# Self-Beliefs of Success for College Calculus Students

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ABSTRACT:

Calculus is often viewed as one of the gateway courses for STEM majors. It is important for STEM educators to understand not only what demographic and prior academic factors contribute to the success of students taking this course, but also the students' perception of their own academic capabilities. In this paper we will present findings from a survey of over 200 Calculus I students at a large research-intensive university. The survey included questions on academic self-efficacy, academic engagement, learning climate, class enjoyment, anxiety, and other emotional factors.

In analyzing the survey results, significant differences were found among students enrolled in different colleges at the university. Specifically, students who studied at the College of Technology, the College of Natural Science and Math, College of Engineering, or other colleges demonstrated significantly different expectations on their success in Calculus. The survey results also indicated an interaction effect of students' grade level of the association between the colleges they are in and their expectation of their final score in the course.

**Keywords:** Calculus, self efficacy, survey, statistical analysis

## Introduction

According to the *Insights and Recommendations* from the Mathematics Association of America (MAA), college Calculus holds a position as a "gatekeeper" to Science, Technology, Engineering, and Mathematics (STEM) disciplines because the majority of STEM majors require at least one semester of Calculus [1]. As part of this five-year study of Calculus programs across the United States the MAA concluded that the Calculus student's attitude towards mathematics is critical since this can impact career choices. They found that on average, student attitudes toward mathematics declined from beginning to end of their first college Calculus course and that the students' confidence in their mathematical abilities dropped almost a half of a point on a six-point scale. Even "enjoyment and desire to persist in studying mathematics also changed in the negative direction from beginning of term to end of term [1]." If we can find out more about students' perception of their own academic capabilities and what influences their attitudes towards mathematics, maybe we can help more students to finish Calculus I with a sense of confidence and satisfaction instead of with a sense of apathy. This change in attitudes should also help create a more positive outlook on mathematics from society.

The purpose of our survey is to understand the relationship between students' attitudes, their self-efficacy towards mathematics, and their success in mathematics. Bandura [2] defines self-efficacy as a "person's belief in their ability to complete tasks and affect events that impact their lives." He also determined that performance-based procedures seem to be most influential for accomplishing psychological changes and serving as means of building and reinforcing expectations of self-efficacy [3]. Bandura's theory of self-efficacy is foundational to understanding attitudes and emotional perceptions of learning.

Pekrun's [4] theory on achievement emotions assumes that if a student's internal control is lacking and success perceived as unattainable, then actually achieving success seems impossible to that student. Not only can emotions impact students' interest, they can affect the students' motivation to learn [4]. Positive emotions can motivate students to learn just as negative emotions, like anxiety, can obstruct it. Pajares [5] states, "knowledge, skill, and prior attainments are often poor predictors of subsequent attainments because the beliefs that individuals hold about their abilities and about the outcome of their efforts powerfully influence the ways in which they will behave." Students will be more likely to persist in problem solving when they have high self-efficacy. Mathematics self-efficacy, particularly college mathematics, can be more predictive of a student's success in STEM courses than prior achievement [5]. Several studies have examined the relationship between motivation, self-efficacy, and achievement in mathematics. In a study of $8^{th} - 10^{th}$ graders, Skaalvik, Federici, and Klassen [6] found that "student motivation – both interest and motivated behavior – is strongly predicted by self-efficacy and moderately predicted by teacher emotional support." Their results showed that the correlation between grades in the students' mathematics class and motivation responses were mediated through both the students' self-efficacy in math as well as the students' perceived emotional support from their math teacher.

Pyzdrowski et al [7] examined student attitudes using a mathematics attitudes inventory survey and interviews of Calculus I students at their university. Students agreed with the research by indicating that positive attitudes lead to success and lack of self-efficacy correlated with difficulties in the class, however, they revealed that their instructors cautioned them on being over confident. One notable conclusion of this study was that "because attitude had the strongest positive correlation with course performance in this study, if a reliable placement system is in place to screen for pre-requisite knowledge, then determining ways to affect students' attitudes is important to foster student success [7]."

Another study of college Calculus I students at a large university [8] had results which showed that if students feel strongly about not being able to solve laborious mathematic problems, they tended to neglect challenging problems and only work on the simple ones. Because of this fixed mindset, the authors found it was important for instructors to aide students in cultivating a growth mindset when it came to solving mathematics problems. Ayebo and Mrutu [8] stressed that the process of studying mathematics "is an affective process that involves attitudes, emotions and beliefs."

Many researchers have studied on the relationship between students' attitude toward mathematics and performance in the subject. From these results, it can be seen that having an understanding of attitudes and expectations is important for helping students be successful in Calculus. Using our survey on academic self-efficacy, academic engagement, learning climate, class enjoyment, anxiety, and other emotional factors, one of the first things we analyzed was demographic differences in expected grades and in academic self efficacy.

*Research Questions*

1) What factors may contribute to differences in college students' expected grade in Calculus I?
2) Are there factors contributing to potential differences in college students' self-efficacy in Calculus I?

## METHOD

### Sample

The sample consisted of 273 undergraduate students who were currently enrolled in Calculus I at a large research-intensive university. There were 135 $(49.5\%)$ males and 138 females $(50.5\%)$ with the mean age of 19.56 (16 - 48 years old). The sample was ethnically diverse, including Asian $(n = 95, 34.8\%)$, Black/African American $(n = 32, 11.7\%)$, Hispanic/Latino $(n = 70, 25.6\%)$, White/ Caucasian $(n = 61, 2.32\%)$, and other races $(n = 14, 5.2\%)$. A paper-based self-report survey was administered in sections of undergraduate Calculus classes in mid-semester (approximately the 7th week of classes). The survey questions academic self-efficacy, academic engagement, learning climate, class enjoyment, anxiety, and other emotional factors. Students consented and completed the survey before or at the end of the lecture period during which the surveys were administered.

### Measures

The survey consists of (a) section of demographic information and (b) section of questions on self-beliefs in success (academic self-efficacy and subjective values), academic engagement (efforts and persistence), learning climate, and achievement emotions (enjoyment, anxiety, hopeless, shame, and anger before, during, and after class). In (a) section, the demographic items measure students' gender (male= 0, female =1), age, race, major, academic year, and self-reported GPA. The (b) section includes 98 Likert-scaled items from 1 (strongly disagree) to 5 (strongly agree) and from 1 (not at all true of me) to 7 (very true of me). All Likert-scaled items were adapted from existing research [9]. Some individual items from academic motivation and achievement emotions instruments were slightly modified to emphasize the academic settings.

*Freshman.* The variable “freshman” assesses whether students are freshman. It was re-coded by the variable “years at the college”. Students who checked “the first years” on the survey were coded as freshman (1), and other students were coded as non-freshman (0).

*College.* The item “college” assesses whether the university students study at College of Technology (1), College of Nature Science and Math (2), College of Engineering (3), or other colleges (4). Colleges are subsets of the university and help narrow down the course of study. The colleges of Technology, Nature Science and Math, and Engineering are the main colleges which require Calculus I of all students. This variable, college, was re-coded based on the item “what is your major?” There were 13 choices and one choice as “Other” for students to specify their major that was not listed in the options.

*Expected grade.* The variable titled “expected grade” assessed the students’ expectations on their final grade of the Calculus I class on a scale from 1 (A) to 9 (below D). This item was then reverse coded so as the greater value (9) represented the expectation on highest grade (A).

*Academic self-efficacy.* The “academic self-efficacy” scale was adapted from Wood and Locke’s study [9]. A total of 8 items evaluate students’ beliefs and expectations in their abilities in comprehension, interpretation, manipulation, and concentration of class contents in the Calculus I, and perception of working on academic tasks. The items are on a scale from 1 (not at all true of me) to 7 (very true of me). Sample items from the scale include: I believe I will receive an excellent grade in this class; I am certain I can understand the most difficult material presented in the readings for this course; I am confident I can understand the basic concepts taught in this course, etc. The internal reliability coefficient of the scale was acceptable ($\alpha = .96$) in this study.

### Statistics Analysis

Descriptive analysis was used to examine the reliability coefficient, mean, and standard deviation for the dependent variable (expectations on final grades in Calculus I classes and self-efficacy in learning Calculus I) and independent variables (years at school and colleges). The EM estimated statistics analysis was conducted to examine the missing data mechanism. We conducted two two-way ($2 \times 4$) analyses of variances (ANOVAs) with post hoc comparisons (Tukey's honestly significant difference) to examine potential effects of students' study years at school and study at different colleges (college of Technology, college of Nature Science and Math, college of Engineering, and other colleges) on expectations of final grades in Calculus I classes, and such effects on students' perceived self-efficacy, respectively. The descriptive statistics, missing data analysis, and two-way ($2 \times 4$) ANOVAs procedures were conducted by using SPSS 26 [10], with an alpha threshold of 0.05.

## RESULTS

### Descriptive Statistics

Descriptive statistics of the measures are described in Table 1. First, there is no significant correlation was found between gender and any other variables. Second, the correlation between the freshmen and expected grade was statistically significant ($r = .20, p < .01$). Because freshman was coded as "1" represented freshman and "0" represented non-freshman, the correlation indicated that freshman positively correlated with expected grade. Third, the correlation between expected grade and self-efficacy was statistically significant ($r = -.73, p < .01$). In addition, the result of EM estimated statistics indicated missing completely at random (Little's MCAR test: $\chi^2 = 3.09, DF = 2, p = .21$).

*Table 1. Mean, standard deviation, and Pearson correlation of the measures (n = 273).*

| Variable | M | SD | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Gender | .52 | .50 | 1 | -.07 | .02 | -.109 | - |
| Freshman | .74 | .44 | - | 1 | .20** | .12 | - |
| Expected grade | 7.22 | 2.01 | - | - | 1 | .73** | - |
| Self-efficacy | 4.99 | 1.47 | - | - | - | 1 | - |
| College | 2.37 | .91 | - | - | - | - | - |

*Note. M and SD represent mean and standard deviation, respectively.*
**Correlation is significant at the 0.05 level*
***Correlation is significant at the 0.01 level*

## Two-way $(2 \times 4)$ ANOVAs

*Effects of Study Years at School and College on Expected Grade*

As the first research question seeking probable differences in college students' expected grade in their Calculus I course across the two independent variables, a $2 \times 4$ full-factorial ANOVA was run to test freshman (freshman and non-freshman) and college (Technology, Nature Science & Math, Engineering, and others) on expected grade. Mean (M) and standard deviation (SD) of freshman and college on students' expected grade are illustrated in Table 2.

*Table 2. Mean and Standard Deviation of Freshman and College on Expected Grade*

| | Freshman | | | | | | | | Non-freshman | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Theology | | Nature Science & Math | | Engineering | | Others | | Theology | | Nature Science & Math | | Engineering | | Others | |
| Measure | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Expected Grade | 5.35 | 2.00 | 7.60 | 1.73 | 8.11 | 1.54 | 6.95 | 1.90 | 6.18 | 2.24 | 6.65 | 2.26 | 6.40 | 2.67 | 7.16 | 1.77 |

*Note. M and SD represent mean and standard deviation, respectively.*

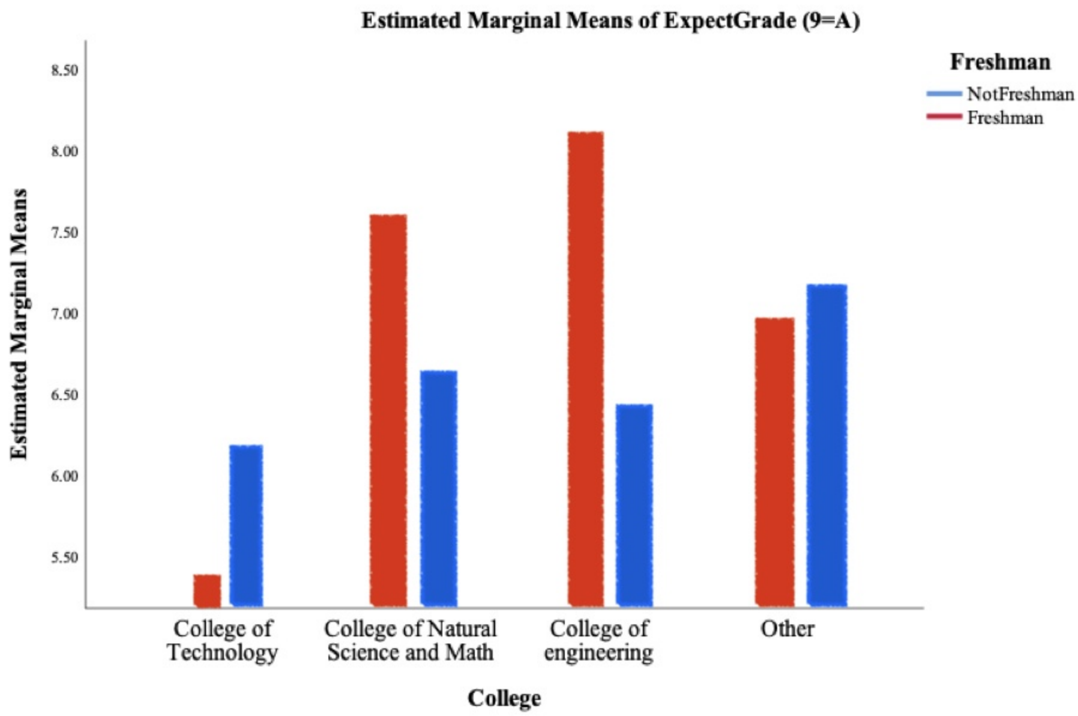
The results of the two-way between-group ANOVA are presented in Table 3. The interaction effect between freshman and college was statistically significant, $F(3, 255) = 3.59, P <$

$.05, Partial = .04$. This indicates an interaction effect of students' years at university on the association between the colleges they are in and their expected grades in Calculus I. The main effect of freshman on expected grade in Calculus I was not statistically significant, $F(1, 255) = 6.70, P > .05, Partial = .01$. In other words, there was no significant difference in students' expected grades on Calculus I found between freshman and non-freshman. On the other hand, the main effect of college on expected grade in Calculus I was statistically significant, $F(1, 255) = 56.43, P < .01, Partial = .06$. This indicates that students' expected grades on Calculus I differ across students who study at the College of Technology, Nature Science & Math, Engineering, and others. These results are shown in Figure 1.

*Table 3. Two-way (2×4) ANOVA result Freshman & College on Expected Grade (n = 273).*

| *Variable* | *Sum of Squares* | *df* | *Mean Square* | *F* | *p* | *Partial* $\eta^2$ |
|---|---|---|---|---|---|---|
| *(Intercept)* | *7461.69* | *1* | *7461.69* | *2173.08* | *.000* | *.90* |
| *Freshman* | *6.70* | *1* | *6.70* | *1.95* | *.164* | *.01* |
| *College* | *56.43* | *3* | *18.81* | *5.48* | *.001* | *.06* |
| *Freshman*College* | *37.01* | *3* | *12.34* | *3.59* | *.014* | *.04* |
| *Error* | *875.59* | *255* | *3.43* | - | - | - |

*Figure 1. Interaction plot between freshman and college*



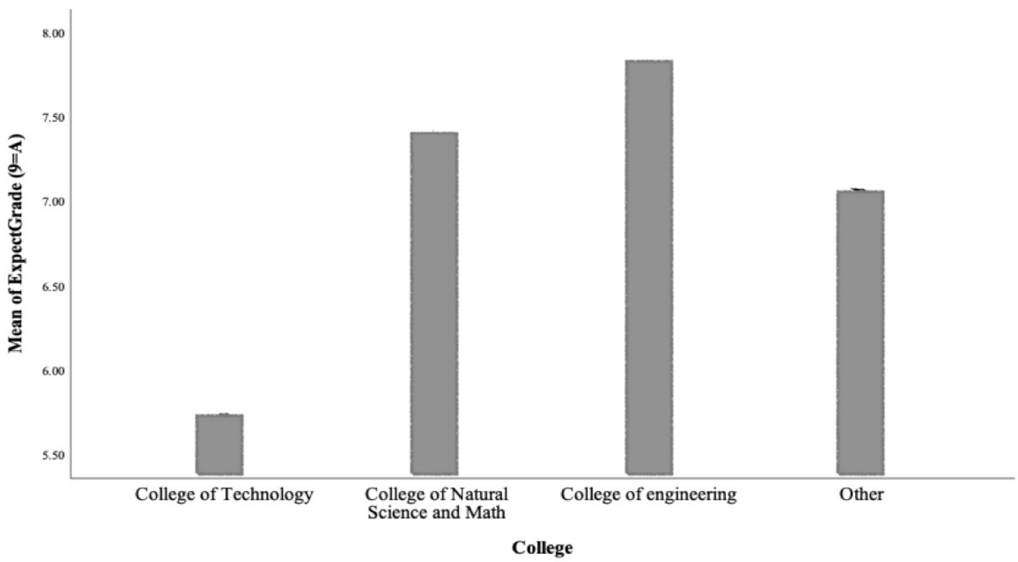

In Table 4, Post-hoc comparisons reveal significant differences in expected grades on the Calculus I course across the College of Technology, College of Nature Since and Math, College of Engineering, and other colleges. Students who study in the College of Technology were less likely to expect high grade on Calculus I than those who study in the College of Natural Science and Math $(MD = -1.65, SE = .34, p < .001)$, the College of Engineering $(MD = -2.02, SE = .48, p < .001)$, and other colleges. The Figure 2 presents the above-mentioned results.

*Table 4. Tukey-HSD Post-Hoc Comparisons of College on Expected Grade (n = 273).*

| *Comparison* | | | | | | |
|---|---|---|---|---|---|---|
| *College* | *College* | *MD* | *SE* | *df* | *p* | *95%CI [LL, UP]* |
| *Technology* | *Natural Science & Math* | *-1.65* | *.34* | *3* | *.000* | *[-2.53, -.77]* |
| | *Engineering* | *-2.02* | *.38* | *3* | *.000* | *[-3.00, -1.04]* |
| | *Others* | *-1.23* | *.42* | *3* | *.020* | *[-2.32, -.14]* |

*Note. MD represents Mean difference.*
*SE represents Standard error.*
*LL and UL represent the lower-limit and upper-limit of the confidence interval, respectively.*

*Figure 2. Mean Plots of Expected Grade across College*




*Effects of Study Years at School and College on Self-efficacy*

To answer the second research question that investigates potential differences in college students' self-efficacy in their Calculus I course across the two independent variables, we conducted a $2 \times 4$ full-factorial ANOVA to assess freshman (freshman and non-freshman) and college (the College of Technology, College of Nature Science and Math, College of Engineering, and others) on students' academic self-efficacy in college Calculus one. Table 5 shows mean (M) and standard deviation (SD) of freshman and college on students' self-efficacy in learning Calculus I.

*Table 5. Mean and Standard Deviation of Freshman and College on Self-efficacy*

| | Freshman | | | | | | | | Non-freshman | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Theology | | Nature Science & Math | | Engineering | | Others | | Theology | | Nature Science & Math | | Engineering | | Others | |
| Measure | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Self-efficacy | 4.67 | 1.44 | 5.04 | 1.31 | 5.57 | 1.31 | 4.44 | 1.76 | 4.52 | 1.46 | 4.67 | 1.73 | 5.63 | 1.76 | 4.60 | 1.57 |

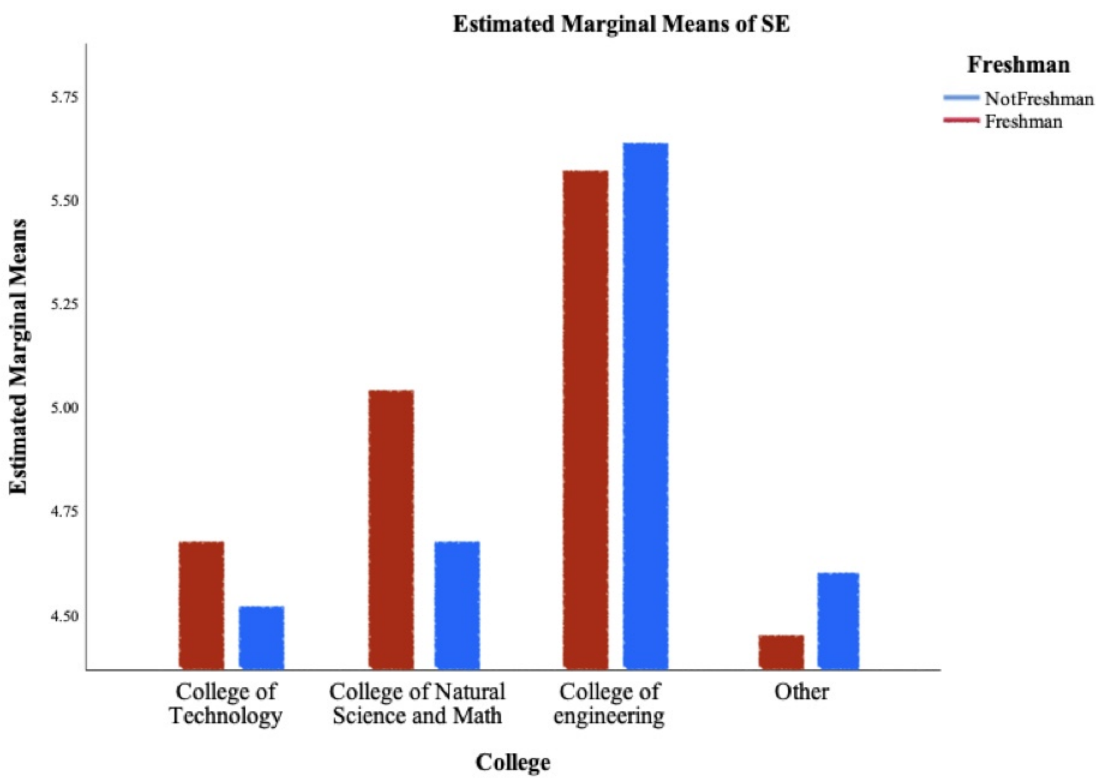
*Note. M and SD represent mean and standard deviation, respectively.*

The results of the $2 \times 4$ between-group ANOVA examining the impacts of freshman and college on self-efficacy were illustrated in Table 6. On students' academic self-efficacy, the interaction effect between freshman and college was not statistically significant, $F(3, 258) = .31, P > .05, Partial = .00$. This implies no interaction effect of students' years at university on the association between the colleges they study in and their academic self-efficacy in learning Calculus I. The simple main effects analysis demonstrated that freshman's academic self-efficacy in Calculus I learning was not significantly different from students who were not freshman, $F(1, 258) = .12, P > .05, Partial = .00$. However, another simple main effects analysis revealed that the effect of college on students' academic self-efficacy was statistically significant, $F(1, 258) = 56.43, P < .01, Partial = .06$. This tells us that students' academic self-efficacy in Calculus learning was different across the College of Technology, College of Nature Science and Math, College of Engineering, and others. Figure 3 presents the results as mentioned above.

*Table 6. Two-way (2×4) ANOVA result Freshman & College on Self-efficacy (n = 273).*

| *Variable* | *Sum of Squares* | *df* | *Mean Square* | *F* | *p* | *Partial* $\eta^2$ |
|---|---|---|---|---|---|---|
| *(Intercept)* | *3746.92* | *1* | *3746.92* | *1857.54* | *.000* | *.07* |
| *Freshman* | *.25* | *1* | *.25* | *.12* | *.728* | *.00* |
| *College* | *23.81* | *3* | *7.94* | *3.94* | *.009* | *.05* |
| *Freshman*College* | *1.85* | *3* | *.62* | *.31* | *.822* | *.00* |
| *Error* | *7027.66* | *258* | - | - | - | - |

*Figure 3. Interaction plot between freshman and college*




The Post hoc analysis was used to compare the mean differences of students' academic self-efficacy in Calculus learning across four colleges where students studied (Table 7). Pertinent comparisons indicate that students who study in college of Engineering were more likely to perceive higher levels of self-efficacy than those who studied at college of Technology $(MD = .99, SE = .28, p < .01)$, college of Nature Science & Math $(MD = .59, SE =$

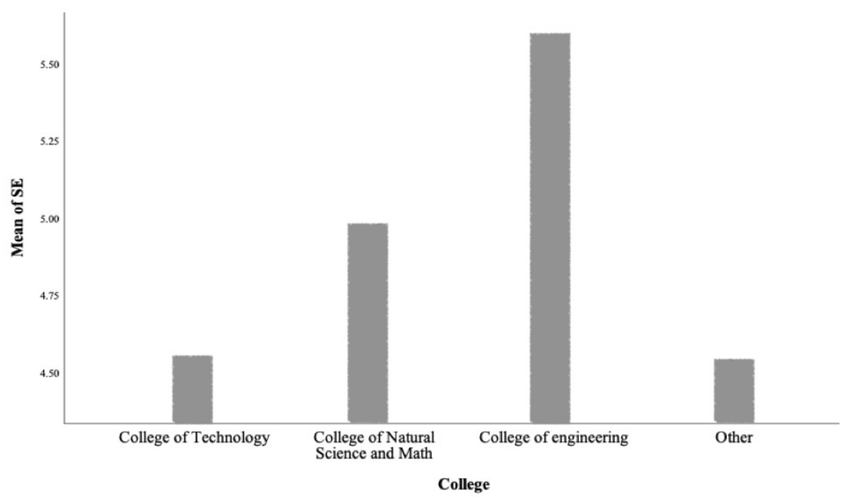
$.22, p < .05$), or other colleges ($MD = 1.06, SE = .30, p < .01$). Figure 4 illustrates the comparisons, as mentioned earlier.

*Table 7. Tukey-HSD Post-Hoc Comparisons of College on Expected Grade (n = 273).*

| *Comparison* | | | | | | |
|---|---|---|---|---|---|---|
| *College* | *College* | *MD* | *SE* | *df* | *p* | *95%CI [LL, UP]* |
| *Engineering* | *Technology* | *.99* | *.28* | *3* | *.003* | *[.26, .173]* |
| | *Natural Science & Math* | *.59* | *.22* | *3* | *.039* | *[.02, 1.17]* |
| | *Others* | *1.06* | *.30* | *3* | *.003* | *[.29, 1.82]* |

*Note. MD represents Mean difference.*
*SE represents Standard error.*
*LL and UL represent the lower-limit and upper-limit of the confidence interval, respectively.*

*Figure 4. Mean Plots of Self-efficacy across College*




## Discussion

The current study assessed college students' expected learning performance and academic self-efficacy in Calculus learning. The result indicated that significant differences of students' expected grade and self-efficacy were found among students enrolled in different colleges at the university. Specifically, students who studied at the College of Technology, College of

Nature Science and Math, College of Engineering, or other colleges demonstrated significantly different expectations on their success in Calculus I. Additionally, the results indicated an interaction effect of students' grade level of the association between the colleges they are in and their expectation of their final score in the course. The present study expands the extant research by showing possible distinctions of college students' year in school and placement in different colleges learning expectations in Calculus learning. These distinctions are specifically rooted in students' expected performance and academic self-efficacy in mathematics learning. On one hand, students who were freshman and studied in College of Math & Science and College of Engineering are more likely to expect high grades in their Calculus I course, comparing with those who were no longer freshman and studied at College of Technology and other colleges. On the other hand, students' academic self-efficacy in Calculus learning is more likely to be influence by placement in different colleges. Students who studied at College of Engineering demonstrated the highest level of academic self-efficacy in Calculus learning.

The findings in current study make an important contribution to the literature by showing students' learning experiences in a Calculus I course from the aspects of expectation and self-efficacy. This tells that students' years of school and placement in college have crucial influence in their mathematics learning expectations. Consequently, students' learning engagement, academic performance, major choice and many other academic outcomes can be different since students' academic expectations and self-efficacy play a vital role in such aspects [11], [12], [13]. The current study provides valuable insight into college students' academic expectation and self-efficacy in Calculus learning, which were from perspectives of their perceived self-expectations differ across various groups. Such differences indicated significant relationships between students' self-expectations and how long they study in the school and what major they study in. Understanding the relationships can help mathematics educators identify students' expectation and motivation and provide appropriate instructions or pedagogical approaches to support their students' mathematics learning success. Moreover, future research can dig more deeply into the association of students' majors and year of school with their academic performance and achievement motivations.

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