Investigating the attitudes toward calculus of engineering students in Taiwan

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ABSTRACT: The purpose of this study was to investigate the attitudes toward calculus of engineering students in Taiwan. Attitude was measured in cognitive, affective and behaviour domains to explore the relation between attitude and the internal factors that affect the learning of calculus among engineering students. Theory and related research was used in this study to develop a questionnaire research tool. The findings of this study show that a high percentage of students do not have positive attitudes toward calculus. A statistically significant difference existed in the mean scores between males and females in the scale of attitudes to calculus. Specifically, statistically significant differences were detected between males and females in two attitude domains: cognitive and behaviour. The correlation between students' attitudes toward calculus and calculus achievement was statistically significant in the self-efficacy scale. The results of this study are that engineering students in Taiwan have different levels of attitude toward calculus. This information could be helpful to calculus lecturers.

INTRODUCTION

Growing evidence supports 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, with no majors in mathematics, often have negative images, beliefs and attitudes toward mathematics [2].

Calculus plays an important role in learning and degree completion requirements for university-level students studying engineering courses. Behavioural attitudes enable researchers to predict behaviour and, thus, it seems appropriate to study engineering students' attitudes toward calculus [3]. Students' attitudes toward calculus may provide information about the perception of the subject as part of an engineering course.

Studies on attitudes toward calculus are scarce. This research was designed to provide quantitative data to help determine attitudes toward calculus among first-year engineering students at six technology universities in Taiwan. Researchers, faculty and administrators may gain a better understanding of their students as a result and put resources and programmes in place to better serve students to successfully assist them through their calculus classes and through their programme of study. The objectives of the study were to:

- Assess students' attitudes toward calculus;
- Determine the differences in attitudes scores between males and females;
- Determine the differences in attitudes scores between students with a calculus grade $\geq$ C and those with a calculus grade < C.

THEORETICAL BACKGROUD

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 [4].

The Tripartite Model postulates that attitude is a response to an antecedent stimulus [5]. The antecedent stimulus can be the independent variable. Attitude is generally classified according to three categories of attitude response, which are affect, cognition and behaviour [6]. 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, behaviour reflects commitments and actions toward the attitude object [7].

The Fennema-Sherman Mathematics Attitude Scales were developed to study domain specific attitudes thought to be related to mathematics learning [8]. These scales have become one of the most popular instruments used in researching attitudes toward mathematics over the past three decades [9]. 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. Researches using the Fennema-Sherman Mathematics Attitude Scales indicate that Fennema's Theory explains the belief that performance in mathematics is an interaction of attitudes, mathematics anxiety, and behaviour [10].

Based on the Tripartite Model and Fennema-Sherman Mathematics Attitude Scales, and in 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 behaviour reflects how students react to calculus.

METHODOLOGY

Subjects: The sampling survey subjects were 792 first-year engineering students at six technology universities in Taiwan. The participants consisted of 257 females and 535 males.

Instrument: Used in the current study was 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 behaviour domains, respectively. The five scales include the cognitive variables of usefulness and self-efficacy; affective variables of motivation and anxiety; and the behaviour variable of learning habit. Each scale contained 12 items for a total of 60 items. Items of the five scales were combined and randomly listed on a single survey that was distributed to the 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 0.77 to a high of 0.89.

The items were made up of 40 positively worded and 20 negatively worded items to which the students were expected to respond by expressing their level of agreement on a five point Likert scale. A negatively worded item was scored in reverse order.

Data analysis: A numerical score for each student was calculated by totalling their response points for all items. The total score for each student indicated the student's attitude toward 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 for 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 of attitude.

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 categorised 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 categorised 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 to their daily lives and engineering course. 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, traditionally have known the importance of mathematics from elementary school, but the examination culture may lead them to high anxiety about mathematics until university. Students who rely on rote learning in learning mathematics are typically more anxious about mathematical work than other students [11].

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 [12].

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 because they make decisions about how much mathematics to take at university.

Table 1: Items for attitudes toward calculus.

Scale	Cronbach's alpha	Mean	SD	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 ***= behaviour

The next lowest subscale with a mean score of 2.99 was self-efficacy of learning calculus. The results of this study show that students did not perceive calculus to be useful in their lives and did not feel confident in their knowledge of 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, behaviour). A higher mean score indicates that the participants' attitudes were more positive. Participants scored lowest on the cognitive catalogue and highest on the affective catalogue. 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 their knowledge of calculus.

Gender Difference in Attitudes Toward Calculus

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

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 was evidenced in the mean scores for males ($M = 36.41$, $SD = 9.16$) and females ($M = 37.92$, $SD = 7.72$; $t(60) = -2.318$, $p = 0.024$), 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. A significant difference exhibited between males and females on the combined dependent variables: $F(5,784) = 7.73$, $P<0.0005$; 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 0.016 (Table 2).

For the cognitive domain: usefulness ($F(1,787) = 10.42$, $P<0.005$, partial eta squared = 0.243) and self-efficacy ($F(1,788) = 12.88$, $P<0.005$, partial eta squared = 0.158). The mean score for the affective and behaviour domains (motivation, anxiety, and learning habit scales) were not significant. This suggests that female participants had more

positive perceptions with more favourable 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	SD	Mean	SD	F	Partial eta squared
Usefulness	33.21	4.12	35.88	4.63	10.42*	0.243
Self-efficacy	33.89	6.13	37.87	6.15	12.88*	0.158
Motivation	40.73	2.81	41.31	2.94	3.07	0.008
Anxiety	37.12	2.81	37.18	2.76	0.43	0.015
Learning Habit	37.09	2.65	37.34	2.58	6.80	0.038

* Significant at $p<0.016$

The comparison of mean scores between males and females for each scale suggests 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 favourable attitudes toward mathematics [13]. This result reveals that male and female participants differ significantly in terms of how they perceived calculus.

Findings also revealed a s tatistically 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 gender did not have an effect on their feelings. This result conflicts with some researches that admit gender differences exist in student attitudes toward mathematics, but male students showed more positive attitudes toward mathematics, compared with females [13].

Calculus Achievement Difference in Attitudes Toward Calculus

Calculus achievement was measured in terms of students' mid-term examination. Students could achieve an A (score above 90), B (score between 80 and 89), C (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 was exhibited between grades $\geq$ C (n = 187) and grades < C (n = 605) on the combined dependent variables with $F(5,784) = 7.85$, $P<0.005$; 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 0.015 (Table 3).

The scale was self-efficacy produced $F(1,788) = 10.37$, $P<0.005$, partial eta squared = 0.231. The other mean score for the scales: usefulness, motivation, anxiety and learning habit were not significant. This suggests that participants who obtained a calculus grade above C, had more positive perceptions of how much effort they should expend to complete a task compared with those who attained a calculus grade below C.

Table 3: Differences between calculus achievement.

Grade $\geq$ C			Grade < C			
Dependent variable	Mean	SD	Mean	SD	F	Partial eta squared
Usefulness	34.87	4.25	34.29	4.48	16.23	0.018
Self-efficacy	38.25	6.12	33.51	6.89	10.37*	0.231
Motivation	41.82	2.79	40.21	2.88	8.54	0.043
Anxiety	37.11	2.63	37.29	2.82	2.82	0.032
Learning habit	40.64	2.13	39.83	2.42	5.862	0.054

* Significant at $p<0.015$

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 toward mathematics, and a lack of interest in any courses involving mathematics [14].

The connection between self-efficacy and achievement becomes 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.

CONCLUSIONS

The result of this study is preliminary, but it s till provides some useful insights, especially for those who teach university calculus. This research collected information on student attitudes toward calculus, and was collected along with demographic information to provide a better picture and understanding of the typical engineering student's attitudes in Taiwan. The results indicated that engineering students had differing levels of attitude toward calculus.

A high proportion of engineering students had negative and moderately positive attitudes toward calculus. This possibly could be due to the way calculus is taught in Taiwan. Calculus is currently taught using the traditional approach. Teaching is in lecture halls, accommodating at least 60 students at one time, where course instructors deliver lectures by transmitting knowledge in a one-way mode, while the students watch, listen and take notes passively.

The result of the study also suggested gender should not be ignored. Female students were found to have more positive attitudes toward calculus. Specifically, females tended to perceive calculus as more important in their everyday lives, compared with males. They were able to see the connection between calculus with what they do in life. Female students also put in more effort, such as doing more calculus exercises than those given by lecturers throughout the calculus course. This is shown by the highest mean scores achieved in the behaviour domain. In other words, females would 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.

As in other research studies, a strong connection between self-efficacy and achievement was found. Enhancing mathematics self-efficacy should be the beginning of any effort to aid in the academic growth of engineering students enrolled in calculus. Continual attempts should be made to enhance the learning experience of students that have been shown to have low levels of self-efficacy, thereby enabling individuals to master the important concepts of mathematics, while enabling them to become lifelong, self-regulated learners.

To conclude, when students have more positive attitudes toward calculus, it is likely they will perform better in calculus assessments. The likelihood of their taking more advanced mathematics courses in later semesters or at degree levels is enhanced. This is true, because measures of attitude are good predictors of behaviour [15].

A study such as this one may help other researchers, faculty and administrators gain a better understanding of engineering students and allow them to put into place the resources and programmes that would better serve the students. Successfully assisting students through their calculus classes and programmes of study would allow them to have a better opportunity to succeed in today's global workplace.

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