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Addressing Adult Innumeracy Via an Interventionist Approach to Mathematics Aversion in Pre-service Primary Teachers

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Abstract

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. If unaddressed, such mathematics aversion will be carried into primary school classrooms, presenting a tangible and substantial risk to the mathematics learning experiences of generations of primary pupils and perpetuating the relationship between adult innumeracy and mathematics anxiety. Here, the role of primary teachers is considered 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. This involves, firstly, a review of an earlier study using the IMAES instrument developed by the author, which identifies the students' perceptions of mathematics, including their own capabilities; and secondly, analysis of the results of a short but comprehensive skills test administered to a different (but comparable) cohort so as to identify facets of the students' understanding of, and capacity to carry out, fundamental mathematical tasks. Finally, 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 provide evidence that the impact of mathematics aversion in primary teachers may be reduced considerably by appropriate interventions during pre-service teacher preparation programs.

Introduction

The endemic adult innumeracy found in most Western societies is inextricably linked with various levels of maths-anxiety and negative mathematics attitudes, together with an often-profound aversion to the learning of mathematics. An earlier study (Klinger, 2009) that sought a better understanding of the innumeracy problem, examined the connection between adult innumeracy and mathematics anxiety. This showed the origin of both to be located in the area of primary education, with a particular focus identified for the role of primary teachers, particularly in the middle to late years of primary education. While matters of curriculum content, pedagogy, and time allocated to mathematics teaching and learning activities were identified as problematic areas, of particular relevance to the present work were the dimensions relating specifically to characteristics of teachers. These were:

1. Teachers' expertise and preparedness to teach mathematics effectively; and
2. The attitudes and anxieties of teachers and prospective teachers.

If one accepts that attitudes and perceptions are defining character attributes, it is perhaps an obvious conclusion that student teachers will ultimately carry theirs into primary school classrooms. If their views of mathematics are profoundly negative, there are deep implications for the perpetuation of poor early mathematics learning experiences and hence, ultimately, for adult numeracy concerns.

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 in a concomitant deficit of functional numeracy skills. Second, the results of a short but comprehensive skills test, administered as a diagnostic intervention to a different (but comparable) cohort, are analysed to identify facets of the students' understanding of, and capacity to carry out, fundamental mathematical tasks. The test is a principle 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 findings support the functional deficit hypothesis, it is also demonstrated that negative attitudes, poor self-efficacy beliefs and anxiety are '…plastic, not steel' (Klinger, 2006). That is, they may be positively modified with appropriate interventions during teacher preparation programs.

Recap – primary teachers and the IMAES instrument

According to the 2003 IEA's Trends in International Mathematics and Science Study (TIMMS), internationally about a quarter of those teaching mathematics at fourth-grade level have a post-secondary specialization in the subject – but the statistic is strongly skewed by very high proportions (ranging from 48-62%) in Latvia, Russia, Moldova, Iran, and Singapore. In the UK and the USA only 8% of primary teachers have a mathematics major and in Australia the proportion is reported as 17%. However, they have an average of 16 years teaching experience and more than 90% of fourth-graders participating in the TIMMS study were taught by teachers 'who felt ready to teach the topics in number, algebra, measurement, and data' (Mullis, Martin, Gonzalez, & Chrostowski, 2003, p. 255). The report also compared qualitative responses from fourth-grade primary school pupils and eighth-graders recently transitioned to secondary school. This indicated that over a four year period there was a substantial 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 (Mullis *et al*, 2003).

Given this substantial decline in pupils' confidence and enjoyment of mathematics learning, the teachers' perceptions of their readiness are incongruent with actual practice and the classroom experience. Perhaps they really mean that they feel prepared to deliver the curriculum. Perhaps their uncertainties and anxieties are such that they lack an appreciation of the distinction between teaching *procedures* and promoting an understanding of the *language* and *process* of mathematics. In that sense, many of them could be regarded as being covertly innumerate at the level of Maguire and O'Donoghue's (2002) integrative phases.

In one study of pre-service teachers, 72% of the subjects perceived their own negativity to be particularly attributable to the primary teachers who taught them (Uusimaki & Nason, 2004). Much more has been written about the consequences 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). Schuck and Grootenboer put it succinctly, stating that the negative beliefs about mathematics generally held by student primary teachers 'prevent them from teaching mathematics that empower children' (Perry, Way, Southwell, White, & Pattison, 2005, p. 626). While this has long been acknowledged, the literature is dominated by qualitative and descriptive methodologies in 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. Empirical results 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 below (zero on each scale indicates neutrality). Compared to all other students, they had stronger responses to negative statements on the questionnaire and weaker responses to the positive statements, and very low p-values provided strong (α=5%) evidence to infer that the observed differences were indeed real effects with some systematic cause (Klinger, 2009). In summary, 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. 'Drilling down' to the level of individual questionnaire statements revealed internally consistent responses that identified strong apprehension of the mathematics classroom experience (whether reflective or anticipatory), fearful perceptions of mathematics itself and the challenges it presents, disinterest in mathematics as an occupation or intrinsically enjoyable activity, and lack of problem-solving confidence. However, it was observed that, on the whole, the subjects' disaffection with mathematics was more a reaction to mathematics *learning* than to mathematics itself. The findings are consistent with those of other researchers reporting the common occurrence among primary education students of negative attitudes towards mathematics and science, including many who are overtly maths-anxious and even maths-phobic as a result of their past mathematics learning experiences (see, for instance, Taplin, 1998; Schuck, 1999; Trujillo & Hadfield, 1999; Hawera, 2004). Indeed, 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.

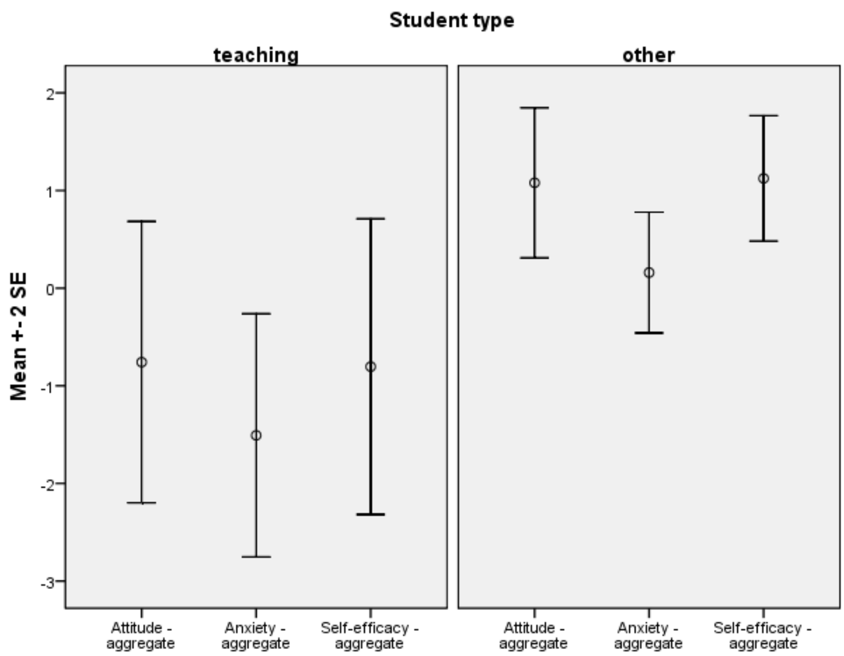

Figure 1 Comparison of aggregate scales in three primary domains by student type

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

For nearly a decade, the University of South Australia's School of Education has responded to the challenge of math-averse primary and junior primary student teachers by adopting a proactive approach within the core course/topic, 'Mathematics Curriculum for Early and Primary Years 1', undertaken by commencing undergraduate and graduate-entry students. The tailored approach consists of several components, described to the students as 'diagnostic tools' presented to provide them with opportunities 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. The components comprise:

- a non-standardised timed (1 hour) diagnostic test in four sections covering:
  1. number: place value, arithmetic operations, money, fractions, decimals, and percentage;
  2. space and measurement;
  3. data (including tables, graphs and diagrams) and chance;
  4. patterns (including simple algebraic relations), number theory (e.g. prime numbers), and order of operations ('BODMAS');
- supplementary lectures and tutorials, extending to 1:1 support as required; and
- a reflective questionnaire.

The questions presented in the diagnostic test/tool (DT) correspond to the level of mathematical attainment expected of a Year 8 pupil in a South Australian school. The test is initially undertaken during the first week of the course/topic without prior preparation and, although presented as a means of functional evaluation for the benefit of the students, it also serves a gatekeeper function: students must demonstrate mastery by attaining a minimum 80% pass rate for each section of the test in order to progress. While they are permitted three attempts (with different questions each time), those who remain unsuccessful after the third attempt are obliged to repeat the entire course/topic.

After the initial administration of the DT, additional (extra-curricular) lectures and tutorials are provided. Attendance is not compulsory but students are encouraged to reflect on their diagnostic results and to seek tuition and support according to their individual needs, which may include making their own arrangements. At the start, 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 in these classes is said to be directed towards promoting understanding rather than being merely functionally remedial and they appear 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 undertaking their final attempt at the DT.

The non-standardised protocol for the DT was adopted so as to afford the lecturer the opportunity to adapt or modify content on the basis of experience informed by practice. While this is desirable pedagogically, it tends to limit the extent to which results from successive cohorts can be directly compared in any longitudinal analysis, although the tendencies exhibited in the data (Table 1) are considered to be generally representative.

	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

Table 1 Summary of Diagnostic Test (undergraduate, 2007)

The results in Table 1 obtained from a cohort of 132 undergraduate students who began the course/topic in 2007. The summary data from the performance of individual cohorts such as this is illuminating on several levels, not least in that very low mastery rates in first attempts reveal the lack of preparedness observed by various researchers noted previously, while subsequent attempts demonstrate the value of perseverance. Moreover, feedback from the reflective questionnaire illustrates the value that the vast majority of students ascribe to the process (see below).

Twenty-five students representing 18.9% of the cohort demonstrated mastery over all sections in their first attempt, with more than 80% identifying weaknesses in one or more sections. Some 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 somewhat less problematic, though each corresponding section provided difficulties for about one third of the students, which is a far from inconsequential outcome. Of particular interest is the proportion of students (some 63%) who were troubled by more than one section of the test, indicating very clearly that their lack of success cannot be explained as a mere aberration, oversight, or simple memory lapse but instead reveals a much broader dysfunction in their lack of preparedness.

Following the first instance of the test, two students withdrew from the course leaving 105 to undertake the second attempt. The majority of these (71.4%) were successful, taking to 75.8% the proportion of the cohort now having exhibited mastery of the material. Of the remaining 30 students who had failed to demonstrate overall mastery at this point, 12 had failed just one section, 16 had failed two sections, one had failed three sections and another individual failed all four sections. Again, the greatest difficulties were encountered with the sections on space and measurement concepts and with order of operations, patterns and number theory, the former being the most problematic. At the third attempt, all but four students achieved the required results and they were invited to re-enrol in the course/topic at the next opportunity, being unable to obtain a passing grade in this instance.

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:

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

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

Here, although a substantial majority (68.5%) of the students were unable to demonstrate mastery, the proportion of successful students was almost double that of the undergraduate cohort. While Section 4 was the most problematic for this group, too, it was rather less so at 46.3% compared to 66.7%. Section 2 performance compared favourably, also, 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 had demonstrated mastery of the test material compared to 71.4% of the first group.

An explanation for these differences might be considered to lie in the greater experience of these graduate entrants, gained by undertaking a first undergraduate degree. Although a tempting speculation, it could, however, be quite misleading without first considering the nature of those studies and particularly the discipline in which they were undertaken. It may be at least as tempting to speculate that, as former undergraduate students in non-teaching degree programs, an IMAES profile would reveal them to be rather less math-averse and anxious and thus in a relatively advantaged position (though apparently not to any great extent).

What is clearest in these differences is that the intervention opportunities afforded by the diagnostic tools and procedures appear to be highly effective in raising students' awareness of their strengths and weaknesses and guiding them to much more successful outcomes. The students themselves express an appreciation of this in the feedback provided via completion of reflective questionnaires. Students were almost unanimous in their agreement that the diagnostic tool was effective in this regard, with comments that (for instance):

"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."

Around 80% of respondents agreed that their strengths and weaknesses had been identified early and their insights as to their needs show broad correspondence with the test results. While many reported that they had discovered the need to review and revise material, similar numbers felt that they had encountered concepts that they had not learned adequately at school. One student commented, "Maths has always been a weakness and this is probably due to primary school teaching as well as lack of review now." Compared to those who felt otherwise, almost twice as many students believed that the diagnostic tool identified areas that needed improvement of which they were previously unaware. 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."

The provision of supplementary tuition was generally appreciated, with a good take-up rate, and students were also proactive with more than 50% of them obtaining outside assistance from family, friends, and former mathematics teachers. They also identified a range of benefits that arose as a consequence of the diagnostic tool and intervention – on a personal level, in terms of improved confidence and greater self-awareness ("I thought I knew it all; boy was I wrong"; "I was very anti maths but now I am much more questioning in a mathematical way"); to their mathematics knowledge base, and as a prospective primary teacher ("Confidence that I know the 'fundamentals' of each area/topic or at least where/how to find more information"; "I can see how I can teach children to love maths without my past negative experiences of maths filtering in").

Finally in these reflective questionnaires, students gave suggestions on how to improve the DT. These focussed overwhelmingly on a desire for more notice and preparation time before the administration of the first test and for the test time to be increased from 1 hour to 1½ hours. Numerous comments suggested that many students experienced test anxiety to which they then attributed their poor outcomes from the initial DT.

Discussion and Conclusion

Although findings for different IMAES and DT cohorts were reported here, experience with the IMAES instrument in numerous contexts has demonstrated that the resulting profiles are robust in their ability to characterise affective, cognitive, and behavioural attributes. There is no evidence that the DT cohorts are atypical in any significant respect and the DT results in fact confirm that the postulated behaviours are manifested in these groups. They also reveal that after two decades the concerns expressed in the Speedy Report (Speedy *et al*, 1989) remain topical. The relationship between a negative IMAES profile and low competency levels is complex and one does not necessarily imply the other; competency can be depressed by anxiety and when this is relieved more accurate assessments of competency can emerge, as Ashcraft (2002) pointed out, observing that highly math-anxious individuals 'do not have a global deficit in math competence' (p. 182). Lack of motivation, though, has been found to contribute to low attainment (Mitchell, 1993) and the Third International Mathematics and Science Study (TIMSS) found a widespread positive correlation between liking mathematics and math achievement (Beaton, Mullis, Martin, Gonzalez, Kelly, & Smith, 1996).

Highly relevant to the present context are the observations that:

1. children's attitudes towards mathematics tend to decline as they progress through primary to secondary education (McLeod, 1994); and
2. children's conceptions 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 & Christou, 1998, p. 192).

It is highly likely that the majority of pre-service primary teachers represented in this study are themselves casualties of these phenomena. Moreover, it is likely that, if left unchecked, they will themselves become perpetrators of such ills in their future classroom. 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.

If one assumes that 100 of the 130 undergraduate students in this study actually enter the profession and further supposing an average career span 20 years with an average conservative teaching load of 25 pupils per year (primary school teachers usually have responsibility for a single class for one year), one teacher might influence (for better or worse) some 500 pupils. On such a basis, this one cohort of student teachers might be expected to reach 50,000 individuals whose early mathematics learning experiences may well determine their future as numerate or innumerate adults over the ensuing 60 or so years. From such a perspective, it is reassuring that the results reported here demonstrate that positive interventions within teacher education programs are not only possible but necessary. However, there remains considerable scope for far greater progress in efforts to beat the numeracy problem. 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.

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