aspects of the students' understanding of, and capacity to carry out, fundamental mathematical tasks. The test is a key component of a multi-faceted approach to the challenge of preparing math-averse primary and junior primary student teachers for their future classroom careers. Thirdly, this latter cohort's attitudes towards and perceptions of mathematics in the context of the intervention are examined from a qualitative perspective via an open questionnaire.

While the functional deficit hypothesis is supported by evidence, there is also evidence that negative attitudes, poor self-efficacy beliefs and anxiety can be positively modified with appropriate interventions during teacher preparation programs.

Recap – primary teachers and the IMAES instrument

The 2003 IEA's Trends in International Mathematics and Science Study (TIMSS) compared qualitative responses from fourth-grade (age 9) primary school pupils and eighth-graders (age 13) recently transitioned to secondary school (Mullis, Martin, Gonzalez, & Chrostowski, 2003). Over a four year period there was a considerable decline in the proportion of pupils who agreed 'a lot' that they 'enjoy learning mathematics' and a corresponding doubling of the numbers who *disagreed* with the statement. Similarly, High SCM (Self-Confidence in Learning Mathematics) assessments declined greatly, while Low SCM assessments doubled. We can infer from these data that over a critical four year period, 60-70% of pupils were at risk (or worse) of being 'turned off' mathematics.

TIMSS also reported that in the UK and the USA only 8% of primary teachers have a mathematics major and in Australia the proportion is reported as 17%. They have an average of 16 years teaching experience and more than 90% of fourth-graders in the TIMSS study were taught by teachers 'who felt ready to teach the topics in number, algebra, measurement, and data' (*ibid.* p. 255). Given the substantial decline in their pupils' confidence and enjoyment of mathematics learning, the teachers' perceptions of their readiness just do not add up. Indeed, causal factors associated with the decline relate to attributes of in-service and pre-service primary teachers and also to the framework of educational systems, schools, and curriculum practices. In a study of pre-service teachers, Uusimaki & Nason (2004) found that 72% of their subjects perceived that their own negativity was particularly attributable to the primary teachers who taught them. Much has been written about the impact this can have in the primary classroom and it is clear that those new to teaching are particularly swayed by their past learning experiences (Stables, Martin, & Arnhold, 2004). This has been acknowledged for a long time but the literature is dominated by qualitative and descriptive studies that report the attributes of pre-service teachers.

In contrast, the IMAES instrument provides *quantitative* profiles that permit comparison with other groups. The details are well documented (Klinger, 2006) but, in brief, it is a multi-part questionnaire that uses (mostly) 5-point Likert scales for responses to statements about maths-attitude, maths-anxiety, mathematics self-efficacy beliefs, and past/early mathematics learning experiences. Some demographic information is also collected and the reliability of the instrument is assessed using factor analysis and so forth. IMAES is a robust instrument that is effective in providing solid quantitative results that permit comparisons to be made between independent groups of subjects. Previous results obtained using the IMAES instrument (Klinger, 2009) showed that pre-service primary teachers scored lower than other students in the three chief constructs of maths-anxiety, maths-attitude, and mathematics self-efficacy beliefs. The results are reproduced in Figure 1 (zero on each scale indicates neutrality).

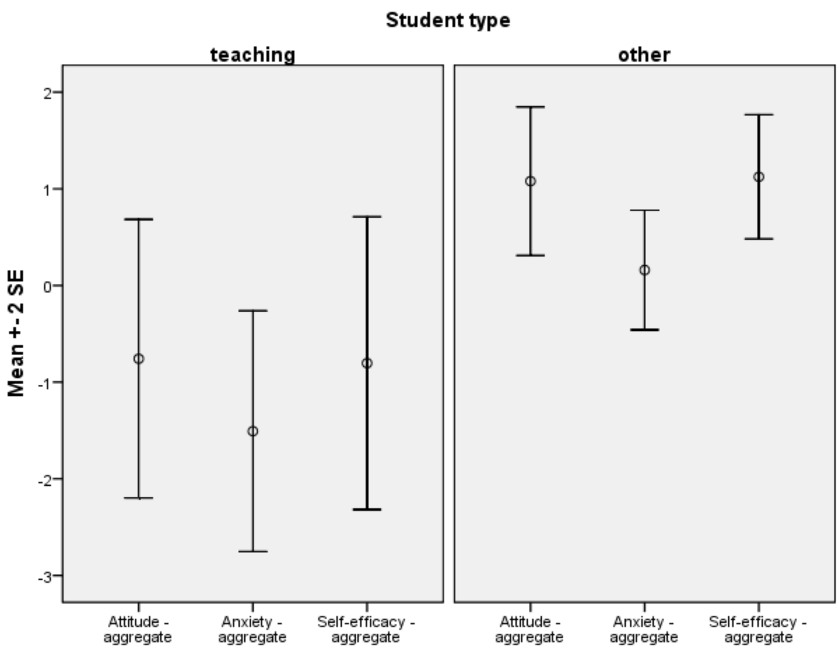

Fig. 1 Comparison of aggregate scales in three primary domains by student type

In short, student primary teachers tend to have pervasive mathematics anxiety, negative attitudes, and low mathematics self-efficacy beliefs that are more extreme than those found in any other undergraduate group. However, it was observed that, on the whole, their disaffection with mathematics was more a reaction to mathematics learning than to mathematics itself. The findings are consistent with those of other researchers (see, for instance, Taplin, 1998; Schuck, 1999; Trujillo & Hadfield, 1999; Hawera, 2004) who have found that negative attitudes towards mathematics and science, including overt maths-anxiety and phobia as a result of past mathematics learning experiences, are a common occurrence in primary education students.

To provide further context for the present purposes, it is useful to consider the characteristics of those drawn to the profession. Some twenty years ago (that is, in the era when the average primary teacher reported in the TIMMS study was in training) the so-called Speedy Report (Speedy, Annice, Fensham, & West, 1989) in Australia stressed the importance of high-order mathematical knowledge and competency while noting serious concerns that many student primary teachers were entering their teaching courses with a very poor knowledge of mathematics.

Diagnosis, evaluation, intervention and reflection – a 'DT' approach

Since 2001, the School of Education at the University of South Australia has responded to math-averse primary and junior primary student teachers by taking a proactive approach with all commencing undergraduate and graduate-entry student teachers. The initiative consists of several components presented in a 3-part strategy:

1. a non-standardised timed (1 hour) diagnostic test (DT) in four sections at the level of mathematical attainment expected of a Year 8 pupil in a South Australian school
2. supplementary lectures and tutorials, extending to 1:1 support as required; and
3. a reflective questionnaire.

The test is first given at the start of the course without prior warning so that students have the opportunity to recognise and expand their mathematical knowledge base, taking into consideration their curriculum needs as future primary ('Reception to Year 7' or R-7) teachers. Students must demonstrate mastery by achieving a minimum 80% pass rate for each section of the test (all sections must be mastered) but they are allowed three attempts, with those who remain unsuccessful after the third attempt being obliged to repeat the entire course/topic. After the first attempt, additional (extra-curricular) lectures and tutorials are provided. These are not compulsory but students are encouraged to reflect on their diagnostic results and to seek appropriate tuition and support.

Initially, tutorial groups are quite large (30-50 students) but well staffed with casual tutors, drawn increasingly from schools and/or professional organisations; many of them, as teachers themselves, are recognised for their expertise in the field of providing mathematics support at this level. Tuition is said to be directed towards promoting understanding rather than being merely functionally remedial (although there are certainly aspects of 'skill and drill' involved and there is little doubt that it becomes increasingly assessment driven). Still, it appears to be sufficient for the majority of students to demonstrate mastery on their second attempt, following which those who remain unsuccessful self-identify to attend small-group tutorials (12-20 students) and also have access to 1:1 tutorial advice before their final attempt at the test.

Table 1 Summary of Diagnostic Test (undergraduate, 2007)

	1st attempt (n=132)				2nd attempt (n=105)			
	Pass		Fail		Pass		Fail	
	n	%	n	%	n	%	n	%
1. Number	83	62.9	49	37.1	99	94.3	6	5.7
2. Space & Measurement	48	36.4	84	63.6	77	73.3	28	26.7
3. Data & Chance	88	66.7	44	33.3	101	96.2	4	3.8
4. BODMAS, patterns & number theory	44	33.3	88	66.7	88	83.8	17	16.2
One section	31	23.5	24	18.2	1	1.0	12	11.4
Two sections	30	22.7	30	22.7	16	15.2	16	15.2
Three sections	24	18.2	31	23.5	12	11.4	1	1.0
Four sections	25	18.9	22	16.7	75	71.4	1	1.0
OVERALL	25	18.9	107	81.1	75	71.4	30	28.6

The results in Table 1 come from a group of 132 undergraduate students in 2007, of whom only 25 (18.9%) demonstrated mastery over all sections in their first attempt, with more than 80% showing weaknesses in one or more sections. This very low mastery rate at the first attempt reveals the lack of preparedness reported in the literature. Around two-thirds of the students encountered difficulties in the sections on space and measurement concepts and with order of operations, patterns and number theory. Questions involving more straightforward arithmetic and finding information from tables and graphs were a little less problematic, although each corresponding section provided difficulties for about one third of the students, which is far from inconsequential. Of particular interest is the proportion of students (some 63%) who were troubled by more than one section of the test. This suggests that their lack of success cannot be explained as aberration, oversight, or simple memory lapse, revealing instead a much broader dysfunction in students' lack of preparedness.

Following the first instance of the test, two students withdrew from the course and 105 made a second attempt some 2-3 weeks later after having had opportunities to receive tuition. Because of the nature of the course structure and the extra-curricular scheduling of tuition, it is not known which students did, and which did not, obtain tuition but the majority (71.4%) of those who required a second attempt were successful, taking to 75.8% the proportion of the cohort now having exhibited mastery of the material. Of the remaining 30 students, 12 failed just one section, 16 failed two sections, one failed three sections and another individual failed all four sections. Again, the greatest difficulties were encountered with the sections on space and measurement concepts, followed by order of operations, patterns and number theory. Ultimately all but four students achieved the required results at a third attempt that could be undertaken when students felt sufficiently prepared, so the final success for the great majority demonstrates the value of perseverance.

A separate cohort of graduate-entry students in the same year, 2007, followed essentially the same protocol of diagnosis and support. An abridged summary is shown in Table 2:

Table 2 Summary of Diagnostic Test (graduate-entry, 2007)

1st attempt (n = 54)	Fail	
	n	%
1. Number	21	38.9
2. Space & Measurement	18	33.3
3. Data & Chance	8	14.8
4. BODMAS, patterns & number theory	25	46.3
OVERALL	37	68.5

Although a substantial majority (68.5%) of these students were unable to demonstrate mastery, the proportion of successful students was almost double that of the undergraduate cohort. While Section 4 was also the most problematic for this group, it was rather less so at 46.3% compared to 66.7%. Section 2 performance compared favourably, too, with the proportion of students encountering difficulties in this area being almost half that of the undergraduate group (33.3% compared to 63.6%) and similarly for Section 3. Only in Section 1 were the respective proportions roughly equivalent. Following their second attempt, 89.5% of the graduate-entry group demonstrated mastery of the test material compared to 71.4% of the undergraduate group.

It is tempting to speculate that an explanation for these differences lies in the greater experience of these graduate entrants, gained by undertaking a first undergraduate degree – that is, one might expect differences between undergraduate and graduate students anyway. However, that could be quite misleading without first considering *what* they had studied and in which discipline. It may be that, as former undergraduate students in non-teaching degree programs, an IMAES profile would reveal that they are less math-averse and anxious and thus in a relatively advantaged position (though not greatly so, apparently).

The intervention opportunities that arose appear to have been highly effective in raising students' awareness of their strengths and weaknesses and guiding them to much more successful outcomes. The students themselves expressed their appreciation of this when they completed a reflective questionnaire and were almost unanimous in their agreement that the diagnostic tool was effective:

> "It was great to see from the beginning what we knew and needed help with."
>
> "I think the remedial classes helped me immensely."
>
> "I had completely forgotten these maths concepts and I now look at my own everyday activities in a very different light."

Some 80% of respondents agreed that their strengths and weaknesses were identified early and many reported that they had discovered the need to review and revise material while others felt that they had encountered concepts that they had not learned adequately at school. The proportion of students who believed that the diagnostic tool identified areas for improvement of which they had been previously aware was almost double that of those who felt otherwise. Their comments included:

> "I had unrealistic ideas about my abilities in all areas."

> "I thought I was doing the question correctly in the original DT however got them wrong."
>
> "It took the DT for me to realize what areas needed revision and I probably would not otherwise have been aware of them."

Although many reported feeling anxious at the first test being administered without notice, feedback from the reflective questionnaire clearly shows that the vast majority of students valued the process as a whole.

Discussion and Conclusion

While different IMAES and DT cohorts were reported here, experience with the IMAES instrument in numerous contexts shows that the resulting profiles are robust in their ability to characterise affective, cognitive, and behavioural attributes. There is no reason to suspect that the DT cohorts are atypical in any significant respect and the DT results in fact confirm that the postulated behaviours are present. They also reveal that after two decades the concerns expressed in the Speedy Report (Speedy *et al*, 1989) remain topical.

Perhaps most relevant to the present context are the dual observations that, firstly, children's attitudes towards mathematics tend to decline as they progress through primary to secondary education; and, secondly, that they suffer from the destructive effects of 'unimaginative instruction and non-positive teacher attitudes' and the pressure to 'cope with highly demanding tasks, frequently at a pace beyond their ambition' (Philippou and Christou, 1998, p. 192). Not only is it highly likely that the majority of pre-service primary teachers represented in this study are casualties of these phenomena but that, if left unchecked, they will themselves perpetrate such ills in their future classrooms. Of this there can be little doubt: the extremes of the negative profile revealed by the IMAES results coupled with the very poor competency levels diagnosed by the first DTs present a tangible and substantial risk to the mathematics learning experiences of generations of primary pupils.

Supposing that 100 of the 130 undergraduate students in this study actually enter the profession and assuming, further, an average career span of 20 years with an average teaching load of 25 pupils per year (primary teachers usually have chief responsibility for a single class for one year), one teacher might influence some 500 pupils. So, this one cohort of student teachers might be expected to reach 50,000 individuals whose early mathematics learning experiences may well determine their futures as numerate or innumerate adults over the ensuing 60 or so years. On that note, it is reassuring that the results here indicate that positive interventions within teacher education programs are indeed possible. They are also necessary: as a matter of public policy, it should be unacceptable that so many prospective teachers should begin their professional education from such a low mathematics base.

Acknowledgement

Many thanks to Anna Rodgers, who convenes 'Mathematics Curriculum for Early and Primary Years 1' at the University of South Australia, for providing details of the innovative approach undertaken there and for making available anonymous summary data of students' test results. Her recognition of students' anxieties and the numeracy problem, together with her dedicated approach in support of her students' aspirations and consultation in the present work are most appreciated.

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