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Sources of Self-Efficacy Influencing Academic Performance of Engineering Students

C.W. Loo[1,*], J.L.F.Choy[2]

[1]School of Engineering, Republic Polytechnic, Singapore
[2]Centre for Educational Development, Republic Polytechnic, Singapore
*Corresponding author: kelvin_loo@rp.edu.sg

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Abstract This study examined (a) the correlation of the four hypothesized sources of self-efficacy (mastery experience, vicarious experience, social persuasion, emotional arousal) with academic performance, and (b) the prediction of the main source of self-efficacy that affects academic performance. A 40-item survey measuring sources of mathematics self-efficacy was administered to 178 third-year engineering students. Academic performance, which includes mathematics module grades and cumulative grade point average (GPA) scores, were collated. The results of the present study showed that self-efficacy sources were correlated with mathematics achievement scores as well as cumulative GPA of electronics-related engineering diplomas. More importantly, mastery experience was found to be the main predictor for academic achievements of mathematics and related engineering modules. Finally, suggestions are offered to help curriculum developers in instructional design so as to improve students' engineering academic performance.

Keywords: *sources of self-efficacy, self-efficacy, academic performance, engineering, mathematics*

1. Introduction

Researchers had found that self-efficacy beliefs could significantly affect academic achievement and the persistence in the field of engineering [3,15,23,27]. Albert Bandura defined self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" [3]. He hypothesized that the level of self-efficacy can determine whether a task will be initiated, the amount of effort that will be expended and the level of persistence to complete the task when face with obstacles and aversive experiences [2]. For example, a runner may be able to attain certain level of achievement in running a marathon based on his skills, abilities and intelligence. Due to some bad experiences, he formed poor judgment in his capability. The lack of self-efficacy will not enable the runner to persist and complete the marathon within a specific time. On the other hand, if he had acquired a high level of self-efficacy belief, he would have motivated himself to put in more effort, persisted longer and completed the marathon in his best timing. Ever since Bandura [2] theorized self-efficacy in his seminal article, extensive studies were done to extend the role of self-efficacy as a mechanism to better understand behavioural change in the area of academic performance, cognitive functioning, health promotion, athletic performance, career choices and coping with mental disorders [3]. Bandura also posited that self-efficacy belief is multidimensional, that is, domain specific or context dependent [3]. This means that a high sense of efficacy in a particular domain may not necessarily translate into having similar level of efficacy in another domain. Even within the same domain, there may be different levels of self-efficacy beliefs occurring in various contexts [2]. Using the same example above, even if the marathon runner is trained well in Singapore and has achieved a high level of self-efficacy, he may not attain the same level of self-efficacy if he runs in South Africa, because of various conditions, such as climate, route and environment. Thus, some level of caution should be exercised when explicating on self-efficacy theory. However, certain generalization to the theory may still be applicable in the academic domain where further explanations will be elaborated below.

2. Relationship between Self-Efficacy and Academic Achievement

In the academic setting, many studies have shown that there is a positive and significant correlation between self-efficacy with academic achievements [1,3,14,15,16,19,20,22,24,28,35]. These studies have shown that regardless of age, gender, domains, disciplines and countries, a student with higher sense of self-efficacy will achieve better academic performance. For example, in a recent research done in the United States, Louis and Mistele [22] reported that although there were differences in level of self-efficacy by gender in young adolescents taking mathematics and science, self-efficacy is still found to be a good predictor of the achievement scores. Congruent with the western studies, in the context of Singapore junior college, Amil [1], through investigating self-efficacy and self-regulated

abilities of students taking Economics at 'A' level, found that there was a significant, positive correlation between self-efficacy with academic performance, and self-efficacy with self-regulated learning. Similarly in another study done in Singapore, which examined self-efficacy, task value and achievement goals in English language ability with a group of secondary school students, Liem et al. [19] also found that self-efficacy is a predictor to English test scores.

Within the domain of engineering, Vogt's [35] research on US undergraduate engineering students across several institutions reported that the level of faculty interaction has a strong correlation with self-efficacy, and that self-efficacy is a strong predictor of academic achievement. More recently, Purzer [28] did a sequential mixed-methods study to examine the relationship between team discourse, self-efficacy and achievement. Results confirmed that self-efficacy is positively and significantly correlated with academic achievement. Earlier analysis of data from Jones et al. [14] also exhibited that the largest predictor of student engineering grade point average (GPA) was expectancies for success in engineering and engineering self-efficacy. In addition, similar to other researches, the level of self-efficacy is found to be different between genders. However, at this point, it is important to note that so far there is no research done in Singapore looking at correlation of self-efficacy with academic achievement in engineering.

3. Theoretical Background on Sources of Self-Efficacy

Since a wide body of literature had covered extensively on the influence of self-efficacy on academic achievement, it is compelling to look into the sources of the belief to understand better how self-efficacy is developed. Bandura [3] had theorized that self-efficacy was developed from four main sources, namely, mastery experiences, vicarious experiences, social persuasions and emotional arousal.

Mastery experience refers to judgments of competence that of one's own previous attainment in a related task [33]. As Bandura explained, "successes raise mastery expectations; repeated failures lower them, particularly if the mishaps occur early in the course of events" [2]. However, neither mere easy success will heighten the efficacy belief, nor do all failures attribute to lower sense of efficacy. The effects of failure on self-efficacy depend on the timing and the total pattern of experiences in which the failures occur [2]. On the same note, difficulties provide opportunities to learn how to turn failure into success by honing one's skills to exercise better control over tasks [3].

Vicarious experience refers to the observation of actions of someone's attainment in a related task [33]. Bandura [2] hypothesized that, as compared to mastery experience, vicarious experience has weaker effects on self-efficacy expectancy. However, placed in an unfamiliar environment where a person is unable to utilize any of his prior experience or knowledge to complete a task, seeing others perform similar task without adverse consequences can generate efficacy expectation and that the observer can improve if he intensify and persist in his effort [2]. In the event where one has experienced mastery in carrying out a particular task, vicarious experience can still be developed in the person as an efficacy source through observation of others performing the same task. This is due to referential comparison with others by comparing the level of achievement in a particular task [3]. Implication of such comparison results in heightened efficacy if he can outperform his peers, but lowered efficacy if his peers surpass him.

Social persuasion refers to feedback, judgments and appraisals from significant others about engaging in related task [33]. It is a means to change efficacy belief through constructive suggestions. Nevertheless, this source of efficacy is not strong to make a significant influence on efficacy belief because it does not provide an authentic experiential base [2]. However, when it is coupled with the right framing of performance feedback as well as in conjunction with mastery and vicarious experience, social persuasion can then result in greater impact to a person's efficacy beliefs [3]. Furthermore, as Bandura noted, "it is easier to sustain a sense of efficacy, especially when struggling with difficulties, if significant others express faith in one's capabilities than if they convey doubts" [3].

Lastly, emotional arousal refers to emotion or physical sensation (e.g. anxiety, fatigue and composure) that one experiences while performing a particular task [33]. It is worth noting that high emotional arousal can debilitate performance [2], due to "people often read their physiological activation in stressful or taxing situations as signs of vulnerability to dysfunction" [3]. In addition, environmental factors exert strong influence on how an internal state is interpreted. Therefore, one's sense of efficacy will vary depending on the situational factors and the meaning given to him [3].

Quantitative studies have shown that mastery experience has the greatest influence to self-efficacy [2,7,13,17,18,25,32,33]. Bandura explained that mastery experience was the most influential efficacy source because they provided the most authentic evidence of whether one could muster whatever it takes to succeed [3]. In addition, some of the studies have also shown that social persuasions and emotional arousal are interrelated with mastery experiences at a statistically significant level [17,18,25]. Contrary to the studies mentioned above, Hodges & Murphy [10] found that vicarious experience had the strongest influence on students' self-efficacy beliefs. One distinct feature of this study was that students were attending a course offered in a learning environment that was unfamiliar to them.

On the qualitative front, researchers used mostly interviews to assess how students formed their academic confidence [11,12,32]. Among middle school students and undergraduates, mastery experience is the main source that influences efficacy belief in the domain of mathematics and engineering. This confirms the findings from the quantitative mentioned studies that the mastery experience was the most influential efficacy source. Hutchison et al. [12] went further into their study by looking through students' responses to their open-ended questions. They found specifically nine categories of prominent factors related to self-efficacy sources in the context of university undergraduates. The nine categories were understanding/learning; drive and motivation; teaming; computing abilities; help; working assignments;

problem solving abilities; enjoyment, interest and satisfaction; and grades [12]. This is important and informative because it allows educators to plan curriculum structure along with the categories to help students build up the sense of efficacy while going through the curriculum. Furthermore, Hutchison-Green et al. reported that their study failed to identify any new sources of self-efficacy among engineering students [11], suggesting that Bandura's theory of the efficacy sources and the current line of inquiry in this area are strongly substantiated.

4. Relationship between Mathematics and Engineering

Generally, mathematics and the field of engineering are closely knitted because both subjects involve complicated manipulation of numbers, critical thinking and problem solving [22]. It has been suggested by Heinze and his colleagues that, "mathematics is a critical factor for success in engineering" [9]. In most institutes of higher learning, mathematics is an entry requirement for students pursuing the study of engineering [8,26,30,31]. Even though mathematics is a pre-requisite to study engineering, students are often required to take additional mathematics modules after they are enrolled into the institution. This goes to show the importance of mathematics in the field of engineering. Furthermore, studies have shown that mathematics was correlated with engineering academic achievements [4,6,29,36]. As such, this seems to imply that if a student has strong background in mathematics, he might be able to do well in engineering subjects.

5. Research Statement

This study aims to investigate the influence of self-efficacy sources on mathematics academic achievements of polytechnic engineering students. In addition, since mathematics has positive correlation with engineering-related modules, it will be meaningful to also examine how these sources of self-efficacy affect engineering students' overall achievement. It is hoped that the results of this study will help to provide insights in helping curriculum developers to design effective intervention strategies to increase the self-efficacy beliefs of students so as to improve their academic performance in engineering subjects.

6. Research Questions

The primary research questions being examined in this study are:

1. Do all the 4 sources of mathematics self-efficacy correlate with mathematics achievement scores?
2. Do all the 4 sources of mathematics self-efficacy correlate with engineering overall achievement score?
3. Which of the sources of mathematics self-efficacy has the strongest influence with respect to mathematics achievement scores?
4. Which of the sources of mathematics self-efficacy has the strongest influence with respect to engineering overall achievement score?

7. Participants

178 third year students (129 males and 45 females) were randomly selected from 4 electronics-related diplomas in Republic Polytechnic. However, data from 174 students were used for the analyses, as 4 survey responses were omitted due to incomplete information. Students ranged in age from 19 to 25. They have completed two mathematics modules, namely, Mathematics (A113) and Mathematics II (A114) during their first year of the diploma programme. Students were informed that their participation will be kept anonymous and that they can refuse or discontinue participation at any time without penalty. All the students have signed an informed consent form that allows the author to use their responses of the survey as well as to extract their academic grades from the database.

8. Instrument

A 40-item instrument was used in this study to address the research questions. The instrument was adapted from the Sources of Mathematics Self-Efficacy scale used by Lent and his colleagues in their investigations on high school and college students [17,18]. The instrument consists of four 10-item scales corresponding to the four primary sources of self-efficacy, namely, mastery experience (e.g., "I received good grades in mathematics modules"), vicarious experience (e.g., "People I look up to (like parents, friends or teachers) are good at mathematics."), social persuasion (e.g., "My friends have encouraged me to take higher level mathematics modules.") and emotional arousal (e.g., "I usually don't worry about my ability to solve mathematics problems."). Some of the questions were modified to use terminologies that the students would be familiar with. Terms like, 'teachers' were changed to 'facilitators', 'mathematics courses' to 'mathematics modules', and 'uptight' to 'nervous'. A statement was re-phrased to suit local context. For example, the original statement used was "I got high scores on the math part of my college entrance exams (e.g., ACT, SAT)". It was changed to "I have got high score for math in GCE 'O' level or in similar high-stake national examination". Students responded by indicating their level of agreement with each statement on a 6-point Likert scale, with higher scores reflecting greater agreement. Half of the items were positively worded and half were negatively worded. The scale had been validated and assessed by Lent et al. [17] with internal consistencies observed to be 0.86 for mastery experience, 0.56 for vicarious experience, 0.74 for social persuasion and 0.9 for emotional arousal.

9. Procedures

Permission to conduct the research was sought and approved by Republic Polytechnic Institutional Review Board. With the approval and after obtaining students' consent to participate in the study, the students completed measures of demographic characteristics and sources of mathematics self-efficacy scale through an online survey. Following that, responses of negative worded statements were re-coded. The strength of each self-efficacy source

was calculated by computing the average of 10 items related to each variable. Students' mathematics module (A113 and A114) grade and cumulative Grade-Point-Average (CGPA) were subsequently collected from the database.

10. Data Analysis

Statistical Packages for Social Sciences (SPSS) version 18.0 was used to analyze the collated quantitative data. The internal consistency of each instrument was first explored by calculating Cronbach's alpha. Subsequently, descriptive, correlational and regression statistics were computed in this study with the level for statistical significance set at $p < .05$. Descriptive statistics was useful in explaining the distribution of students' responses, its mean and standard deviation. The Pearson's product correlation was used to investigate whether all the four sources of self-efficacy are correlated with academic grades (Research Question 1 and 2). Lastly, hierarchical linear regression analysis was employed to examine which of the four sources of self-efficacy is the greatest predictor of academic grades (Research Question 3 and 4).

11. Results

Each measure of the self-efficacy source was tested for internal consistency. The calculated Cronbach's alpha for mastery experience, vicarious experience, social persuasion and emotional arousal were 0.82, 0.53, 0.59 and 0.89 respectively. The results of the internal consistency for individual self-efficacy source were close, except for social persuasion, to that reported by Lent and his colleagues [17], who had first developed and validated the instrument.

Table 1 presents the mean and standard deviation of the four sources of self-efficacy as well as students' mathematics module grades and cumulative grade point average (GPA) of 4 semesters. The computed analyses showed that the mean scores for the sources of self-efficacy range from 3.72 to 3.81 with the standard deviation between 0.55 and 0.99 on a 6-point scale. In addition, with a maximum grade point of 4, the means of the students' academic achievements indicate that the academic level for this cohort of students is slightly above average.

Table 1. Descriptive Statistics of Sources of Self-Efficacy and Academic Achievements

	N	Mean	Std. Deviation
Mastery	174	3.73	.82
Vicarious	174	3.75	.55
Persuasion	174	3.81	.61
Emotional	174	3.72	.99
A113	174	2.74	.91
A114	174	2.62	1.08
GPA	174	2.58	.80

Note. Measures of self-efficacy source are based on a 6-point scale. Grades are based on maximum score point of 4

Table 2 summarizes the results of Pearson's product correlation analysis which investigate the correlation between the four self-efficacy sources, as well as the correlation with Mathematics (A113), Mathematics II (A114) and cumulative GPA. First of all, results revealed that all four self-efficacy sources were significantly interrelated. Secondly, there is a significant correlation between academic achievements with mastery experience, social persuasion and emotional arousal. Mastery experience was shown to have highest correlation on all academic achievements ($.50 \leq r \leq .65$) and vicarious experience was shown to have the weakest correlation with all academic achievement ($.13 \leq r \leq .27$). Lastly, there is a direct and strong correlation between mathematics modules and cumulative GPA.

Table 2. Correlations of Self-Efficacy Sources and Academic Achievements

Variable	1	2	3	4	5	6	7
1. Mastery	1						
2. Vicarious	.30**	1					
3. Persuasion	.70**	.33**	1				
4. Emotional	.78**	.34**	.63**	1			
5. A113	.52**	.13	.40**	.44**	1		
6. A114	.65**	.27**	.50**	.54**	.80**	1	
7. GPA	.50**	.15	.41**	.40**	.82**	.85**	1

**. Correlation is significant at the 0.01 level (2-tailed)

Hierarchical linear regression analysis was performed to investigate which of the four self-efficacy sources is the greatest predictor of Mathematics (A113), Mathematics II (A114) and cumulative GPA. Several combinations with different sequence of self-efficacy sources were entered into the software, for example, entering vicarious experience in the first step, followed by social persuasion, emotional arousal, and lastly mastery experience in the final step. However, a more commonly used model by researchers [13,17], which was also a hypothesized model by Bandura [3], was to enter mastery experience in the first step, followed by vicarious experience, social persuasion and lastly emotional arousal in the final step. Nonetheless, the final outcome still yielded the same results. Table 3 summarizes the results of the hypothesized model. The findings revealed that only mastery experience explained significant variance in predicting Mathematics (R2 = .27), Mathematics II (R2 = .42) and cumulative GPA (R2 = .25). The results also showed that when the model included mastery experience, the other three self-efficacy sources, namely, vicarious experience, social persuasion and emotional arousal had little or no influence in predicting academic achievements.

Table 3. Hierarchical Linear Regression of Predicting Self-Efficacy Sources on Academic Achievements

Dependent Variable/ Predictor	R^2	R^2 Change	F Change	β
A113				
Mastery	.27	.27*	63.23*	.42*
Vicarious	.27	.00	.12	-.04
Persuasion	.27	.00	.97	.08
Emotional	.28	.00	.51	.08
A114				
Mastery	.42	.42*	123.29*	.54*
Vicarious	.42	.01	1.71	.06
Persuasion	.43	.00	.89	.07
Emotional	.43	.00	.29	.05
GPA				
Mastery	.25	.25*	56.60*	.40*
Vicarious	.25	.00	.00	-.02
Persuasion	.26	.01	2.01	.13
Emotional	.26	.00	.01	.01

*. Significant at the 0.01 level

Table 4 presents a further analysis of students' responses about their judgment of competency with regards to mathematics. An average score of the responses was computed for each question categorize under mastery experience. The results showed that questions pertaining to students' experience in doing mathematics tasks, per se, obtained higher average scores (mean > 3.91).

12. Discussions

This study sets out to determine the main source of mathematics self-efficacy that predicts academic achievements of polytechnic engineering students. The results were generally consistent with the findings gathered by Lent and his colleagues [17] where the instrument was originated from as well as supported the theory hypothesized by Bandura [2]. Although earlier segment of the analyses in this study showed that self-efficacy sources were significantly interrelated and these sources were correlated with academic achievements, hierarchical regression analysis suggested that mastery experience was the strongest predictor over the other three sources when predicting the academic achievements of mathematics modules and cumulative GPA. This implies that when an engineering student has strong and positive judgment about his/her prior knowledge in mathematics, he/she may achieve good grades in the subject and more importantly, he/she may also score well in engineering-related subjects. Moreover, further analysis from the students' responses unveiled that students' judgment were framed mainly based on actual experience they had while solving mathematics problems and not so much on how they "feel" about their ability. This supported Bandura's theory that the ability to accomplish mathematics tasks was a significant and important source of information for students to achieve better grades [2].

Table 4. Mean Scores of Questions on Mastery Experience

Question	Mean
1. I have got high score for math in GCE 'O' level or in similar high-stake national examination.	4.13
2. I received good grades in math modules.	4.26
3. In math classes, I rarely get the answer before my classmates do.*	3.38
4. Among my friends I'm usually the one who figures out math problems (e.g. like dividing up a restaurant bill).	3.91
5. I have received special awards for my math ability.	2.93
6. Math has always been a very difficult subject for me.*	3.77
7. I am rarely able to help my classmates with difficult math problems.*	3.48
8. I took fewer mathematics modules than most other students did.*	3.70
9. When I come across a tough math problem, I work at it until I solve it.	4.37
10. I have always had a natural talent for math.	3.40

* Negatively worded statement

Besides, hierarchical regression analyses have also shown that with mastery experience included in the model, the other three sources of self-efficacy have insignificant influence in predicting academic achievements. This was true regardless of how the sequence of self-efficacy sources were entered. However, this result did not support Bandura's hypothesis that each self-efficacy source have some influence of a lesser extent on one or more other sources [2]. One explanation of this could be due to the weak internal consistency of vicarious experience and social persuasion found in this study which might have weakened the predictive level of these sources. Similar to this result, low reliability of vicarious experience was also found in other studies [13,16,17]. Bandura [2] argued that the other sources of self-efficacy may be important when students were lack of more direct knowledge of their capabilities. However, in the case of this study, congruent to the contention put up by Lent et al. [17], students will have sufficient and compelling information about their abilities in solving mathematics tasks through their personal experiences and performance over past years. As such, other sources would seem redundant when the students have established a certain level of self-efficacy based on those experiences.

So far, most of the studies examined only the relationship between self-efficacy sources and self-efficacy [5,10,13,17,21,32,33] or self-efficacy and academic achievements [1,3,14,15,16,19,20,22,24,28,35]. This study managed to establish a direct relationship that sources of self-efficacy were significantly correlated with academic achievements and that mastery experience could best predict the academic performance of mathematics module as well as overall engineering modules. These findings have practical implications which strengthened the conception of curriculum developers that tapping of students' prior knowledge and experience are critical in mathematics and related engineering modules. Thus, during the process of developing mathematics curriculum, curriculum developers should plan activities that could help students to reinforce their prior knowledge and to instil positive experience of accomplishing mathematics tasks in class. For example, curriculum developers could design activities to help students relate which of their background knowledge can be applied to solve their current mathematics or engineering tasks. This could allow students to recognize that they have the ability to solve what may seem to be initially difficult. Another example, curriculum developers could design smaller tasks to allow students to have more confidence in completing. Tasks should be given progressively and gradually so as to develop strong students' efficacious beliefs. As long as students start to build up significant level of confidence in mathematics, they would do well in the subject and could also do well in other engineering modules. Finally, the established mastery experience could be strengthened by giving students more opportunities to apply their new knowledge in a different context.

13. Limitation and Recommendation

There are a few limitations in this study. First of all, the results showed weak internal consistency for vicarious experience and social persuasion. This might have

attenuated the influence of these sources in predicting academic achievements. Next, the sample was limited only to students from electronics-related diplomas, thus, the study cannot be generalized and results may differ in other fields of engineering. Lastly, the measure used was specifically targeted on mathematics. Although there is a strong correlation between mathematics modules and overall academic achievements for the sampled group of engineering students, more investigation is needed to widen the scope to the field of engineering. As such, the present study raises certain issues for future research. Firstly, it may be worthwhile to further investigate the reason causing low reliability of vicarious experience and social persuasion. This may shed some light of whether there could be hidden issue of how the study was conducted. Secondly, it would be useful to replicate and extend these findings to different student populations and domains. This could help to further strengthen and generalize the theory that was presented in this study. Lastly, further exploration to examine if students' achievements in Mathematics can indeed be a strong predictor for their achievements in engineering would enhance the current literature on the relation between these two domains.

14. Conclusion

This study determined the main source of mathematics self-efficacy that affects the academic achievements of polytechnic engineering students. The results of the present study showed that all four self-efficacy sources were significantly correlated with mathematics achievement scores as well as cumulative GPA of electronics-related engineering diplomas. More importantly, mastery experience was found to be the main predictor for academic achievements of mathematics and related engineering modules. Suggestions are offered to help curriculum developers in curriculum design so as to improve students' engineering academic performance. Although the findings of this study cannot be generalized and may only apply to mathematics and electronics related engineering field, they can be used to provide insight for the development of similar study in future.

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