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Engineering Self-Efficacy Contributing to the Academic Performance of AMAIUB Engineering Students: A Qualitative Investigation

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Abstract:
This research study aims to determine the factors of engineering skills self- efficacy sources contributing on the academic performance of AMAIUB engineering students. Thus, a better measure of engineering self-efficacy is needed to adequately assess engineering students' beliefs in their capabilities to perform tasks in their engineering coursework and their future roles as engineers. A descriptive, survey research design was chosen to investigate the sources of engineering self-efficacy of college students. A quantitative survey design approach was used for this study. The survey was administered to all engineering students enrolled during the third trimester of school year 2014-2015. The results were generally consistent with the findings gathered by Lent and his colleagues where the instrument was originated from as well as supported the theory hypothesized by Bandura. This implies that when an engineering student has strong and positive judgment about his/her prior knowledge in engineering, he/she may achieve good grades in the subject and more importantly, he/she may also score well in engineering-related subjects. This supported Bandura‟s theory that the ability to accomplish tasks was a significant and important source of information for students to achieve better grades. This study managed to establish a direct relationship that sources of self-efficacy were significantly correlated with academic achievements and that engineering design experience could best predict the academic performance 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. Although there is a strong correlation between engineering skills self-efficacy 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 to other sources of self-efficacy. 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.
Keywords: engineering self - efficacy, academic performance, general engineering skills, tinkering skills, research sills, engineering design skills

1. Introduction

The National Science Board (2012) reported that about 4% of all bachelor's degrees awarded in the United States in 2008 and in 2009 were in engineering. The United States earned only 10% of the five million undergraduate degrees awarded in science and engineering worldwide in 2008 compared to China, which had 23%, and the European Union, which earned about 19%. In 2011, the American Society of Engineering Education reported that the number of degrees awarded at all degree levels grew from the past year. Yet, the number of engineering degrees awarded to American students at all degree levels decreased by 4% [1]. To maintain its global competitiveness, the United States must be able to supply the market demand for engineers. Engineering educators in the United States are challenged with addressing the decline in numbers of engineering graduates [2].

Engineering plays a significant role in the modern world since it is always present in day to day activities concerning construction, computers, technology, energy, electronic devices, and manufacturing process. Clearly, having quantitative skills upon entering engineering programs helps prepare students for the rigors of the engineering curriculum and will likely help them get through their first year of engineering courses. However, having these skills alone does not ensure that students will be motivated to complete their engineering degrees.

Even though studying the effects of self-efficacy on academic achievement of students in elementary, middle and even high school could result in interventions that may produce improvements for not only the students but also mathematics education in general, studying the effects on the collegiate level is just as significant and important. The number of students enrolling in colleges or universities over the past few decades has steadily increased and students' academic choices regarding mathematics have been acknowledged to not only affect a student's choice in a college major, but also to influence a student's likelihood for completing his or her college education [6]. It is no surprise then that this area of research have resulted in many studies focusing on the effects of self-efficacy on mathematics achievement. Consequently, the research has shown in school mathematics that “perceived self-efficacy contributes to academic performance irrespective of the level of intellectual ability, and correlates strongly with academic outcomes, such as performance in problem solving, attitudes towards mathematics and math anxiety” [7].

Individual’s success in engineering lies not only in their achievement and ability but also in their social cognition and self-beliefs [8]. Students’ self-efficacy has been identified as a significant factor contributing to their persistence and achievement [9]. Self-efficacy refers to “the beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” [10]. For engineering students to function most effectively in their degree programs, they must have the required skills and competencies. They must also have the belief that they are able to perform these skills.

Researchers have explored self -efficacy in engineering by measuring self-efficacy in engineering-related domains such as mathematics and science. Even though mathematics and science are part of the engineering curriculum, researchers in engineering education emphasize that there is a growing need to study engineering in its distinct context to capture engineering experiences specific to its domain. Researchers also have recommended that engineering educators must commit to identifying the skills that are important to practice engineering profession and to incorporate strategies that enhance confidence in performing such skills [11]. On a general level, engineering students should then possess the knowledge of fundamental engineering principles and should be able to apply the knowledge and to convert this theory into practice. In addition, engineering students should have intellectual skills such as logical thinking, problem solving skills and communication skills [12].

Engineering educators have also identified engineering-specific skills that students should possess to become professional engineers. Engineering design skill, the ability to design a system or component to meet an identified need, is another important skills that engineering students must have in preparing the students in the real work environment [13, 14]. Researchers have also identified tinkering skills and technical skills, which are useful in creating and modifying products, as crucial for engineers. Tinkering skills involve engaging in manual activities whereas technical skills refer to applying technical academic subject matter.

The researcher’s concern, then, is to investigate practices that widen participation in the study of engineering consequently in evaluating the effectiveness of the different programs, one measure we are investigating is perceived self-efficacy in engineering and in particular perceived self-efficacy in applying mathematics.

The researcher’s objective is to determine the factors of engineering skills self- efficacy sources contributing on the academic performance of AMAIUB engineering students. Thus, a better measure of engineering self-efficacy is needed to adequately assess engineering students’ beliefs in their capabilities to perform tasks in their engineering coursework and their future roles as engineers. Specifically, it seeks answers to the following questions: (a) What are the profile of the respondents designed to assess mathematics self-efficacy and engineering skills self-efficacy in terms of age, gender, and major or specialization?; (b) Do all the engineering skills self-efficacy correlate with the academic performance of engineering students?; (c) Is there a significant mean difference in the engineering self- efficacy scores in terms of age, gender, and major or specialization?; (d) What is the unique contribution of each of the following: engineering self-efficacy, achievement goals, and task value to the prediction of achievement and intent to persist?

Conceptual Framework/Theoretical Framework

This research adapted Mamaril (2014) Engineering Self-Efficacy and Sources of Middle School Mathematics Self-Efficacy Scale by Usher & Pajares, 2009. The academic performance of the respondents will be calculated from the grade point average and the actual final examination grade. The conceptual framework shows the relationship between the three variables: E SSE, MSE and Academic Achievement of students as shown below:

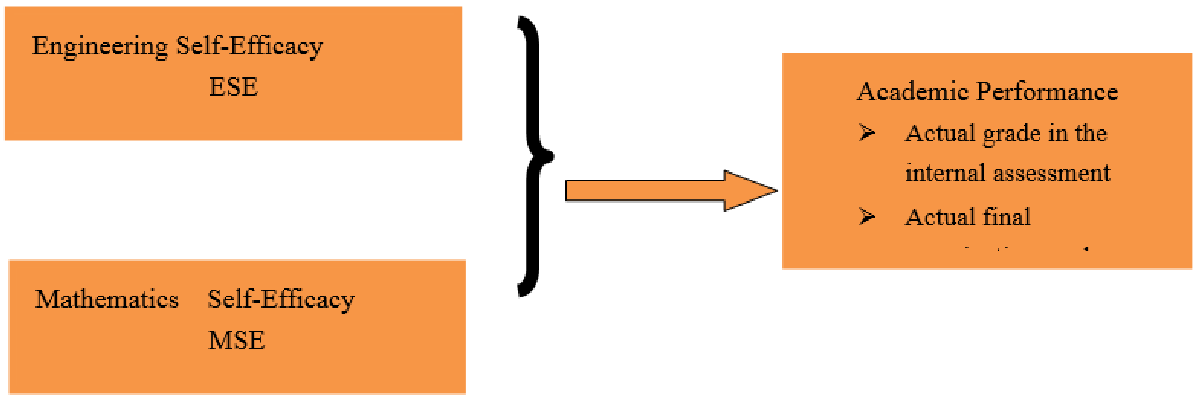

Figure 1 Conceptual Framework of the Study

2. Research Methodology

The present study had both quantitative and qualitative components. The development process for the questionnaire involved item construction, reliability analysis, and establishing the construct validity of mathematics and engineering self-efficacy items through exploratory factor analysis. Instructor comments and student interviews were used to improve items and interpret the results of the factor analysis. The purpose of this study was to determine which student characteristics influence the sources of mathematical and engineering self-efficacy of college students, if any. First, the research design section will define the type of research design, the population and sample, the instrument, and the procedures used for the study. Second, the data analysis section will define all the variables used in the study, as well as describe the statistical analysis process of the study. Finally, the validity section focuses on the reliability and validity of the instruments, as well as the research study as a whole.

2.1 Research Design

A descriptive, survey research design was chosen to investigate the sources of mathematical and engineering self-efficacy of college students. The students will fill a self-report questionnaire. A quantitative survey design approach was used for this study. The survey will be administered to all engineering students enrolled this third trimester of school year 2014-2015. This study included the development and evaluation of engineering self-efficacy scales for college students and the examination of the predictive validity of mathematics and engineering self-efficacy measures. The development and validation of the Engineering Self-Efficacy Scales involved: (a) item development and assessment of content validity, (b) evaluation of scale reliability and construct validity, and (c) establishment of concurrent and predictive validity. Construct validity will be further explored by correlations with other motivation constructs (achievement goal orientations and task value).

2.2 Data Gathering Procedures

The sources of mathematical self-efficacy will be analyzed by various means as outlined in the review of literature chapter of this study. However, four specific scales [27,28,29,30] have been developed and used more consistently within the research. Since this research study focused on analyzing the influence of student characteristics on the four theorized sources of self-efficacy, it was important to select an instrument that closely aligned with theory and had been validated in other research studies. [30] developed their scale for the sources of mathematical self-efficacy using the self-reported grades of the students as their mastery experience score. However, this does not correspond with the theoretical nature of Bandura's mastery experience construct. "Mastery experience" refers to the manner in which an individual cognitively processes previous successes and failures. When students only report their grades, it does not analyze how the grade affected their competence in mathematics. Since one student may view a *C* in a course as good and another could view it as bad, then their grades would not be an accurate indicator of their level of self-efficacy (Usher & Pajares, 2009), Ozyurek (2005) developed a measurement for the sources of mathematics-related self-efficacy referred to as Math-inform. The Math-inform consisted of only three sources of self-efficacy, because the first factor contained items related to both mastery experience and social persuasion. It was not apparent as to why those two constructs were combined, as they are theorized by Bandura to represent completely different constructs. Additionally, the instrument used a 4-point Likert scale, which is not sensitive enough to account for the nuances within cognitive processing (Bandura, 2006). Lent, Lopez and Bieschke (1991) developed a scale to analyze the four sources of mathematical self-efficacy of college students. Usher and Pajares (2009) developed the Sources of Middle School Mathematics Self-Efficacy Scale through a 3-phase process. The first phase began with a 6th grade focus group to determine the understandability of the wording of the instrument. Before the instrument was used again during the third phase, the authors submitted their items to experts within the social cognitive theory field (Bandura, Zimmerman, and Schunk) for feedback. Based on the feedback from the experts more modifications were made, which resulted in an instrument containing 73 items at the beginning of the final phase. However, through revisions based on various types of analysis during the final phase, the official Sources of Middle School Mathematics Self-Efficacy Scale has 24 items consisting of six items per source. Each of the source sections had Cronbach's alpha reliability coefficients above 0.80 indicating that over 80% of the variance in the total score for each source of mathematical self-efficacy is shared within the six specific items on the scale [31]. More specifically, the Cronbach's alpha coefficients for each source was 0.88 for mastery experience, 0.84 for vicarious experience, 0.88 for social persuasions, and 0.87 for physiological state (Usher & Pajares, 2009).

"Comparing the correlation between the sources measures and self-efficacy outcomes to those obtained in previous research studies of the sources reveals that the measures created in this study are not only sound, but demonstrate greater predictive utility than have past measures" [30]. For this reason, as well as the desire to use a valid and calibrated instrument to help further the research on the sources of mathematics self-efficacy, the Sources of Middle School Mathematics Self-Efficacy Scale was chosen for this research study. It was adapted to be used with college students. The Sources of Middle School Mathematics Self-Efficacy Scale used a six-point Likert scale designed for middle school students where the choices were **F** – Definitely False, **F** – Mostly False, F – A little bit False, T – A little bit True, **T** – Mostly True, and **T** –Definitely True. The researcher choose to use the exact same Likert scale for this research study, because the choice of *false* and *true* seemed more appropriate for the items in the scale than the standard *agree* and *disagree*. The Likert scale was converted to a number from 1 to 6, with 1 representing *Definitely False* and 6 representing *Definitely True*.

A meeting was held to inform the Dean of the College and Academic Affairs of my intention to visit engineering classes to talk about the current study and to invite students to participate in the study. A curriculum matrix of the two undergraduate programs in the College of Engineering was created to help identify classes from which to recruit . Classes that were offered in the third trimester from different year levels were chosen. Emails were sent to the department chairs to request five minutes of class time for the presentation of the study and to recruit participants. Department chairs gave their approval to visit classes in their departments. Data for the final engineering self-efficacy measure will be collected before the end of the third trimester.

2.3 Data Gathering Instruments

Each of the motivation variables used in this study with the exception of the engineering self-efficacy scale will be assessed with previously validated scales often used in studies of academic motivation. Using a 6-point Likert-type scale, students rated their level of agreement to statements related to the motivation variables. In the self-efficacy scales, students assessed their level of certainty that they can perform general and task specific activities in engineering using a 6-point Likert-type scale (1 = *completely uncertain*; 6 = *completely certain*).

Engineering Skills Self-Efficacy Scale

The items was adapted from previously published, validated scales and by developing new items based on field standards and qualitative studies in engineering self-efficacy (see Table 1). These items assessed engineering students' beliefs in their abilities to perform engineering tasks related to engineering coursework. Majority of the items were derived from "General Criterion 3. Student Outcomes" set by the Accreditation Board for Engineering and Technology (ABET; www.abet.org). These items reflect engineering skills expected from graduates of undergraduate engineering programs. Evaluation of student performance must be based on the demonstration of specific skills required for the completion of an engineering degree. Moreover, these skills are linked to three fundamental engineering activities that Schreuders et al. (2009) considered to be specific to engineering disciplines: designing, building, and analysis.

2.4 Statistical Treatment of Data

Pearson r correlation method was used to analyze the data in this study and statistical analysis will be done using SPSS. The purpose of this research study was to identify the student characteristics that might causally influence a student's score on each of the four sources of mathematical self-efficacy. In other words, the researcher wanted to determine how much variability existed in the means of the sources of mathematical self-efficacy across groups of students. Huck (2000) contends that analysis of variance (ANOVA) ranks first in popularity for applied researchers when comparing three or more means. However, the researcher had to determine which type of ANOVA (one-way, factorial, or multivariate) was appropriate based on the research question and the data collected. A one-way ANOVA (also referred to as ANOVA) would determine whether there are mean differences in the scores of one of the sources of mathematical self-efficacy based on the groups defined by one of the independent variables [31]. In other words, an ANOVA would determine whether the groups formed by gender (male and female) had statistically significant mean differences on the mastery experience dependent variable. This analysis would be performed in SPSS by selecting ANALYSIS – COMPARE MEANS – ONE

WAY ANOVA. The purpose of a factorial ANOVA would be "to study the independent and simultaneous effects of two or more independent variables on an outcome" [32].

3. Results and Discussion

3.1 Demographic Profile of the Respondents

Table 1. Profile of the Respondents According to Gender

Gender	Frequency	Percent
MALE	120	87.0
FEMALE	18	13.0
Total	138	100.0

As shown in Table 1, 120 or eighty - seven (87%) percent of the respondents are male and 18 or thirteen percent are female. This shows that majority of students taking engineering courses are male than female.

Table 2. Profile of the Respondents According to Age

Age	Frequency	Percent
15-20 YEARS OLD	14	10.1
21-25 YEARS OLD	87	63.0
26-30 YEARS OLD	12	8.7
ABOVE 30 YEARS OLD	25	18.1
Total	138	100.0

As presented in Table 2, majority of the respondents are in the age range between 21- 25 years old which comprises of 63 percent, seconded by above 30 years old which is 18 percent of the respondents.

Table 3. Profile of the Respondents According to Major or Specialization

Major/Specialization	Frequency	Percent
BSIE	51	37.0
BSME	87	63.0
Total	138	100.0

It can gleaned in Table 3 that majority of the respondents are major in Mechatronics Engineering which comprise of 87 or 63 percent while 51 or 37 percent are specializing in Informatics Engineering.

3.2 Sources of Engineering Self-Efficacy

Table 4. Descriptive Statistics of General Engineering Self-Efficacy Sources and Academic Achievement

GESES	N	Mean	Std. Deviation
ESE5	138	4.1957	.87844
ESE6	138	3.9275	.80725
ESE13	138	3.9565	.80934
ESE28	138	4.2754	.68101
ESE31	138	4.0725	.77023
CGPA	138	2.4710	.96804

Table 4 above presents the mean ad standard deviation of the four sources of engineering skills self-efficacy as well as the respondents cumulative grade point average The computed analyses showed that the mean scores for the general engineering self-efficacy sources ranges from 3.9275 to 4.2754 with the standard deviation between .77 and .88 on a 6 point scale. In addition, with a maximum grade point of 5, the means of the students" academic achievements indicate that the academic level for this cohort of students is slightly average.

Table 5 Descriptive Statistics of Tinkering Skills Self-Efficacy Sources and Academic Achievement

TSSES	N	Mean	Std. Deviation
ESE2	138	4.4493	.60500
ESE4	138	4.4275	.76309
ESE11	138	3.9710	.77311
ESE12	138	3.8478	.79140
ESE14	138	3.9275	.80725
ESE17	138	3.8551	.72041
ESE18	138	3.9855	.73480
ESE19	138	4.5290	3.55189
ESE24	138	4.0362	.75850
ESE27	138	4.2174	.74225
CGPA	138	2.4710	.96804

Table 5 above shows the mean ad standard deviation of the tinkering skills engineering skills self-efficacy as well as the respondents cumulative grade point average The computed analyses showed that the mean scores for the tinkering skills self-efficacy sources ranges from 3.85 to 4.53 with the standard deviation between .60 and 3.55 on a 6 point scale. Among the ten items, ESE 19 got the highest mean which means that they prefer engineering major courses compare to other courses. In addition, with a maximum grade point of 5, the means of the students‟ academic achievements indicate that the academic level for this cohort of students is slightly average.

Table 6 Descriptive Statistics of Research Skills Self-Efficacy Sources and Academic Achievement

RSSES	N	Mean	Std. Deviation
ESE3	138	4.2899	.74680
ESE7	138	4.2246	.78320
ESE9	138	4.2029	.75609
ESE15	138	4.1522	.74385
ESE16	138	4.1014	.74765
ESE20	138	3.9493	.75766
ESE21	138	4.0435	.70317
ESE22	138	4.0290	.75399
ESE25	138	4.0217	.68846
ESE29	138	4.3188	.65050
ESE32	138	3.9783	.63323
ESE33	138	3.9348	.70666
CGPA	138	2.4710	.96804

Table 6 above shows the mean ad standard deviation of the research skills engineering skills self-efficacy as well as the respondents cumulative grade point average The computed analyses showed that the mean scores for the research skills self-efficacy sources ranges from 3.93 to 4.32 with the standard deviation between .63 and 0.78 on a 6 point scale. Among the twelve items, ESE 29 got the highest mean which means that they can ask for help when they have trouble in working with their project followed by ESE3 that when they see a new machine , they are curious to know how it is made.. In addition, with a maximum grade point of 5, the means of the students‟ academic achievements indicate that the academic level for this cohort of students is slightly average.

Table 7 Descriptive Statistics of Engineering Design Skills Self-Efficacy Sources and Academic Achievement

EDSSES	N	Mean	Std. Deviation
ESE1	138	4.1377	.71677
ESE8	138	4.1594	.77597
ESE23	138	4.0870	.78748
ESE26	138	4.2754	.68101
ESE30	138	4.9130	5.89999
CGPA	138	2.4710	.96804

Table 7 above shows the mean ad standard deviation of the engineering design sources of engineering skills self-efficacy as well as the respondents cumulative grade point average The computed analyses showed that the mean scores for the engineering design self-efficacy sources ranges from 4.09 to 4.91 with the standard deviation between .68 and 5.90 on a 6 point scale. ESE30 which states that " They can do their best to solve their problems in engineering field "obtained the highest weighted mean of 4.91. In addition, with a maximum grade point of 5, the means of the students" academic achievements indicate that the academic level for this cohort of students is slightly average.

Table 8 below summarizes presents the mean and standard deviation of the four sources of engineering self-efficacy as well as students' cumulative grade point average (GPA). The computed analyses showed that the mean scores for the sources of engineering self-efficacy range from 4.08 to 4.31 with the standard deviation between 0.72 and 1.77 on a 6-point scale. Among the four clusters, cluster 4, the engineering design skills self-efficacy sources obtained the highest weighted mean of 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 average.

Table 8 Descriptive Statistics of Engineering Self-Efficacy Sources and Academic Achievement

Sources	N	Mean	Std. Deviation
Cluster 1	138	4.0855	0.7893
Cluster 2	138	4.1061	0.9976
Cluster 3	138	4.1039	0.7226
Cluster 4	138	4.3145	1.7722
CGPA	138	2.4710	.96804

Table 9 summarizes the results of Pearson"s product correlation analysis which investigate the correlation between the four engineering self-efficacy sources, as well as the correlation with 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 of the respondents and the four sources of engineering skills self-efficacy.

Table 9. Correlations of Engineering Self-Efficacy Sources and Academic Achievements

		CLUSTER1	CLUSTER2	CLUSTER3	CLUSTER4	CGPA
CLUSTER1	Pearson Correlation	1	-.065	-.050	.094	-.611
	Sig. (2-tailed)		.918	.936	.881	.273
	N	5	5	5	5	5
CLUSTER2	Pearson Correlation	-.065	1	.206	-.547	-.071
	Sig. (2-tailed)	.918		.543	.340	.835
	N	5	11	11	5	11
CLUSTER3	Pearson Correlation	-.050	.206	1	-.792	-.290
	Sig. (2-tailed)	.936	.543		.110	.360
	N	5	11	12	5	12
CLUSTER4	Pearson Correlation	.094	-.547	-.792	1	.275
	Sig. (2-tailed)	.881	.340	.110		.654
	N	5	5	5	5	5
CGPA	Pearson Correlation	-.611	-.071	-.290	.275	1
	Sig. (2-tailed)	.273	.835	.360	.654	
	N	5	11	12	5	138

This study sets out to determine the main source of engineering skills self-efficacy that predicts academic achievements of engineering students. The results were generally consistent with the findings gathered by Lent and his colleagues [27] where the instrument was originated from as well as supported the theory hypothesized by Bandura [8]. Although earlier segment of the analyses in this study showed that engineering self- efficacy sources were significantly interrelated and these sources were correlated with academic achievements using the cumulative GPA. This implies that when an engineering student has strong and positive judgment about his/her prior knowledge in engineering, 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].

So far, most of the studies examined only the relationship between self-efficacy sources and self-efficacy or self-efficacy and academic achievements This study managed to establish a direct relationship that sources of self-efficacy were significantly correlated with academic achievements and that engineering design 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 instill 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.

4. Conclusions and Recommendations

This study determined the main source of engineering self-efficacy that affects the academic achievements of AMAIUB engineering students. The results of the present study showed that all four engineering self-efficacy sources were significantly correlated with mathematics achievement scores as well as cumulative GPA of engineering students. More importantly, engineering design 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 other mechatronics and informatics related engineering field, they can be used to provide insight for the development of similar study in future.

Although there is a strong correlation between engineering skills self-efficacy 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 to other sources of self-efficacy. 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.

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