A Critical Review of Research in Self-Efficacy in Mathematics Education

Priscilla Murphy  
MIT, Auckland  
<priscilla.murphy@manukau.ac.nz>

Leigh Wood  
Macquarie University, Sydney  
<leigh.wood@mq.edu.au>

Leanne Carter  
Macquarie University, Sydney  
<leanne.carter@mq.edu.au>

This review examines the role of self-efficacy and its relation to learning constructs within the context of tertiary mathematics education. Using a research software (NVivo 10), we conducted a content analyses of sixteen research articles in mathematics education. Most quantitative findings showed that personal efficacy was related to mathematical performances and study strategies (deep and surface learning) and prior mathematical experiences. However, qualitative studies theorised self-efficacy to Bandura’s (1997) four sources of self-efficacy (mastery, vicarious, social persuasion and physiological state). Based on the research findings, we discussed the potential strengths and pitfalls of the research methods. Finally, for future research, we propose a conceptual framework, linking relationships between the motivational construct, learning variables and mathematical performances (grades).

Introduction

The main goal of our literature review is to develop a conceptual framework within the context of tertiary mathematics education, whereby the effects of these motivational and learning constructs: self-efficacy, study strategies and prior mathematics experiences and personal factors (such as, gender), on mathematics performances are examined. We consider our review to be important as it broadens our knowledge about student learning and how it contributes to its conceptual understanding of affect in learning and methodological implications in mathematics education research. We subscribe to McLeod’s (1994) argument that “the research community is still struggling to build a suitable framework for the study of beliefs and attitudes related to mathematics learning” (p.643). He emphasized that

more studies that focus on affective issues would have stronger links to research on other topics related to the improvement of practice in mathematics education….If we are to study affective issues in the context of the reform movement in mathematics education, we must choose methods that will help us capture the complexity of the issues.

(McLeod, 1994, p.641, 644).

In our review, we first hypothesize that self-efficacy is a key affect in mathematics education. Schunk and Pajares (2002) found that students, who were not academically prepared to cope with increasingly challenging academic tasks, developed a low sense of self-efficacy. In a New Zealand research project to investigate the secondary-tertiary transition of mathematics students, Thomas et.al. (2010) identified the problems of mathematics students as becoming less prepared for tertiary mathematics education. Other mathematics education studies found that tertiary students from America and the United Kingdom associated low mathematical self-efficacy beliefs with inadequate prior mathematical knowledge and past failures in mathematics (Hall & Ponton, 2005; Pampaka, Kleanthous, Hutcheson, & Wake, 2011; Parsons, Croft, & Harrison, 2009). These studies warranted further investigation into the role of self-efficacy in learning mathematics.

Second, we emphasize the fact that educators should consciously help our students develop a high sense of self-efficacy in order to ameliorate their mathematical performances. In particular, student performances in the NZ tertiary institutions are benchmarked against course
completion and qualification completion indicators (TEC, 2011). With a greater emphasis on improving tertiary sector performances, we consider that students require a strong sense of self-efficacy in order to develop autonomy and meet the demands of learning tertiary mathematics. Despite increasing political pressure to meet status quo, our review should not only focus on mathematics grades which contribute to course completion. If we strive for vigorous research in mathematics education and endeavour to fully encapsulate students’ experiences of learning mathematics, we should incorporate personal and motivational constructs such as, performances in mathematical tasks, study approaches, mathematics background and personal factors. Therefore, within the context of tertiary education, our key objectives are to examine the relations between self-efficacy beliefs and other learning and motivational constructs and to further propose a conceptual framework for future research within the context of tertiary mathematics education.

**Theoretical Framework**

Bandura (1997) states that perceived self-efficacy is a judgment or belief of one’s ability to execute given types of performances. Performance is a task-oriented accomplishment which leads to an outcome (e.g. self-satisfaction, final grade). Those who perceive themselves to be highly efficacious will expect favorable outcomes, whereas those who judge poor performances of themselves will attain negative outcomes. In education, if a student strives for a rewarding outcome such as good grades, he/she will tend to persist in their studies to bring about the outcomes. According to Bandura (1997), there are four main sources of self-efficacy: enactive mastery experiences, vicarious experiences, verbal persuasions and physiological and affective states. Enactive mastery experience is the most influential source of efficacy information because they provide the most authentic evidence of whether one can master certain skills. Vicarious experience is formed as one appraises one’s capability in relation to the attainment of others and modelling behaviour. Verbal persuasion is the third source of self-efficacy. The impact of the persuasion is stronger if the recipient trusts the person who gives the advice. The fourth source of self-efficacy stems from physiological and affective states. Low achievers are easily affected by physiological stresses, bad mood and aversive thoughts of past failures whereas high achievers are emboldened by positive moods and optimism which conjures up thoughts of past achievements.

**Procedure**

For our literature search, we utilised international educational databases and key words e.g. self-efficacy, higher education and mathematics. The articles were in English. We selected ten quantitative, one qualitative and five mixed method studies, focusing on mathematical self-efficacy studies within the context of college and tertiary mathematics education. In order to better manage the abundant amount of information, we used the research software known as NVivo 10 (QSR, 2013) to carry out a content analysis of all the articles and identify the emerging themes e.g. study strategies, prior mathematics experiences, gender, anxiety.

**Findings**

In the following sections, we first describe the extent in which self-efficacy is related to mathematical performances. Then, we will describe the relationships between self-efficacy and study strategies, prior mathematics experience and personal factors such as, anxiety and gender. Finally, we will discuss the strength and weaknesses of the various methods.
Relations between self-efficacy and mathematical performances
A study by Jaafar and Ayub (2010) found that self-efficacy was positively related to mathematical performances (i.e. calculus grades). Conversely, Schunk and Pajares (2002) found that the mathematics students scored low grades despite their high levels of mathematical self-efficacy. One possible explanation for such negative correlation was Bandura’s (1997) notion of social constraints and inadequate resources that could impede academic performances. Therefore, we construed that apart from considering the role of self-efficacy per se, we should consider other factors which influence mathematical performances.

Relations between self-efficacy and study strategies
One such mediating factor is study strategies. Fenollar (2007) categorized study strategies into deep and surface learning. Deep learning involves understanding the meaning of concepts whereas surface learning focuses on memory strategies and retention of knowledge. A study by Fenollar (2007) found that non-mathematics university students’ self-efficacy indirectly affects performances via deep learning. Given the dearth of mathematics research in this area, future research should investigate whether mathematics students with high self-efficacy will shift from surface to deep learning and achieve success in learning mathematics.

Relations between self-efficacy and prior mathematics experience
Prior mathematics experience was also related to self-efficacy. A study by Betz and Hackett (1983) found that college mathematics students, who have completed more mathematics subjects (as forming their prior experiences) developed a high sense of self-efficacy. Another study by Carmichael and Taylor (2005) found that prior mathematics experiences was associated with the students’ age. They found that mature mathematics students (older than 25 years old) in a mathematics preparatory college were less confident in learning mathematics due to the long time lapse between their secondary education and tertiary studies.

Relations between self-efficacy and anxiety
Anxiety is an emotional arousal and physiological state (Bandura, 1997). While some studies by Betz and Hackett (1983) and Hoffman (2010) found that high anxiety was associated with low self-efficacy, we should gain a better insight of how anxiety was related to learning mathematics and self-efficacy. First, Hoffman’s study (2010) related low anxiety in problem-solving to a high sense of self-efficacy. Second, Betz and Hackett (2010) found that male students, who scored relatively lower anxiety levels and higher self-efficacy than the female students, tended to choose science-based college majors. Lastly, a study by Warwick (2011) found tertiary mathematics students’ anxiety were due to inadequate basic mathematics knowledge and their use of calculators. Despite their high anxiety levels, undergraduate degree students adopted higher expectations of their own mathematical skills and eventually scored better grades than diploma students.

Relations between self-efficacy and gender
We found mixed findings about gender differences in self-efficacy studies. Some quantitative studies by Betz and Hackett (1983) and Hoffman (2010) found that male students had stronger self-efficacy than female students. Other qualitative studies by Hutchison, et al. (2006) and Pampaka, et al. (2010) found that male students viewed mathematics grades as part of
their mastery experiences whereas female students’ vicarious experiences were positively formed by team work and peer support. Contrary to the quantitative findings, other research by Pampaka, et al. (2010) and Wheeler and Montgomery (2009) found that gender differences were insignificant. Pampaka, et al.’s (2010) mixed study found that students who had completed Traditional Mathematics and Use of Mathematics (UoM) courses, developed high personal efficacies in learning mathematics but showed no gender differences. The Traditional Mathematics course covered pure mathematics concepts whereas the UoM course focused on application and problem-solving of mathematical concepts. We noted this finding was interesting and gender differences might be influenced by other confounding factors such as, age and study strategies.

Strength and Limitation

Quantitative Research

Not surprisingly, we found that quantitative researchers used a variety of mathematics self-efficacy scales that were tailored to suit the domain of functioning. This methodological approach ties in closely with the idea of self-efficacy assessments that should be both domain and task-specific and ought to match the learning outcomes. The logic of quantitative research is to make deductive analyses based on the numerical evidence gathered from the quantitative measures. In summary, we found two main spectrums of scales. One group of scales focused on assessing self-efficacy in performing mathematical tasks and learning mathematics e.g. Mathematics Self-Efficacy Scale (MSES) (Betz & Hackett, 1983) and MSES Revised (MSES-R) (Carmichael & Taylor, 2005; Kranzler & Pajares, 1997) and mathematics expectations survey (Warwick, 2010). Second, Motivated Strategies for Learning Questionnaire (MSLQ) (Carmichael & Taylor, 2005) were used to assess learning approaches and self-efficacy. We concluded that MSLQ, MSES and MSES-R were most commonly used and considered as valid and reliable tools in several studies.

In spite of the common applications of these scales, we view a common pitfall of using the scales was lack of contextual validity. One set of findings in a local context might not be applicable to another group of students of different demographics and educational context. In order to make valid analyses and generalisation, researchers might need to be aware of the circumstances in which the research have been carried out, the nature of the students being assessed and the components of the scales used.

Qualitative and Mixed Methods Research

We found mixed methods studies enabled triangulation of results and richer information. A mixed study by Liston and O’Donoghue (2009, 2010) found that self-concept was initially assessed using a self-concept scale but subsequent interviews revealed low self-concept was associated with an inability to adjust to independent learning, poor grades, task unfamiliarity and surface learning. Self-concept is defined as a person’s belief in their ability to perform in situations involving mathematics. Another study by Mesa (2012) showed a surprising finding that the tutors had under-estimated their remedial students’ ability contrary to the students’ perceptions of their own abilities.

Qualitative studies tended to present findings that exposed the sources of self-efficacy (Parsons, et al., 2011) whereas quantitative studies could not reveal the sources of self-efficacy. For instance, a quantitative study by Carmichael and Taylor (2005) failed to gather information about how the classroom environment supported students, and this could well account for the
high failure rate of the course. Conversely, qualitative research enabled researchers to adopt a grounded and inductive approach to understanding students’ self-efficacy. Past qualitative research tended to match the four sources of self-efficacy beliefs to the students’ responses of mathematics learning experiences using phenomenological lens (Hutchison, et al., 2006). In this study, the students developed low self-efficacy even though their parents persuaded them to study advanced mathematics. Their low self-efficacy was influenced by a fixed perception of their parents as incompetent mathematicians, and this judgement shaped their vicarious experiences of learning mathematics.

Conclusion and Future Research

Research on self-efficacy in tertiary mathematics education is in its infancy and has the potential to provide educators with ways to enhance learning and outcomes in teaching mathematics. The bulk of quantitative findings revealed mixed findings of the relationships between self-efficacy and learning variables, that is, prior knowledge, study strategies and personal factors. On the other hand, qualitative findings of phenomenological studies focused mainly on theorising the research to the four sources of personal efficacies.

To date, however, no substantive quantitative research has been done to define the relationships between self-efficacy in learning mathematics, study strategies, student prior mathematics experiences and mathematics performances at tertiary level. Hence, in order to design a robust research, we propose such an investigation into the nature of these relationships between self-efficacy, learning and personal constructs and mathematical performances (Table 1).

Table 1: A Conceptual Framework

<table>
<thead>
<tr>
<th>SELF-EFFICACY IN LEARNING</th>
<th>LEARNING MATHEMATICS</th>
<th>PERFORMANCE</th>
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<tr>
<td>PRIOR MATHEMATICS BACKGROUND</td>
<td>GENDER AND ETHNICITY</td>
<td>STUDY STRATEGIES</td>
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<td>MATHEMATICS RESULTS</td>
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References


