Preliminary Investigations of Pre-service Teacher Numeracy

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It is essential that pre-service teacher educators address pre-service teacher numeracy but with careful consideration as it incorporates more than mathematics skills. Numeracy also involves disposition towards mathematics—attitudes, confidence and mathematics anxiety; that is, the level of willingness to use mathematics skills. As part of an emphasis on developing pre-service teacher numeracy, a new first year unit was introduced. Pre-service teachers were given tools to investigate their competence, attitudes towards, confidence with, and anxiety regarding mathematics. This paper outlines the changes that were identified in the numeracy of these pre-service teachers at the completion of the unit.

Before pre-service teacher numeracy is investigated, a consideration of what numeracy is needs to be undertaken. This is highly pertinent as the Australian Government, through the Australian Institute for Teaching and School Leadership [AITSL], is developing a test of numeracy for pre-service teachers (Australian Government Department of Education [ADE], 2013). Descriptions of numeracy often incorporate mathematical skills and their application. The Australian Core Skills Framework [ACSF] (Australian Government Department of Industry [ADI], n.d.) considers numeracy in terms of the following:

> using mathematics to make sense of the world and applying mathematics in a context for a social purpose … dealing with situations that involve the use and application of a range of mathematical skills and knowledge … understanding and applying mathematical skills … drawing on knowledge of the context in deciding when to use mathematics, extracting the mathematical information from the context and choosing the appropriate mathematics to use … reflecting on and evaluating the use of the mathematics, and being able to represent and communicate the mathematical results (n.p.)

Five levels of learning indicators are also provided within the ACSF and they reflect a hierarchy in terms of the recognition, identification, communication, and evaluation of mathematical information and ideas (ADI, n.d.) reminiscent of the categories proposed by Bloom in his taxonomy (see Krathwohl (2002) for a detailed discussion). The Australian Association of Mathematics Teachers (AAMT, 1997) description of numeracy incorporates mathematical skills together with an additional aspect: "a person's disposition to use mathematics is also critical in numeracy. This includes personal confidence, comfort and willingness to 'have-a-go'" (p. 14). The differentiating factor between these two descriptions is the willingness to use the skills. The omission of this willingness risks incurring Dottin's (2009, p. 84) concern that "having the ability to act (the knowledge and skills) does not guarantee the inclination to do so".

Developing Pre-service Teacher Numeracy

What Should Pre-Service Teacher Numeracy Consider?

As shown above, numeracy can be described as the application or use of mathematical skills in the real world (ADI, n.d.). This view of numeracy focuses on the mathematical skills involved and the use of the skills, reflecting what Ananiadou and Claro (2009) saw as the delineation between skill and competence, with competence as "a broader concept

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that may actually comprise skills (as well as attitudes, knowledge, etc)" (p. 8). This provides two components of numeracy—competence with mathematics skills and attitudes.

The AAMT (1997) description provides another component—confidence—as well as willingness. The incorporation of the willingness to use mathematical skills is highly pertinent in a consideration of numeracy as evidenced by Dottin's (2009) delineation between having a skill and having the inclination to use it. However, there are difficulties in how willingness can be determined, as directly asking if a respondent was willing to do mathematics may not delve sufficiently to obtain a worthwhile response. One solution would be to look for an opposing factor such as mathematics anxiety. If mathematics anxiety is present, there may be an avoidance of mathematics and mathematical activities (Isiksal, Curran, Koc, & Askum, 2009) and a discomfort to complete mathematical tasks (Brady & Bowd, 2005). These seem to indicate that mathematics anxiety would likely reduce the "willingness to 'have-a-go'" (AAMT, 1997, p. 14).

From the discussion above, four components of pre-service teacher numeracy can be distilled and incorporated into an overall indicator of pre-service teacher numeracy. These are competence with mathematical skills and components that can be grouped together as an indication of disposition towards mathematics—attitudes towards mathematics, confidence with mathematics, and, as a contrasting component, mathematics anxiety. Previous research has measured attitudes to mathematics and confidence with teaching mathematics (Beswick, Ashman, Callingham, & McBain, 2011) and mathematics anxiety (Cavanagh & Sparrow, 2010). Competence in mathematics can be measured in a mathematics test, particularly if it is the application of mathematical skills that was tested.

How can Pre-Service Teacher Numeracy be Addressed in Teacher Education Courses?

This question was a focus of the mathematics education team at a large Australian metropolitan university. In 2010, research was initiated to investigate pre-service teacher situational mathematics anxiety (e.g., see Cooke et al., 2011). In 2012, the modified versions of the instruments on attitude and confidence from Beswick et al. (2011) were incorporated into the research (e.g., Cooke & Hurst, 2013) to look for connections between mathematics anxiety, attitudes towards mathematics and confidence with mathematics. At the same time, emphasis on pre-service teacher education programs ensuring pre-service teaches demonstrated numeracy commensurate with the top 30% of the population was emerging (AITSL, 2011). The results of the research conducted at the university, together with the necessity for pre-service teachers to demonstrate numeracy, culminated in the creation of a new unit first year unit for pre-service teachers.

Research Question

The numeracy of pre-service teachers needs to be investigated. Likewise, new units need to be evaluated to determine whether the unit aims and goals were achieved. The focus of the unit—helping pre-service teachers re-vision how they saw mathematics—was to assist pre-service teacher numeracy development by addressing their mathematics skills and numeracy through experiences that would increase their confidence and willingness to use mathematics in their everyday lives. This paper considers the question:

- Did pre-service teacher numeracy, as measured by their mathematics competency, attitudes to mathematics, confidence with mathematics and levels of mathematics anxiety, change over the duration of the unit?

Method

Pre-service teacher perceptions of mathematics, their mathematical skills and, potentially, their use of mathematics, have been constructed from their beliefs about the world and their experiences within that world. However, their interaction with the world and others who exist within that world would have resulted in changes to their perceptions. Likewise, different individuals may have different perceptions that impact on what they "know" (Crotty, 1998). As a result, this research is situated within the constructivism ontology as this ontology supports the investigation of pre-service teacher constructions of their knowledge, attitudes, confidence and anxiety from within their interactions with the world (Crotty, 1998). In addition, a social constructionist epistemology that views knowledge as being constructed by the individuals within the social context (Crotty, 1998) is suited to the use of tests and survey instruments as they enable individual perceptions and knowledge to be shared (Willig, 2001).

Participants

The initial unit enrolment of 297 pre-service teachers included those enrolled either on-campus or online for the Bachelor of Education (Primary or Early Childhood). At the time of the second administration of the survey there were 275 enrolments and at the time of the third administration of the survey there were 266 enrolments. The mathematics competency test was made available within the week that the surveys were administered. Although the test and surveys were made available at specific times, students were not forced to complete them and could complete them at a later time that suited them or not at all if they wished. Table 1 shows the number of students who completed the mathematics competency test and each instrument for the three administrations.

Table 1
Number of Students Completing the Instruments for each Administration of the Mathematics Competency Test and the Surveys

	First	Second	Third
Mathematics Competency Test	241	229	220
Attitudes to mathematics in everyday life	223	173	103
Attitudes to mathematics in the classroom	226	171	103
Attitudes to mathematics teacher education	222	170	105
Confidence to complete mathematics activities	237	165	102
Mathematics anxiety when thinking of working with peers	217	164	99
Mathematics anxiety when thinking of working on a test	200	162	100
Mathematics anxiety when thinking of teaching	189	159	101

Data Collection

A test and survey instruments were used to collect data. Mathematics competency was collected via a mathematics competency test. Survey instruments were used to collect the data regarding attitudes towards mathematics, confidence with mathematics and mathematics anxiety. The mathematics competency test and instruments used to collect the data are outlined below.

Competence. The mathematics competency test was created on a commercial online platform. The test contained 50 questions that needed to be completed within 60 minutes. The questions were designed to require an understanding and application of mathematics and involved mathematical ideas that would be addressed in primary school. The maximum mark per question was 1 mark, with half marks awarded for partial completion and 0 marks awarded for incorrect answers. The final mark was provided to participants as a percentage, with 80% deemed the pass mark. More information regarding the mathematics competency test is available in Cooke and Sparrow (2012).

Attitude towards mathematics. Beswick et al. (2011) created a questionnaire that contained instruments addressing attitudes to mathematics. The instruments investigated three situations: attitudes regarding mathematics in everyday life, attitudes regarding mathematics in the classroom and attitudes regarding mathematics in teacher education. The first two instruments each contained 15 items and the third instrument contained 16 items (Beswick et al., 2011). Modified versions of these instruments that reduced the responses to the Likert-style questions to four (strongly disagree, disagree, agree and strongly agree) were used. Further information on the use of these instruments in earlier research is provided in Cooke and Hurst (2013).

Confidence to complete mathematics activities. The questionnaire created by Beswick et al. (2011) and containing the attitudes to mathematics instruments discussed above also contained an instrument designed to address pre-service teachers' confidence to teach mathematics. The 21 questions were designed specifically to address aspects of the content strands and proficiency strands of the Australian Curriculum: Mathematics (Beswick et al., 2011). This instrument was modified for use by changing the reference to completing activities (rather than teaching) and reducing the responses to the Likert-style questions to four categories (strongly disagree, disagree, agree and strongly agree). Further information on the use of this instrument is provided in Cooke and Hurst (2013).

Mathematics anxiety. Cooke, Cavanagh, Hurst, and Sparrow (2011) modified the questionnaire developed by Cavanagh and Sparrow (2010) for use with pre-service teachers. The questionnaire has three instruments that each contain 22 items with responses on 4-point Likert-style scales with categories of strongly disagree, disagree, agree and strongly agree. Each instrument used the same 22 items applied to three different situations for which pre-service teachers were asked to rate their anxiety: when thinking about working on mathematics in a group situation, when thinking about working on mathematics in a test situation and when thinking about teaching mathematics.

Data Analysis

The mean and standard deviation were calculated for each administration of the test and survey instruments. Missing data cells were not included in the calculations. As the mean for the mathematics competency test was calculated from a percentage, the mean was also a mark out of 100. With the attitudes to mathematics and confidence to complete mathematics activities instruments, a mark of 1, 2, 3, or 4 was allocated to the responses strongly disagree, disagree, agree and strongly agree, respectively, and the mean was calculated. With the three mathematics anxiety instruments, the order of the marks was reversed, with marks of 4, 3, 2, or 1 allocated to the responses strongly disagree, disagree, agree and strongly agree, respectively, and the mean was calculated. A mean closer to 4 indicated a more positive response, either in terms of the attitude towards mathematics, more confidence to complete mathematics activities, or lower anxiety.

Results

Means were calculated to investigate whether changes occurred in pre-service teacher numeracy The results for the three administrations of the test and the survey instruments are organised by the components of numeracy identified above—mathematics competency, attitudes to mathematics, confidence with mathematics and mathematics anxiety.

Mathematics Competency

The mean mathematics competency result increased for each administration of the test (see Table 2) from below the set pass mark of 80% for the first administration to above the set pass mark for the second and third administrations. The standard deviation decreased over each of the administrations, indicating a reduction in spread of the results.

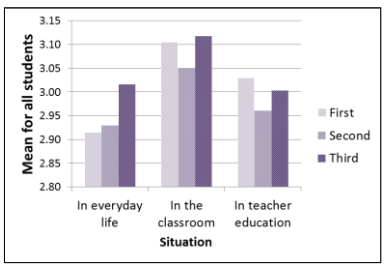
Table 2
Mean and Standard Deviation for the Three Administrations of the Test and Surveys

	First		Second		Third	
	Mean	SD	Mean	SD	Mean	SD
Mathematics Competency Test	74.63	15.38	80.84	13.07	84.35	11.67
Attitudes to mathematics – everyday life	2.91	0.27	2.93	0.26	3.02	0.30
Attitudes to mathematics – the classroom	3.10	0.24	3.05	0.25	3.12	0.27
Attitudes to mathematics – teacher education	3.03	0.24	2.96	0.23	3.00	0.25
Confidence to complete mathematics activities	2.74	0.44	2.81	0.39	2.96	0.41
Mathematics anxiety – working with peers	2.28	0.45	2.76	0.44	2.86	0.48
Mathematics anxiety – working on a test	2.33	0.48	2.65	0.53	2.76	0.53
Mathematics anxiety – teaching	2.24	0.52	2.84	0.53	2.97	0.54

Attitudes to Mathematics

All means for all situations and administrations of the instruments were above the half-way mark for the scale (see Figure 1 (a)). The mean for attitudes to mathematics in the classroom and attitudes to mathematics in teacher education were both lower for the second administration, though the mean for attitudes to mathematics in the classroom for the third administration surpassed that of the first administration. The mean for attitudes to mathematics in teacher education increased slightly from the second to the third administrations but did not pass the mean for the first administration. The standard deviations were fairly consistent.

(a)



(b)

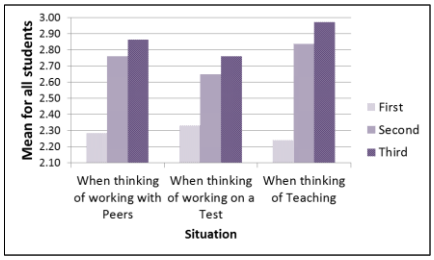


Figure 1. The results for the three administrations of the attitudes towards mathematics (a) and mathematics anxiety instruments (b).

Confidence in Completing Mathematics Activities

The mean confidence in completing mathematics activities was above the half-way point for each of the administrations and increased with each administration. As shown in Table 2, the increase from the second to the third administration was double that from the first to the second administration (0.15 compared to 0.07, for a total increase of 0.22). Overall, the standard deviation was fairly constant, decreasing slightly between the first and second administration, increasing slightly between the second and third administration, with an overall slight decrease between the first and third administration.

Mathematics Anxiety

All means for all situations and administrations of the instruments were above the half-way mark for the scale. The mean for mathematics anxiety improved for each situation for each successive administration as shown in Figure 1(b). The means for mathematics anxiety when thinking about working on mathematics in a test situation had the highest mean in the first administration but increase the least overall. The mean for mathematics anxiety when thinking about teaching mathematics had the lowest mean in the first administration and the greatest increase overall, resulting in the highest mean of all three situations for the final administration of the instruments. The standard deviation for each situation was fairly consistent over the three administrations.

Discussion

The components of pre-service teacher numeracy—mathematical competence and disposition towards mathematics—changed over the three administrations of the test and survey instruments; however, these changes did not all occur in the same manner. The results for the survey instruments addressing attitudes to mathematics did not change in the same way as the other results, with a drop in the mean for the middle administration (see Figure 1). The changes in the means for the attitudes to mathematics in the classroom and attitudes to mathematics in teacher education over the three administrations may be due to what Cooke and Sparrow (2012) discussed in reference to Naeve's (as cited in Cooke & Sparrow, 2012) awareness-knowledge framework: until the pre-service teachers became aware of the range of mathematics addressed in primary school (and beyond, at times) through the unit, they were unaware of the mathematics they knew and what they needed to know to teach. This could have resulted in the initial drop in attitudes to mathematics in the classroom and the initial decrease and then slight increase to under the first administration mean for attitudes to mathematics in teacher education. In their research, Isiksal et al. (2009) found a reduction in the mathematical self-concept scores of Turkish pre-service teachers (which were much higher than the scores for the American cohort), although the scores for the American pre-service teachers were relatively stable. Isiksal et al. attributed the initial differences to the Turkish pre-service teachers' greater exposure to mathematics in preparation for university but offered no explanation for the decrease.

The means for the mathematics competency test and the confidence to complete mathematics activities instrument increased successively over the three administrations. The patterns of these increases can be explained by Graven's (2004) proposition that teacher confidence with mathematics was both "a product and a process of their learning" (p. 177). The means for the mathematics anxiety instruments for the three situations also followed the same increasing pattern, indicating decreases in anxiety. This result reflects

the negative relationship Brady and Bowd (2005) found between pre-service teacher mathematics anxiety and confidence to teach mathematics.

The changes in the results over the three administrations of the test and the survey instruments were commensurate with Beswick's (2006) findings that mathematics education units and education courses can positively influence and change beliefs of pre-service teachers. Likewise, they reflect Isiksal's et al. (2009) findings that pre-service teacher mathematics anxiety decreased between junior and senior years at university. Except for attitudes towards mathematics in teacher education (as discussed above) the findings of this research replicate the findings of previous research.

Overall, the results and the studies discussed above all support Brady and Bowd's (2005) contention that pre-service teacher education courses needed to provide experiences that improve pre-service teacher attitudes towards mathematics and mathematics education. They argue that these improvements are essential as they could reduce mathematics anxiety and increase confidence with mathematics. Cooke and Hurst (2013) found that these improvements could be even more crucial as these pre-service teachers need to have the disposition towards mathematics to ensure they are able to "use their mathematical knowledge *in-front* of others without a *do-over*" (p. 3), a situation that would be commensurate with teaching in the classroom.

The data collection method did not enable the results of the three administrations of the survey instruments to be linked, limiting the opportunity for further statistical analysis. Other limitations due to the use of survey instruments and tests and the structure of the research make it impossible to claim that the unit alone was responsible for the change in the results. Likewise, the use of averages of scores for each of the instruments may "hide" specific responses that could be noteworthy. However, what has developed from the research is the hope that the emphasis on pre-service teacher numeracy (ADE, 2013) will not focus purely on the application of mathematics skills such as those outlined in the ACSF (ADI, n.d.) but will also consider what the AAMT (1997, p. 14) refers to as "personal confidence, comfort and willingness to 'have-a-go'"; what this paper refers to as disposition towards mathematics. Both of these terminologies embed Katz and Raths' (1985, p. 304) plea: "It is not a matter of emphasizing skills or dispositions; it is our view that the acquisition of skills and the dispositions to use them must be mutually inclusive goals." This dual emphasis needs to be investigated further and over a longer timeframe to determine whether the changes that occurred in this research are replicable and sustainable.

Conclusion

Pre-service teacher numeracy is more than having mathematical skills; it incorporates the willingness to use those skills and the confidence in their use, referred to in this paper as disposition towards mathematics. The results of this research show that pre-service teachers' competence and their disposition towards mathematics—their attitudes, confidence to complete mathematics activities, and mathematics anxiety—can change over time. Incorporating tools that enable pre-service teachers to be aware of these changes can be valuable in helping them develop numeracy. Future research could examine the responses to specific items within the instruments as well as investigating whether there are relationships between the items. Likewise, the incorporation of open-ended items and interviews, and the efficaciousness of these in helping pre-service teachers develop an understanding of their personal numeracy, is an avenue to be explored.

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