Mathematics for Initial Teacher Education Students (MITES): Developing self-efficacy and competence in Mathematics and teaching Mathematics

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Abstract

There are a number of reasons why initial teacher education students in the early childhood and primary fields may lack confidence and competence in mathematical problem-solving when they arrive at university. Despite their levels of achievement in high school mathematics, it is usually some time since initial teacher education students were directly involved in solving mathematical problems at the early childhood or primary levels and this distance can impact on students' levels of competence and self-efficacy in relation to solving mathematical problems and teaching at these lower levels. It is disturbing, however, that Brady and Bowd (2005) found that teachers who lack confidence in teaching mathematics often site not just lack of knowledge but negative experiences in their own mathematics education for their anxieties. It was also found that teachers who are anxious about teaching mathematics have the potential to pass on their anxieties to their own students. The needs of initial teacher education students, therefore, can range from those needing to revisit mathematical concepts briefly to re-familiarise themselves with those concepts to those needing to learn or re-learn material that was once the centre of negative and anxious experiences in their own mathematics education.

This paper will provide the theoretical framework on self-efficacy and its measurement, drawing on the seminal work of Bandura (1986) and more recent research in the area of mathematics, after describing the background of the Mathematics for Initial Teacher Education Students (MITES) project. How self-efficacy is assessed in the project (Moriarty, 2008) and the impact of an intervention on students' levels of self-efficacy with regard to solving mathematics problems and teaching others to solve problems will be discussed.

Keywords: Pre-service teacher self-efficacy; Mathematics for Initial Teacher Education (MITES); mathematics self-efficacy

The purpose of the Mathematics for Initial Teacher Education Students (MITES) project is to examine the effects on self-efficacy of interventions or programs that aim to increase levels of mathematics competence among initial teacher education (ITE) students. Successive stages of the project have found that as ITE students become more competent at solving mathematical problems their confidence in their own mathematical problem solving abilities and their confidence in being able to teach mathematical problem solving in the future also increases (Moriarty, 2008).

The MITES project began in the middle 1990's in response to concerns about levels of mathematics competency among initial teacher education students at a regional Australian university. Additional classes were provided for first year students so that they could increase their understanding and working knowledge of mathematical concepts that were the focus of their mathematics curriculum and pedagogy classes. The students were taught in their additional classes by practitioners who used co-operative learning methods. A video tape of the project (*A chance to shine: A research study into cooperative learning*, 1996) that showed how the students were taught and had students talk about their experiences was produced. Self-efficacy scales to measure students' levels of confidence to solve mathematical problems taught in the classes were developed as part of the project and these scales were then also used in the UK with minor modifications where similar concerns had been expressed (Moriarty & Sanders, 1996; Sanders & Morris, 2000).

The early childhood and primary degrees to which the first year mathematics curriculum and pedagogy subject was attached at the regional Australian university underwent major reviews in 2000. In partnership with leading schooling authorities, key principles around which the new degrees would operate were developed. One principle was that ITE students would work on their competence in Mathematics and English in the first year of their degree, with progressively more emphasis being placed on the curriculum and pedagogy of these subjects and practical experiences in teaching further into the degree. In order to pass the mathematics curriculum and pedagogy subject in the first year of the new degrees, therefore, students were required to demonstrate a minimum of 80% competence in solving mathematical problems corresponding to the content of the subject as well as to pass the curriculum and pedagogy assessments in the subject. Following on from earlier stages of the MITES project, students were tested on the mathematical concepts that formed the content in the curriculum subject at the start of the semester and provided with details of the results of their competence tests in the second week of semester. Apart from the Mathematics curriculum and pedagogy classes an additional 10 hours of content classes was made available over the ensuing weeks of the semester. At the end of the semester those students who gained less than 80% on the initial test of competence completed a parallel test of competence to determine whether they had reached the minimum 80% level. The MITES project in several of its stages examined ITE students' levels of self-efficacy to determine the extent to which self-efficacy levels changed over the semester as students proceeded from not competent to competent in their mastery of the mathematical content of the subject. (See, for example, Moriarty, 2008, 2010).

Later parts of this paper will describe in more detail the methods used to assess self-efficacy levels in the project and some of the key findings related to the hypothesis that self-efficacy levels will increase significantly as ITE students gain greater competence in mathematical problem solving. The next part of the paper, however, considers the concept of self-efficacy, including the reasons why ITE students may have low levels of self-efficacy regarding their abilities to solve mathematical problems when they enter teacher education programs and why it is important to monitor self-efficacy pre and post the delivery of interventions intended to help students increase their competence. Also considered in the discussion and conclusions at the end of the paper are the implications of competence and self-efficacy levels in mathematics of ITE students for later practice as in-service teachers.

The Concept of Self-efficacy

The most seminal work on self-efficacy is attributed to Albert Bandura, whose theory has been tested across a wide range of domains and subject areas at all levels of education. In his (1986) book, *Social foundations of thought and action: A social cognitive theory*, Bandura described the basic tenets of his theory. A scan of databases and an examination of recent research across education, including educational psychology, as well as sociology and medicine, for example, indicates the continued relevance of the concept in helping researchers to expand their understanding of human behaviour.

One of the reasons why self-efficacy theory has been of such great interest across many areas is because of the connections between levels of self-efficacy and willingness to expend effort in particular areas of endeavour. Bandura (1986) maintained that being able to predict with reasonable accuracy how well they might perform tasks would likely lead people to determine whether effort expended would be worthwhile. Even when individuals are slightly over-optimistic in their estimations the results can be positive because of the belief that putting in the effort is likely to be rewarded. This means that sometimes people can achieve goals that might otherwise have been slightly out of reach. Having estimations that are significantly higher than what might seem appropriate in the circumstances can often lead to disappointment when people fail unexpectedly. Self-efficacy levels that are very low compared to what could be expected in particular cases can lead to people not even attempting tasks that they should be able to execute successfully. In fact, in reviewing studies into self-efficacy and mathematics, Bandura (1993) concluded that having a low sense of self-efficacy can lead to poor performance even when ability is not a concern.

Bandura’s (1986) idea that self-efficacy should be defined in specific rather than global terms, is still a key part of the construct. As Williams and Williams (2010) noted, most self-efficacy scales are specific in nature. Researchers with compelling reasons why they needed a level of differentiation within and across respondents has lead to a proliferation of self-efficacy scales in different subject areas that conform with Bandura’s insistence on specificity. The self-efficacy scales in the MITES project are no exception. Asking people how well they believe that they will be able to perform mathematical operations more generally, for example, cannot be answered with a single response if candidates believe that they have a better chance of successfully performing some mathematical operations compared to others. Where the responses to any attempts to apply global measures indicate that respondents have similar levels of mathematical self-efficacy, therefore, any underlying differences among respondents in their levels of self-efficacy across different areas within mathematics could be masked. Further, as Pajares and Miller (1994) and Pajares (1996) concluded, studies that violated Bandura’s caution about specificity and had a delay between the measurement of self-efficacy and performance found a low correspondence between self-efficacy and performance.

Another important tenet of Bandura’s (1986) theory is that the level at which students believe that they have performed in the past in specific areas is the key determinant of how well they think that they will perform in the future in the same area. Consistent with this point, Moriarty, Douglas, Punch and Hattie (1995) and Punch and Moriarty (1997) found that asking children in the 9-10 year old age range how well they thought that they had performed certain tasks in the recent past was an effective way of then asking the children to focus on how well they thought that they would perform in related areas in the future. It has also been found that teachers who have low levels of self-efficacy for teaching mathematics, often attribute their current lack of confidence to anxieties and negative experiences associated with learning mathematics as children, together with low levels of content knowledge, as the reasons for their lack of confidence (Brady & Bowd, 2005). This means that circumstances and events surrounding learning in childhood can have long-lasting effects. Even though research has focused less on the effects of self-efficacy on the behaviours of in-service teachers compared to pre-service teachers (Swackhamer, Koeliner, Basile, & Kimbrough, 2007), Bandura’s point about the connections between past performance and self-efficacy still applies. It has implications for understanding how some ITE students feel when they take mathematics subjects or mathematics curriculum and pedagogy subjects. Given the potential for ITE students who are anxious about mathematics to pass on their anxieties to their future students, Brady and Bowd maintain that the cycle must be broken. This is why it is important to test levels of self-efficacy pre and post interventions intended to help ITE students gain competence in mathematics.

Methods

Each stage of the MITES study has followed three cautions stipulated by Bandura (1986). First, the self-efficacy scales developed and used for the project measure the construct in specific terms within mathematics rather than more globally. The self-efficacy scales used for the most recent stages of the study have changed little over the time of the project, with each scale asking students how confident they are in completing particular mathematics problems and then how confident they are in teaching others to solve problems in the same areas. The items are clustered under scales that match the different areas of mathematics problem solving and relate to concepts, number, measurement, fractions, space, and chance and data (formerly probability and statistics). The scales on measurement are provided in the appendix as examples. Each of these scales has items on area, volume, perimeter, kg, L, mL, cm, km, minutes and the 24 hour clock, thus conforming to the first of Bandura's cautions regarding specificity.

Second, Bandura (1986) stipulated that each self-efficacy scale should match specific tasks that students are asked to complete. In the MITES project, the self-efficacy scales relate to the same particular problem areas within mathematics that are represented on the competence tests that are administered to students after they have completed the self-efficacy scales. This means, for example, that the items on the self-efficacy scales related to measurement, as shown in the appendix, were matched by items on the pre- and post-tests of competence. The self-efficacy scales were designed to be succinct and able to accommodate easily any further changes to the curriculum. This ensures that Bandura's second caution is always heeded.

Finally, there is no delay between the administration of the self-efficacy scales and the administration of the competence tests. This third caution, that there should be little delay between the self-efficacy testing and the performance of the related tasks, according to Bandura, increases the predictive power of the measures of self-efficacy. This is because there is no time between the completion of the self-efficacy scales and the competence tests for other factors that might alter levels of self-efficacy to intervene. The reliabilities on the MITES scales have always been high. The self-efficacy scales used for the most recent stages of the study are available on request.

The schedule for the most recent stages of the MITES project throughout a single semester of study is outlined below.

Week 1: Students completed the self-efficacy scales, followed by a pencil and paper mathematics test that measured performance in the same areas of mathematics that were to be covered in the curriculum and pedagogy subject.

Week 2: Students received the results of the mathematics test, showing them how well they performed in each area and their overall results.

Students were provided with a schedule of 10 x 1 hour classes spread across the remainder of the semester, indicating which mathematics concepts would be the focus each week. This meant that students could choose to attend only those classes that were areas of concern on their competence tests or they could attend all classes.

End of semester: All students who did not demonstrate at least 80% competence in the first week of semester sat a parallel test of competence. Immediately prior to completing the test, students completed the same self-efficacy scales that they had completed at the beginning of the semester. Students also answered an additional item asking them to indicate whether they had attended competence classes and, if so, whether they had attended once or twice, quite a few times, or on a regular basis.

Key Findings

Using a repeated measures design meant that relatively small sample sizes could be accommodated. For example, 81 subjects participated in the stage of the study reported by the author in 2008. This design also meant that between-subject differences could be removed from the experimental error. It was possible to take account of the dependence created by the repeated measures through the use of general linear modelling, which was used to measure differences across subjects on the dependent variables.

The hypothesis that ITE students' levels of self-efficacy in relation to solving mathematical problems and being able to teach others to solve the same mathematical problems increases significantly as students improve their own levels of competence was accepted at each stage of the MITES project and across each of the mathematical problem-solving areas of concepts, number, measurement, fractions, space, and chance and data. This result was consistent regardless of the circumstances around which the interventions to help students improve their competence were introduced. For example, this result occurred in the early stages of the project when all students attended the additional classes that used co-operative learning methods and later when students could choose which classes to attend depending on their needs and which particular areas of competence were of concern in their competence tests. In the latter situation, students' levels of self-efficacy increased significantly from pre- to post-test regardless of the number of classes attended. The results were also consistent across different campuses of the same university and regardless of whether the competence classes and the requirement to meet particular levels of competence were an official part of mathematics curriculum and pedagogy subjects.

Discussion and Conclusions

It seems logical that ITE students will be more likely to be able to cope with the requirements of their mathematics curriculum and pedagogy subjects if they understand the content and can solve mathematical problems in the same areas. Consistent with this logic is that in different stages of the MITES project it has been found that there is a high correlation between ITE students' self-efficacy with regard to their own ability to solve mathematical problems and their self-efficacy in terms of being able to teach others to solve those same mathematical problems. If ITE students think that they have low levels of ability in mathematics, then the implication is that they are unlikely to be confident when they teach mathematics, regardless of their actual ability levels. It is not surprising, then, that as ITE students' competence levels improve, so do their levels of self-efficacy with regard not only to their own abilities to solve mathematical problems but to teach others to solve similar problems.

It can be confronting to receive results of mathematics competence tests just as students are about to commence mathematics curriculum and pedagogy subjects. ITE students who perform poorly on self-efficacy or competence tests prior to having the opportunity to learn or relearn some of the content may do so for several reasons. Some students may have performed very well in mathematics at senior high school level but when asked specifically how well they think that they could solve mathematical problems based on content that they have not covered since primary school they may be less confident. It is possible that such students need only a short revision of some areas of the curriculum to increase their confidence. More disturbing, are situations in which poor levels of self-efficacy at the ITE level relate to prior experiences that have made students anxious about mathematics. Expecting students to study mathematics curriculum and pedagogy subjects without having opportunities to address their low levels of competence and self-efficacy associated with high levels of anxiety means that these students are more likely, as indicated by Brady and Bowd (2005) to pass on their anxieties to their own students when they graduate. It is important, therefore, to know whether interventions and programs intended to increase levels of competence among ITE students to solve mathematical problems also increase significantly students' levels of self-efficacy.

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Appendix
Mathematics for Initial Teacher Education Students (MITES)

3a. How confident would you of solving **problems in measurement,** when dealing with such concepts as**:** *

Concept	**1**	**2**	**3**	**4**	**5**	**6**
Area						
Volume						
Perimeter						
kg						
L						
mL						
cm						
km						
Minutes						
24 hour clock						

*** Key**
1 = Not very confident at all
2 = Only just confident
3 = Reasonably confident
4 = Very confident
5 = Extra confident
6 = Super confident

3b. Now could you please indicate below how confident you would feel **teaching others to solve measurement problems** involving**:** *

Concept	**1**	**2**	**3**	**4**	**5**	**6**
Area						
Volume						
Perimeter						
kg						
L						
mL						
cm						
km						
Minutes						
24 hour clock						