AC 2010-725: AN INVESTIGATION OF ENGINEERING STUDENTS' ATTITUDES TOWARD CALCULUS IN TAIWAN

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An Investigation of Engineering Students' Attitudes toward Calculus in Taiwan

Abstract

The purpose of this study was to investigate engineering students in Taiwan to (1) assess their attitudes toward calculus, (2) determine the difference in attitudes scores between males and females and (3) assess the relationship between students, attitudes toward calculus and their calculus achievement. Attitude was measured in cognitive, affective, and behavior domains explore the relation between attitude and its internal factors of calculus learning among engineering students in Taiwan. This study used theory and related research to develop a questionnaire research tool. The internal factors of calculus learning that we choose were usefulness, self-efficacy, motivation, anxiety, and, learning habits. The contributions of this study are as follows：The findings show that a high percentage of students do not have positive attitudes toward calculus. A statistical significant difference existed in the mean scores for males and females in the calculus attitudes scale. Specifically, statistical significant differences were detected between males and females in two attitude domains: cognitive and behavior. The correlation between students' attitudes toward calculus and calculus achievement was statistically significant in the self-efficacy scale. This study reveals that engineering students in Taiwan have different levels of attitudes toward calculus. This information could be helpful to calculus lecturers.

Introduction

Growing evidence support the importance of students' attitudes and beliefs toward mathematics for their achievement in and successful application of the subject.[1] Research studies have shown that students in higher education who are not mathematics majors often have negative images, beliefs and attitudes towards mathematics.[2] Mathematical achievement has often been correlated with positive attitudes the subject. A number of studies have reported that engineers subsequently view mathematics as a toolkit, the application of which needs to be learned. Engineers also have difficulty using mathematics in relatively low-level problem solving and non-routine engineering applications .[3]

With diminishing budgets and increasing competition from universities, Taiwan universities are trying now more than over to better understand their student population to better serve their students to improve teaching and learning. Low achievement or repeated failure in mathematics often leads to negative attitudes and lowered confidence, resulting in reduced effort or even mathematics avoidance, leading to further failure. Engineering majors are required to complete at least one semester of calculus at all Taiwan universities. Calculus plays an important role in learning and degree completion requirements of university-level students studying engineering course. Behavioral attitudes enable researchers to predict behaviors from the attitude construct,[4] thus it seems appropriate to study engineering students ’ attitudes toward calculus. Students’ attitudes toward calculus may provide information about their relevance perception of calculus as part of the engineering course.

Studies on attitudes toward calculus are scarce. This research was designed to provide quantitative data to help determine attitudes towards calculus among 792 first year engineering students in six technology universities in Taiwan. Researchers, faculty, and administrators may gain a better understanding of their students as a result and put resources and programs in place to better serve students in successfully articulate themselves through their calculus classes and through their program of study.
The objectives of the current study are to:
(i) assess students’ attitudes toward calculus;
(ii) determine the differences in attitudes scores between males and females;
(iii) determine the differences in attitude scores between calculus grade $\geq \mathbf{C}$ and calculus grade $\prec \mathbf{C}$.

Theoretical Background

This research focuses on the theory that a person’s attitude affects the way they view a subject, pursue, and achieve within that subject area. McLeod speaks of stability in students’ affective responses. Beliefs and attitudes are often considered relatively stable while emotions change more readily.[5] He further suggested that:

> "Affective issues play a central role in mathematics learning and instruction. When teachers talk about their mathematics classes, they seem just as likely to mention their students' enthusiasm or hostility toward mathematics as to report their cognitive achievements. Similarly, inquiries of students are just as likely to produce affective as cognitive responses; comments about liking (or hating) mathematics are as common as reports of instructional activities. These informal observations support the view that affect play a significant role in mathematics learning and instruction".[5](p.575)

The Tripartite Model postulates that attitude is a response to an antecedent stimulus.[6] The antecedent stimulus can be the independent variable. Attitude is generally classified according to three categories of attitude responses which are affect, cognition and behaviour.[7] Affect is related to the evaluation of feelings toward the attitude object while cognition reflects the perception of information about the attitude object and lastly, behavior reflects commitments and actions toward the attitude object.[8]

The Fennema-Sherman Mathematics Attitude Scales were developed to study domain specific attitudes thought to be related to mathematics learning.[9] These scales have become one of the most popular instruments used in researching attitudes towards mathematics over the past three decades.[10] The Fennema-Sherman Mathematics Attitude Scales have been used to evaluate students of various ethnic backgrounds and gender and at various academic grade levels from middle school to college level students. Researches using the Fennema-Sherman Mathematics Attitude Scales indicate that Fennema's Theory explains the belief that mathematics performance is an interaction of attitudes, mathematics anxiety, and behavior.[11]

Based on the Tripartite Model and Fennema-Sherman Mathematics Attitude Scales, and the context of attitudes toward calculus in this study, affect refers to positive or negative feelings toward calculus. Cognition refers to how students perceive calculus, such as perceiving the usefulness of calculus in their lives or relating calculus to their daily lives, while behavior reflects how students react to calculus.

Methodology

Subjects: Our sampling survey objects were792 first year engineering students in six technology universities in Taiwan. The participants consisted of 257 females and 535 males. The mean age of the participants was 19.8 years old (SD= 1.1).

Instrument：The current study used the research instrument Students' Attitude Towards Calculus (SATC). The SATC is an adapted instrument from the modified Fennema-Sherman Mathematics Attitude Scales based on the Tripartite Model. The instrument consists of Section A that deals with students' gender, college major, calculus studying time, internet time, the frequency of asking calculus questions per week, and calculus achievement of the last semester. Section B is based on the Tripartite Model, with five scales developed according to affective, cognitive and behavior domains respectively. The five scales include the cognitive variables of usefulness and self-efficacy, affective variables of motivation and anxiety, and the behavior variable of learning habit. Each scale contained twelve items for a total of sixty items. Items of the five scales were combined and randomly listed on a single survey that was distributed to participants of this study.
This research conducted a validity analysis of the five scales on 396 first year engineering students in Taiwan. The cronbach alpha coefficient was computed to determine its reliability and the value obtained was 0.82. Coefficients for each scale in this study ranged from a low of .77 to a high of .89.

The items were made up of forty positively worded and twenty negatively worded items to which the students were expected to respond to by expressing their level of agreement on a five – point scale of Strongly Agree (SA)(5), Agree (A)(4), Not Sure (NS)(3), Disagree (D)(2) and Strongly Disagree (SD)(1) if positively warded. A negatively warded item was scored in reverse order.

Data analysis: A numerical score for each student was calculated by totaling their response points from all items. The total score for each student indicated the student's attitude towards calculus. A One-Way Analysis of Variance was used to compare the means for each affective variable, confidence, usefulness, and anxiety. Cronbach's alpha, mean, standard deviation, range, and mean/item were computed for each attitude scale. Bivariate correlation coefficients between all scales were computed.

Results and Discussion

The results reported in this section are mainly based on the quantitative data obtained from the Likert-style items. Descriptive statistics (means and standard deviations) were used to report the data gathered through Likert-style items. The t-test was used to determine the attitude difference between males and females and calculus achievement difference in terms of the five domains (usefulness, self-efficacy, motivation, anxiety, and learning habit) of attitudes.

Attitudes Toward Calculus

Table 1 shows the results of participants who answered the final version of the survey, with the means and standard deviations. The overall mean was 3.10. The work categorized attitudes into four levels: negative, moderately positive, positive and highly positive according to the 25th, 50th and 75th percentage. The findings showed that 50% of the participants had negative (23.1%) and moderately positive (26.9%) attitudes while the remainder had positive (30.4%) and highly positive (19.6%) attitudes toward calculus. The results reveal a high percentage of students categorized with negative and moderately positive attitudes toward calculus. This finding needs to be taken seriously, because students with such attitudes may possibly find calculus useless and boring. These students also failed to relate and use calculus in their daily lives and engineering courses. They did not agree that calculus was a useful topic to learn. They also did not see the connection between calculus and the areas that they would be involved with in the future.

Two scales in Table 1 were above the overall mean (3.10). The scale " Motivations " had the highest mean (3.42) while the second highest mean (3.11) for the scale " anxiety " suggests that participants were willing to study calculus, but worried about learning calculus. The phenomenon of high motivation and high anxiety is interesting and contradictory. Students in Taiwan, have traditionally known the importance of mathematics from elementary school. But the examination culture may lead them to high anxiety about mathematics until university. Students in Taiwan are accustomed to rote learning and are more likely to see the parts of mathematics they have learned as disjointed units of methods or rules, resulting in their not being able to see the connections between different concepts or underlying crucial properties. Students who rely on rote learning in learning mathematics are typically more anxious about mathematical work than other students.[12]

The lowest mean of 2.88 shows that engineering students felt that calculus was not a useful tool they would use regularly during their engineering courses and careers. Attitudes toward mathematics indicated students' perceptions of the usefulness of mathematics.[13] The importance or relevance a student attaches to his/her study of mathematics is related to his/ her perception of its usefulness. The usefulness of calculus for educational and career goals is one factor affecting participation in mathematics. A better understanding of the importance of calculus in a wide range of careers and in engineering education is important for students as they make decisions about how much mathematics to take in university.

Table 1 Items for attitudes toward calculus

Scale	**Cronbach's αlpha**	**Mean**	**S.D.**	**Mean/Item**
Usefulness*	0.86	34.58	4.35	2.88
Self-efficacy*	0.89	35.88	6.14	2.99
Motivation**	0.84	41.02	2.87	3.42
Anxiety **	0.79	37.30	2.79	3.11
Learning Habit***	0.77	37.22	2.62	3.10

Mean of means=3.10 *= cognitive **= affective ***= behavior

The next lowest subscale with a mean score of 2.99 was regarding self-efficacy of learning calculus, Self-efficacy is the perception of individual ability to perform and complete tasks, which has been shown to be a mediating influence on motivation and performance.[14] The results of this study show that students did not perceive calculus it to be useful in their lives, and did not feel confident in calculus. Self-efficacy influences academic achievement and motivation, but high motivation and low self-efficacy is another interesting and contradictory phenomenon.

The scales were summed up to arrive at an overall score for each construct (affective, cognitive, behavior). A higher mean scores indicates that the participants' attitudes were more positive. Participants scored lowest on the cognitive catalog and highest on the affective catalog. This indicates that participants reacted positively toward calculus but did not perceive it to be useful in their lives, and did not feel confident in calculus.

Gender Difference in Attitudes Toward Calculus

The analysis was split according to gender, showing that females scored higher than males in all scales. Female participants seemed to have better attitudes toward calculus compared to the males based on the mean score of each item. However, we cannot assume that the differences were significant because this stage only carried out descriptive analyses.

An independent-samples t-test was conducted to find out if a significant difference exists in male and female attitudes toward calculus. A significant difference evidenced in the mean scores for males (M= 36.41, SD= 9.16) and females [M= 37.92, SD=7.72; t(60)= -2.318, p=.024], although the differences of the means were small (eta squared= 0.082).

Further analyses were carried out to determine if differences exist between male and female students in usefulness, self-efficacy, motivation, anxiety, and learning habit domains. A MANOVA test was conducted for this purpose. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices and multicollinearity, with no serious violations noted. A significant difference exhibited between males and females on the combined dependent variables: F(5,784)=7.73, P<.0005; Pillai's Trace=0.726, partial eta squared=0.27. When the results for the dependent variables were considered separately, the mean scores for the two domains reached statistical significance using the Bonferroni adjusted alpha level of .016 (Table 2).

The domain was cognitive: usefulness [F(1,787)= 10.42, P<.005, partial eta squared= 0.243] and self-efficacy [F(1,788)=12.88, P<.005, partial eta squared=.158]. The mean score for the affective and behavior domains: motivation, anxiety, and learning habit scales were not significant. This suggests that female participants had more positive perceptions with more favorable reactions toward calculus compared with males. However, there was no significant difference between the two when measured in terms of their feelings toward calculus.

Table 2 Differences between males and females

	Males		Females			
Dependent variable	Mean	S.D.	Mean	S.D.	F	Partial eta squared
Usefulness	33.21	4.12	35.88	4.63	10.42*	.243
Self-efficacy	33.89	6.13	37.87	6.15	12.88*	.158
Motivation	40.73	2.81	41.31	2.94	3.07	.008
Anxiety	37.12	2.81	37.18	2.76	0.43	.015
Learning Habit	37.09	2.65	37.34	2.58	6.80	.038

* Significant at p< .016

The comparison of mean scores between males and females for each scale suggests that females generally have more positive attitudes. The t-test analysis confirmed a significant difference between females and males in terms of their attitudes toward calculus. The results seemingly contradict the findings that males have more favorable attitudes toward mathematics.[15] This result reveals that male and female participants differ significantly in terms of how they perceived calculus. Findings also revealed a statistically significant difference between both groups in terms of how they reacted to calculus. The findings detected no significant difference between male and female feelings about calculus, suggesting that gender did not have an effect on their feelings. This result conflicts some researches that admit that gender differences in student attitudes toward mathematics exist, but male students showed more positive attitudes toward mathematics compared to females.[15] What made this difference? Both personal and situational environments may impact on this gender difference regarding to attitude and learning.[16]

Calculus Achievement Difference in Attitudes Toward Calculus

Calculus achievement was measured in terms of students' mid-term examination. Students could achieve an A(the score above 90), B(the score between 80 and 89), C(the score between 70 and 79), D(the score between 60 and 69)grade, etc. A total of 792 students indicated their grades. One significant difference exhibited between grade $\geq$C (n=187) and grade$\prec$C (n=605) on the combined dependent variables F(5,784)=7.85, P<.005; Pillai's Trace=0.756, partial eta squared=0.26. When the results for the dependent variables were considered separately, the mean scores for one scale reached statistical significance using the Bonferroni adjusted alpha level of .015 (Table 3).

The scale was self-efficacy [F(1,788)=10.37, P<.005, partial eta squared=.231]. The other mean score for the scales: usefulness, motivation, anxiety, and learning habit were not significant. This suggests that participants who got a calculus grade above C had more positive perceptions of how much effort they should expend to complete a task compared with those who got a calculus grade below C.

Table 3 Differences between Calculus Achievement

	Grade ≥ C		**Grade ≺ C**			
Dependent variable	Mean	S.D.	Mean	S.D.	F	Partial eta squared
Usefulness	34.87	4.25	34.29	4.48	16.23	.018
Self-efficacy	38.25	6.12	33.51	6.89	10.37*	.231
Motivation	41.82	2.79	40.21	2.88	8.54	.043
Anxiety	37.11	2.63	37.29	2.82	2.82	.032
Learning Habit	40.64	2.13	39.83	2.42	5.862	.054

* Significant at p< .015

A growing body of research reveals a positive, significant relationship between students' self-efficacy beliefs and their academic performance. This result is in line with research findings that when students believe they are incapable of achieving or have a low confidence level in mathematics, the result is high levels of failure, bad attitudes towards mathematics, and a lack of interest in any courses involving mathematics.[17] The connection between self-efficacy and achievement gets stronger as students advance through school. By the time students are in university, their self-efficacy beliefs are more strongly related to their achievement than any measure of their ability. Building stronger self-efficacy as early as possible is essential to developing high educational achievement among engineering students

Conclusion

The result of this study is preliminary but it still provides some useful insights, especially for those who teach university calculus. This research collected information on student attitudes toward calculus along with demographic information to provide a better picture and understanding of typical engineering students in Taiwan. The results indicate that engineering students have differed levels of attitudes toward calculus. A high proportion of engineering students have negative and moderately positive attitudes toward calculus. This could possibly be due to the way calculus is taught in Taiwan, using the traditional approach. Teaching is conducted in lecture halls, accommodating at least sixty students at one time where course instructors deliver lectures by transmitting knowledge in a one-way mode while students watch, listen and take notes passively.

The result of the study also suggests that gender should not be ignored. Findings show that female students have more positive attitudes toward calculus. Specifically, females perceive calculus as more important in their everyday lives compared to males. They see the connection between calculus and what they do in life. Female students also put forth more effort, such as working more calculus exercises than those given by lecturers throughout the calculus course, shown by the highest mean scores achieved in the behavior domain. In other words, females most likely perform better than males in calculus because of their more positive attitudes, and they probably have a higher tendency than males to choose mathematics related jobs.

Similar to other researches, this study found a strong connection between self-efficacy and achievement. Enhancing mathematics self-efficacy should mark the beginning of any effort to aid in academic growth of engineering students enrolled in calculus. Continual attempts should be made at enhancing the learning experience for students with low levels of self-efficacy, thereby enabling them to master important mathematical concepts to become lifelong, self- regulated learners.

Students with positive attitudes toward calculus will likely perform better in calculus assessments, increasing the likelihood of them taking more advanced mathematics courses in later semesters or at degree levels. This is because measures of attitudes are good predictors of behaviors.[18]

This study may help other researchers, faculty, and administrators gain a better understanding of engineering students and allow them to put resources and programs into place that would better serve the students. Students who can successfully articulate themselves through their calculus classes and their programs of study will have a better opportunity to succeed in today's global workplace.

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