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Relationship between Students' Attitudes toward Mathematics and Their Achievement in Probabilities and Statistics: A Case of Engineering Students at ITC[1]

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ABSTRACT

The objectives of this study were (i) to understand the students' achievement in probabilities and statistics, (ii) to understand the students' attitudes toward mathematics, and (iii) to identify the relationship between the students' attitudes and their achievement. A total of 319 engineering students who had just finished their 2nd year program at the Institute of Technology of Cambodia (ITC) participated in the data collection with an online survey. The result indicated that the students' performance in probability and statistics was fairly good, and the students' background knowledge in mathematics played a certain role in shaping their achievement. Overall, the students had positive attitudes toward mathematics, especially in terms of their interest and confidence in mathematics; however, they also expressed certain fear toward mathematics. The students' gender played no significant role in shaping their attitudes toward mathematics, but their background knowledge in mathematics indicated specific associations. Spearman's correlations proved that, despite being weak in the relationship, the relations existed among all the three factors of the students' attitudes toward mathematics. These relations showed that the more positive the students felt about mathematics, the better they would perform in learning this subject.

KEYWORDS: Relationship, student's achievement, attitudes toward mathematics, probabilities and statistics, Institute of Technology of Cambodia (ITC)

[1] ITC is an abbreviation for Institute of Technology of Cambodia, a higher education institution providing degree programs in engineering and other science related majors.

សង្ខិត្តន័យ

វត្ថុបំណងនៃការស្រាវជ្រាវនេះគឺ (១) ស្វែងយល់ពីលទ្ធផលសិក្សាលើមុខវិជ្ជាប្រូបាប៊ីលីតេនិងស្ថិតិរបស់និស្សិតវិស្វកររៀនវិទ្យាស្ថានបច្ចេកវិទ្យាកម្ពុជា (២) ស្វែងយល់អំពីឥរិយាបថរបស់និស្សិតទៅលើមុខវិជ្ជាគណិតវិទ្យា និង (៣) កំណត់ពីទំនាក់ទំនងនៃលទ្ធផលសិក្សារបស់និស្សិតជាមួយនឹងឥរិយាបថរបស់គេទៅលើមុខវិជ្ជាគណិតវិទ្យា។ វិធីសាស្ត្រស្រាវជ្រាវបរិមាណវិស័យអមជាមួយនឹងកម្រងសំណួរតាមអនឡាញ ត្រូវបានប្រើប្រាស់ដើម្បីប្រមូលទិន្នន័យពីក្រុមគោលដៅដែលបានកំណត់។ និស្សិតវិស្វកចំនួន៣១៩នាក់ ដែលទើបនឹងបញ្ចប់ការសិក្សាឆ្នាំទី២នៅវិទ្យាស្ថានបច្ចេកវិទ្យាកម្ពុជា បានចូលរួមក្នុងការសិក្សានេះ។ ការសិក្សាបានបង្ហាញថា លទ្ធផលសិក្សារបស់និស្សិតទាំងនេះ លើមុខវិជ្ជាប្រូបាប៊ីលីតេនិងស្ថិតិ ស្ថិតក្នុងកម្រិតល្អប្រសើរ ដោយលទ្ធផលក៏បានបង្ហាញបន្ថែមថា សមត្ថភាពសិក្សាគណិតវិទ្យារបស់ពួកគេនៅថ្នាក់ចំណេះទូទៅ បានចូលរួមចំណែកក្នុងការសិក្សាមុខវិជ្ជាប្រូបាប៊ីលីតេនិងស្ថិតិ នៅថ្នាក់ឧត្តមសិក្សាផងដែរ។ បន្ថែមពីលើនេះ លទ្ធផលក៏បង្ហាញថា ឥរិយាបថទូទៅរបស់និស្សិតលើមុខវិជ្ជាគណិតវិទ្យា មានទំនោរវិជ្ជមាន ជាពិសេសពាក់ព័ន្ធនឹងកត្តា "ចំណូលចិត្ត" និងកត្តា "ភាពជឿជាក់" លើមុខវិជ្ជាគណិតវិទ្យា បើទោះបីជាពួកគេក៏បានបង្ហាញផងដែរនូវអារម្មណ៍ភ័យខ្លាចខ្លះៗទៅលើមុខវិជ្ជាគណិតវិទ្យាក្តី។ ឥរិយាបថរបស់និស្សិតទាំងនេះលើមុខវិជ្ជាគណិតវិទ្យាពុំមានភាពខុសប្លែកគ្នានោះទេបើផ្អែកលើកត្តា "ភេទ" ក៏ប៉ុន្តែសមត្ថភាពគណិតវិទ្យាពីថ្នាក់ចំណេះទូទៅរបស់ពួកគេ បានចូលរួមចំណែកក្នុងការកំណត់ឥរិយាបថរបស់ពួកគេលើមុខវិជ្ជានេះ។ លទ្ធផលតេស្តទំនាក់ទំនងស្ពៀមែន (Spearman's Ccorrelation) ក៏បានបង្ហាញផងដែរថា "កត្តាទាំងបីនៃឥរិយាបថរបស់និស្សិតទៅលើគណិតវិទ្យា" មានទំនាក់ទំនងខ្សោយជាមួយនឹង "សមត្ថភាពគណិតវិទ្យា" របស់ពួកគេ បើទោះបីជាទំនាក់ទំនងនេះមិនខ្លាំងក៏ដោយចុះ។ ទំនាក់ទំនងនេះក៏បានបង្ហាញផងដែរថា និស្សិតទាំងនេះមានទំនោរនឹងអាចរៀនមុខវិជ្ជានេះបានកាន់តែប្រសើរ ប្រសិនបើគេមានអារម្មណ៍វិជ្ជមានជាមួយនឹងគណិតវិទ្យា។

ពាក្យគន្លឹះ: (១) ទំនាក់ទំនង (២) លទ្ធផលសិក្សា (៣) ឥរិយាបថចំពោះគណិតវិទ្យា (៤) ប្រូបាប៊ីលីតេនិងស្ថិតិ (៥) វិទ្យាស្ថានបច្ចេកវិទ្យាកម្ពុជា

1. INTRODUCTION

Mathematics is one of the most critical subjects in school education, and according to Enu et al. (2015), mathematics plays a significant role as the foundation of scientific-technological knowledge that contributes to a nation's social-economic development. In the wake of modern technology and advancement in research and development, STEM-related subjects have become the core focus in school subjects and university levels. With the nature of the subject, mathematics is the core subject for STEM-related disciplines. In Cambodia, the Ministry of Education, Youth and Sport (MoEYS) has also focused on teaching and learning STEM-related subjects (Nov, 2020). Despite its importance in school subjects, many researchers found that students are struggling in this subject (Gafoor & Kurukkan, 2015). In their study, Ignacio et al., (2006) found that students perceived mathematics as tedious, challenging, and impractical despite its importance in contemporary education and economic development.

The issues in students' learning and their performance in mathematics have been the centre of focus among mathematics educators, researchers, and specialists in the field of education (Anghelache, 2013). There have been several studies that found out the factors determining the learning process and highlighted possible relations among elements related to the quality of education, the teaching strategies used in the classroom, and the quality of pupils' and students' performance (Ignacio et al., 2006; Konarzewski, 2019; Ma & Kishor, 1997; Marchis, 2011; Mata et al., 2012; Mazana et al., 2018; Subia et al., 2018). Mathematics has been one of the most challenging subjects for high school and college students alike. Learning mathematics is a complicated task, and being successful in this subject is related to several factors and requires students to engage and practice regularly. In general, the learning of this subject is a gender bias, where male students tend to outperform their female peers (Leedy et al., 2003; Mehraein & Gatabi, 2014). Besides gender, there are other numerous factors

associated with the success or failure in this subject where the attitude toward mathematics is among these factors.

According to Mazana et al. (2018), several other factors affected the students' learning and performance in mathematics, including their attitudes towards the subject, teachers' instructional practices, and school environment. Moreover, Pilotti et al. (2017) highlighted three crucial aspects of students' engagement in order for them to succeed in mathematics learning. These engagement dimensions include behavioral, cognitive and emotional engagement. Many research studies in mathematics education suggested that achievement in this subject is attributable not only to cognitive factors but also to affective variables, such as attitudes, beliefs, and motivation (Alibraheim, 2021; Ayob & Yasin, 2017; Capuno et al., 2019; Hannula, 2002; Ignacio et al., 2006; Konarzewski, 2019; Ma & Kishor, 1997; Mata et al., 2012; Mazana et al., 2018; Motanya, 2018; Panerio, 2020; Subia et al., 2018). Concerning this, Mensah et al. (2013) mentioned that the role of attitudes in mathematics learning has attracted the attention of educational researchers and mathematics educators for a very long time. Many researchers have investigated the relationship between the affective and the cognitive domains. Maker. (1982) as cited in Maker. (1982) as cited in (Ma & Kishor, 1997) emphasized the importance of this relationship:

> "*It is impossible to separate the cognitive from the affective domains in any activity. The most important is that there is a cognitive component to every affective objective and an affective component to every cognitive objective. (pp. 30-31).*"

Some students may pay great attention to their learning in mathematics education, putting much effort into practicing and engaging in their mathematics classrooms. Long-decade literature indicated that learners' attitudes towards mathematics have become an aspect that has been studied persistently to find out if there is a relationship between the learner achievement and their attitudes (Aiken, 1970, 1974; Debellis & Goldin, 2006; Ignacio et al., 2006; Konarzewski, 2019; Langat, 2015; Lipnevich et al., 2011; Ma & Kishor, 1997; Mehraein & Gatabi, 2014; Minato & Yanase, 1984; Motanya, 2018; Panerio, 2020; Peteros et al., 2019). With this, Enu et al. (2015) added that the students' attitudes towards mathematics plays an important role in their efforts to learn, understand and practice the concepts and skills required to master the subject. Most of these studies have highlighted the significant role of attitudes in the teaching and learning mathematics.

1.1. Attitudes toward Mathematics

Attitudes are part of our life that centres on a particular feeling such as liking or dislike, love, fear, or appreciation towards a particular object (Hannula, 2002). In addition to this, Ma and Kishor. (1997) asserted that attitudes towards mathematics might be defined as "an aggregated measure of a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities." According to Guimaraest. (2005), as cited in Moenikia & Zahed-Babelan. (2010)), attitude is classified into three components: (i) a cognitive component that refers to opinions or beliefs in something (ii) affective component that is related to emotion or feeling (like or dislike) on a particular thing, and (iii) action that can be expressed by the behavioural activities or readiness to respond something. By relating these views, attitude toward mathematics refers to a person's mental set or disposition that includes all three dimensions to engage and practice in mathematics lessons regularly. Additionally, Moenikia and Zahed-Babelan (2010) stated that attitude is not just a passive result of past experiences; it also drives behaviour and guides its forms and manner.

1.2. Contextual Understanding

The subjects of this study were engineering students studying at the Institute of Technology of Cambodia (ITC). Being one of the leading higher institutions in Cambodia, ITC focuses on building qualified human resources in STEM and engineering-related disciplines. The first two years at ITC are a foundation year providing a strong background in science subjects, specifically mathematics and physics. In these two years, mathematics courses are among the essential subjects the students need to study for four semesters with six courses. Probability and statistics courses are compulsory for two semesters at ITC.

The students admitted into ITC need to pass grade 12 (BacII examination) and ITC's entrance

examination, and they have a solid academic background in mathematics and science subjects. Those who keep doing well in mathematics during their first two years tend to have good progress in their learning throughout their academic years at ITC.

1.3. Research Problem

It has been argued that attitudes are part of human identity (Mohamed & Waheed, 2011), and as pointed out in above section, human's attitude encompasses the feeling of hate, love, enjoyment. Theoretically, mathematics is an object that could also be loved, feared, hated, or disliked, just like any other object. It then follows that the learning of a particular subject could be linked to the attitudes that one has on that subject, as suggested in Zan & Di Martino. (2007) that there is "a strong interaction between cognitive and emotional aspect." Therefore, it follows that the emotional aspect (part of attitude) could come into play in the learning of mathematics (cognitive). We may deduce that poor performance in mathematics could therefore be partly attributed to learners' attitudes towards mathematics.

With some years of experience teaching high school students in mathematics, regardless of geographical areas, gender, or other factors, we (the authors) have observed that most of the students we have taught had negative feelings about mathematics, while some even expressed a certain level of fear toward mathematics. In Cambodia, the students' learning performance has been a hot topic among scholars, educators, and teachers alike. There were studies conducted to assess factors affecting the students' performance (Heng, 2012, 2013, 2014); however, none was focussed on students' performance in mathematics, especially the issue concerning the relation with the students' attitudes toward the subject.

With the lack of literature about the proposed study and the lack of interest in research about mathematics education in Cambodia, it is vital to study the students' attitudes toward mathematics, especially the relationship with the students' performance in this subject.

1.4. Research Objectives

This study aimed at seeking the relationship between the attitudes exhibited by the engineering students towards mathematics and their mathematics achievement. Specifically, this study focused on the following objectives:

- To understand the differences in the students' achievement in probabilities and statistics with regard to gender and their BacII Math Grades.
- To explore the students' attitudes toward mathematics and their association with gender and the students' BacII Math Grades.
- To identify the relationship between the students' attitudes towards mathematics and their achievement in probabilities and statistics.

1.5. Conceptual Framework

This study centres on the definition of attitudes from (Hannula, 2002; Ma & Kishor, 1997) which stated that attitudes are related to the feeling or perception toward mathematics. This study relies on the theoretical foundation laid by (Debellis & Goldin, 2006), whose study focuses on the affective and cognitive aspects of students' mathematics learning. A number of long-decade researches have indicated that, regardless of levels and contexts, there was a positive relationship between the students' attitudes toward mathematics and their mathematics performance (Debellis & Goldin, 2006; Langat, 2015; Lipnevich et al., 2011; Ma & Kishor, 1997; Minato & Yanase, 1984; Moenikia & Zahed-Babelan, 2010; Ndifor et al., 2017; Randhawa et al., 1993; Stage & Kloosterman, 1991; Walsh, 1991; Yasar, 2016).

However, recent research studies demonstrated that the relationship between students' attitudes toward mathematics and their mathematics performance is negative or somehow poorly related and could not be considered practical significance. For instance, the international data from TIMSS 2015 shows that the mean attitude toward mathematics of the fourth graders among participating countries negatively affected their mathematics performance (Konarzewski, 2019). In addition, despite positive relation, the study was conducted by Ma and Kishor. (1997) found that the

students' attitudes toward mathematics were poorly related.

In this study, we proposed the investigation on engineering students' attitudes toward mathematics and its relation to their mathematics performance. The investigations were primarily on how the students feel about mathematics and whether there is a positive or negative relationship between their attitudes toward mathematics and their performance in probabilities and statistics.

2. METHODOLOGY

This research centered on students' attitudes toward mathematics and its relation to their mathematics performance in probabilities and statistics. Quantitative methodology (Creswell & Creswell, 2018) with an online survey method was employed.

2.1. Sample and Data

The participants of this study were 319 engineering students who had just finished their second-year engineering program at the Institute of Technology of Cambodia (ITC). The data collection was from August 15, 2021, to August 20, 2021. The recruitment of the participants followed a voluntary sampling technique, where the link of the survey questionnaire (Google Form) was sent to the students via ITC Telegram and Messenger groups. The students who responded to the questionnaire were regarded as research samples. Nine hundred engineering students received the survey link, and 319 of them filled out the questionnaire. The response rate was approximately 35.44%.

2.2. Research Instrument

The instrument in this study was an online survey questionnaire that measured the students' attitudes toward mathematics. The attitudes statements were adapted and developed from conceptualizing of several related studies. The structure of the questionnaire had two parts as follows:

- Part 1: Student's Background

  This part covers the participants' personal information such as gender, their overall BacII Grades and their BacII Math Grades.

- Part 2: Students' Attitudes toward Mathematics

  Part 2 contains 21 statements describing different attitudes toward mathematics. The 21 statements were measured a with a 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree).

The researchers did the Exploratory Factor Analysis (EFA) on the 21 items using the absolute value of coefficients above .40, and found that eight items were loaded in more than one component; therefore, the researchers decided to drop these items one by one and re-run the EFA each time an item was eliminated. The final result remained with 13 items describing three attitude factors below:

Table 1

The Exploratory Factor Analysis (EFA) of the attitude statements and the loading factors (based on Rotated Component Matrix) and their respective reliability Cronbach's Alpha

Item	Component			Factor (Reliability)
	1	2	3	
Q1	.702			**FACTOR 1** Interest in Mathematics ($\alpha = .717$)
Q2	.681			
Q3	.692			
Q7	.678			
Q6		.565		**FACTOR 2** Confidence in Mathematics ($\alpha = .726$)
Q8		.501		
Q11		.561		
Q12		.771		
Q14		.737		
Q15			.698	**FACTOR 3** Fear of Mathematics ($\alpha = .633$)
Q16			.688	
Q19			.628	
Q21			.726	

Factor 1 represents the students' interest in mathematics (*Math-Interest*), with a reliability scale of .717. Factor 2 denotes the students' confidence in mathematics (*Math-Confidence*) with a reliability scale of .726. Factor 3 signifies the students' fear of mathematics (*Math-Fear*), which is reliable .633. According to Whitley & Kite, the reliability of Factor 1 and Factor 2 were considered high, according to Whitley & Kite. (2013) stated that an instrument's acceptable reliability using the Likert

Scale should be at least .70. However, Factor 3 had low instrument reliability according to the same author above.

The mathematics performance in this study was measured using the probabilities and statistics course scores for the second semester (2020-2021 Academic Year) at ITC. The students also provided these scores while filling out the online survey questionnaire.

2.3. Data Analysis

The collected data were entered and analysed using a statistical package SPSS V.25. The dependent variables in this study were the students' probabilities and statistics scores and the students' attitudes toward mathematics. Shapiro-Wilk tests indicated that the students' score was not normally distributed ($W(319) = 0.973, p = .001$), while the students' overall attitudes toward mathematics were found to be normally distributed ($W(319) = 0.993, p = .122$). In this case, the students' overall attitudes toward mathematics were obtained from the combination of the 13 attitude items presented in Table 1 above. The four items in Factor 3 were reversed with measurement scales, which meant Q15➔RQ15, Q16➔RQ16, Q19➔RQ19 and Q21➔RQ21 with the reverse values from 1➔5, 2➔4, 3➔3, 4➔2 and 5➔1. The three factors of the students' attitudes toward mathematics were found to be not normally distributed: Factor 1, ($W(319) = 0.968, p = .001$), Factor 2, ($W(319) = 0.980, p = .001$) and Factor 3, ($W(319) = 0.980, p = .001$); therefore, the analyses of the data with regard to these constructs were presented in the below table.

Table 2
The data analysis techniques used for each research objective

Research Objective	Statistical Techniques
1	▪ Descriptive Statistics *To descriptively check the students' performance using mean score and standard deviation.* ▪ Mann-Whitney *To associate the students' performance with regard to their gender.* ▪ Kruskal Wallis *To compare the students' performance with regard to their BacII Math Grades*
2	▪ Descriptive Statistics *To check the students' attitudes toward mathematics descriptively.* ▪ Student's t-Test *To associate the students' overall attitudes toward mathematics with regard to gender.* ▪ One-Way ANOVA To compare the students' overall attitudes toward mathematics with regard to BacII Math Grades. ▪ Mann-Whitney *To compare the students' attitudes toward mathematics (the three factors) with regard to gender.* ▪ Kruskal Wallis *To compare the students' attitudes toward mathematics (the three factors) with regard to BacII Math Grades.*
3	▪ Spearman Correlation *To assess the relationship between each factor of the students' attitudes toward mathematics and their performance in probabilities and statistics.*

The choice of these non-parametric tests was in accordance with Bee Wah & Mohd Razali (2011), who stressed that employing parametric tests with data that violate the normality assumption may lead to unreliable or invalid interpretation and inferences.

Within the score range of 0-100, the judgment and interpretation of the students' performance in the probabilities and statistics course followed the following criteria:

Table 3
The judgment and interpretation criteria of the students' performance in probability and statistics

course

Score Range	Interpretation
90 - 100	Excellent
80 - 89	Very Good
70 - 79	Good
60 – 69	Fairly Good
50 - 59	Poor
0 - 49	Very Poor

The interpretation of the overall students' attitudes (Math-Attitudes) and each factor of their attitudes toward mathematics were based on the criteria defined in the following table:

Table 4

Criteria for interpretation of the students' overall attitudes and the three factors of their attitudes toward mathematics

Factor	Scale Range	Interpretation
Overall Attitudes	39 or less	Negative Attitudes
	More than 39	Positive Attitudes
Math-Interest	12 or less	No interest in mathematics
	More than 12	Have interest in mathematics
Math-Confidence	15 or less	No confidence in mathematics
	More than 15	Have confidence in mathematics
Math-Fear	12 or less	No fear of mathematics
	More than 12	Fear of mathematics

The decision for criterion points (cut points) for overall attitudes toward mathematics and each factor was based on the neutral point (value 3) times the total number of variables for the overall attitudes or the total number of variables for each factor. The overall attitudes contained 13 variables; therefore, the criterion point was $3 \times 13 = 39$. With the same principle for calculation, the criterion point for Factor 1 and Factor 3 was $3 \times 4 = 12$, and for Factor 2 was $3 \times 5 = 15$. The interpretation of mean scores for the students' attitudes toward mathematics with value below or above these criterion points was translated as in **Table 4** above.

3. RESEARCH FINDINGS

3.1. Participants' Information

The participants in this research were second-year engineering students studying at the Institute of Technology of Cambodia (ITC). The recruitment of these research participants was presented in **Section 2.1** above. It was revealed that 220 male students participated in the study, which accounted for 69% of the total sample. Moreover, the majority of the participants had overall BacII certificates of Grade B and Grade C with the proportions of 35.1% and 37.3%, respectively. Only 8.78% of the participants possessed a Grade A certificate, while Grade E (3.76%) filled the smallest proportion.

Table 5

Distribution of research participants with regard to gender and their BacII overall grade

	BacII Overall Grade					Total
	A	B	C	D	E	
Female	10	29	37	18	5	99
Male	18	83	82	30	7	220
Total	28	112	119	48	12	319

To the respondents' BacII Math Grades, the finding revealed that 22.57% of the participants got Grade A, while Grade B comprised 25.07% of the sample. The majority (26.33%) of the students possessed Grade C (26.33%), Grade D (16%), and Grade E filled only 10.03% of the distribution (Table 6).

Table 6

Distribution of research participants with regard to gender and their BacII Math Grades

	Math BacII Grades					Total
	A	B	C	D	E	
Female	19	21	25	18	16	99
Male	53	59	59	33	16	220
Total	72	80	84	51	32	319

3.2. Students' Achievement in Probability and Statistics Course

It was found that, overall, the 2nd Year ITC engineering students' performance in probabilities and statistics was ranked as "*Fairly Good*" ($Mean = 68.82,\ SD = 16.476$), according to the criteria in **Table 3**. Moreover, it was seen that 10% of them failed this course while only 8.2% of the participants fell into excellent performance. It was also shown

that 14.4% of the students performed poorly in probabilities and statistics.

Table 7
The distribution of 2nd year engineering students' performance in probability and statistics course

	Frequency	Percent
Very Poor (Failed)	32	10.0
Poor	46	14.4
Fairly Good	82	25.7
Good	73	22.9
Very Good	60	18.8
Excellent	26	8.2
Total	319	100.0

In terms of association with gender, the result of the Mann-Whitney test showed that there were no significant differences in the students' performance in probabilities and statistics with concerning their gender ($U(99,220) = 10207.50, Z = -.896, p = .370$). However, Kruskal Wallis test signified that their performance was significantly different in term of their BacII Math Grades ($H(4) = 27.566, p = .001$). Post hoc tests for pairwise comparisons of BacII Math Grades proved that the participants' performance was statistically different among three pairs of their BacII Math Grades (Table 8).

Table 8
Comparisons of differences in students' performance based on paired BacII Math Grades

Group Tests	Paired Median	$Sig.$	$Adj.Sig.$
D & E	(64.98, 66.10)	.880	1.000
D & C	(64.98, 68.91)	.185	1.000
D & B	(64.98, 70.98)	.012	.115
D & A	(64.98, 78.67)	.001	.001
E & C	(66.10, 68.91)	.332	1.000
E & B	(66.10, 70.98)	.045	.453
E & A	(66.10, 78.67)	.001	.002
C & B	(68.91, 70.98)	.165	1.000
C & A	(68.91, 78.67)	.001	.002
B & A	(70.98, 78.67)	.022	.219

Evidently, the students' performance was varied among the students who possessed grades 'A&*D'*, '*A&E*' and those who obtained 'A&C*'*. These results proved that the students who possessed higher mathematics grades in their BacII examination tend to perform better in probabilities and statistics courses at the university level.

3.3. Students' Attitude toward Mathematics

Table 9 below presents the findings of the participants' attitudes toward mathematics, including the students' overall attitudes and the three factors of the students' attitudes toward mathematics. It was revealed that the engineering students' overall attitudes toward mathematics were positive ($Mean = 44.03, SD = 5.40$). The findings for each attitude factor revealed that, with regard to Factor 1 (Math-Interest), the participants were interested in mathematics, though the level of their interest was not high, according the magnitude of the mean score ($Mean = 15.18, SD = 2.22$). Similarly, for Factor 2 (Math-Confidence), the result indicated that the students' level of confidence in mathematics was found to be positive ($Mean = 17.33, SD = 2.87$). In addition to these positive trends in the participants' attitudes, the finding for Factor 3 (Math-Fear); however, showed that the students expressed a certain level of fear toward mathematics ($Mean = 12.48, SD = 2.41$).

Table 9
The students' overall attitudes toward mathematics and the analysis of the three factors of attitudes toward mathematics

Factor	$Mean$	SD	Interpretation
Overall Attitudes	44.03	5.40	Positive Attitudes
Math-Interest	15.18	2.22	Have interest in mathematics
Math-Confidence	17.33	2.87	Have confidence in mathematics
Math-Fear	12.48	2.41	Have a fear of mathematics

Supplementing to the descriptive findings above, the results from inferential statistics revealed that the students' overall attitudes were found to be of no significant differences among male and female students ($t(317) = -1.455, p = .147$). However, the One-Way ANOVA test signified that there were significant differences in the students' overall attitudes toward mathematics in term of their BacII Math Grades, ($F(4,314) = 3.487, p = 0.08$).

We did a post hoc test for pairwise comparison of the students' overall attitudes with regard to their BacII Math Grades, and the result revealed that the differences in their overall attitudes

were seen only with a pair of BacII Math Grades: A&E (Table 10). This finding seemed that the students' mathematics background might play some role in shaping their attitudes toward mathematics in general.

Table 10
Comparisons of differences in students' overall attitude based on paired BacII Math Grades

Group Tests	SE	$Sig.$
A & B	.864	.770
A & C	.854	.174
A & D	.973	.387
A & E	1.130	.004
B & C	.831	.821
B & D	.953	.942
B & E	1.112	.059
C & D	.944	1.000
C & E	1.105	.323
D & E	1.199	.329

Statistically, we did not have enough evidence to conclude the differences in the students' overall attitudes toward mathematics among other pairs of BacII Math Grades.

In relation to the three attitude factors, the results from Mann-Whitney U tests revealed that the students' attitudes toward mathematics did not differ with regard to their gender. With these findings, we can conclude that male and female students felt the same way toward mathematics, whether in terms of their interest, confidence, or fear of mathematics.

Table 11
Comparisons of the students' attitudes toward mathematics, in term of the three factors, with regard to the participants' gender

	Math-Interest	Math-Confidence	Math-Fear
Mann-Whitney U	9959.5	9760.5	10171.0
Wilcoxon W	14909.5	14710.5	34481.0
Z	-1.245	-1.492	-.951
Sig. (2-tailed)	.217	.136	.341

a. Grouping Variable: Gender

We compared the students' attitudes (the three factors) about the participants' BacII Math Grades. The Kruskal-Wallis tests revealed that the differences in the students' attitudes were seen only in their confidence in mathematics.

Table 12
Comparisons of differences in students' attitude based on paired BacII Math Grades

	Math-Interest	Math-Confidence	Math-Fear
Kruskal-Wallis H	6.382	13.945	8.021
df	4	4	4
Asymp. Sig.	.172	.007	.091

a. Kruskal Wallis Test
b. Grouping Variable: BacII Math Grades

A post hoc test for pairwise comparison of the students' confidence in mathematics with each pair of the students' BacII Math Grades provided the following results.

Table 13
Post hoc test for comparison of the students' confidence in mathematics with regard to their pairwise BacII Math Grades

Group Tests	Paired Median	$Sig.$	$Adj.Sig.$
A & B	(18.0, 18.0)	.763	1.000
A & C	(18.0, 16.0)	.019	.186
A & D	(18.0, 17.0)	.103	1.000
A & E	(18.0, 16.0)	.002	.025
B & C	(18.0, 16.0)	.035	.352
B & D	(18.0, 17.0)	.164	1.000
B & E	(18.0, 16.0)	.005	.045
C & D	(16.0, 17.0)	.653	1.000
C & E	(16.0, 16.0)	.203	1.000
D & E	(17.0, 16.0)	.127	1.000

With the adjusted significant level, it was evidenced that the differences in the students' confidence in mathematics were found among the students who got BacII Math Grades of "A&E" and "B&E". There was not enough evidence to prove the significant differences in other pairs, according to Table 13 above. We also found that the students with Grade A and Grade B of mathematics background were more confident in mathematics, ($Mdn_A = 18.0, Mdn_B = 18.0$) than those who got Grade E ($Mdn_E = 16.0$) at the BacII level.

3.4. Attitude and Performance Relations

This section presents the relationships between the students' performance in probabilities and statistics with their attitudes toward mathematics (the three factors). The results from Spearman's correlation analyses revealed the positive relations

between the students' performance with their interest in mathematics ($rs(319) = .293, p = .001$) and their confidence in mathematics ($rs(319) = .210, p = .001$). These relationships were found to be significant within 99.99% confidence interval. However, the finding indicated a negative relation between the students' performance and their fear of mathematics ($rs(319) = -.119, p = .034$).

Table 14
Spearman correlation tests of the students' attitudes toward mathematics and their performance in probabilities and statistics course

	1	2	3	4
1. Students' Scores	1.00	.293**	.210**	-.119*
2. Math-Interest		1.00	.539**	-.110*
3. Math-Confidence			1.00	-.189**
4. Math-Fear				1.00

**. Significant at the 0.01 level (2-tailed).
*. Significant at the 0.05 level (2-tailed).

Despite being weak in the relationship, we can conclude that the more positive the students felt toward mathematics, the better they might be doing in their probabilities and statistics classes. From the strengths of these relationships, we could deduce that the attitudes toward mathematics did not contribute much to their learning performance. This may indicate that other factors play a significant role in the students' mathematics learning.

4. DISCUSSION

The following section presents the overall discussion about the proposed objectives: (i) to understand the association of the students' performance in probabilities and statistics with gender and their BacII Math Grades, (ii) to explore the students' attitudes toward mathematics and the association with the two independent variables mentioned earlier, and (iii) to determine the relationship between the students' attitudes toward mathematics and their performance.

Students' Mathematics Performance

It was revealed that the students' performance in probabilities and statistics was fairly good, with a score range of 68-69, and their performance was proven to have no significant difference among male and female students. The result was in contrast to several studies that found that male students performed better than female students in terms of mathematics. Past research studies have indicated gender bias in learning mathematics (Leedy et al., 2003; Mehraein & Gatabi, 2014), which in general, male students tend to outperform female students in learning mathematics. The reason for contradicting the mentioned studies may be related to the research context. As mentioned in **Section 1.2** above, ITC is a unique higher education institution due to its new-student admission policy. With its strict entrance examination, the students who passed the exam and were admitted into ITC programs need to have a strong education background in mathematics and science in general. In this case, regardless of their gender, the students may possess similar mathematics learning capacities.

In addition, the research found that the students' performance at the university level differed in terms of their mathematics background during their general education. The findings provided concrete evidence that the students with a more robust mathematics background in their BacII examination tended to perform better at the university level. Enu et al. (2015) supported this finding, whose research also found that students' entry math grades played a significant role in their mathematics performance at the university level.

Students' Attitudes toward Mathematics

It was widely known that the students' attitudes towards mathematics have been a critical factor contributing to the success or failure in learning this subject. Students who have positive attitudes toward mathematics tend to perform better than those who hold negative perceptions. Concerning Objective 2 of this research, the results showed that engineering students generally had positive attitudes toward mathematics. The findings were consistent with numerous pieces of literature

(A.K. et al., 2006; Anokye-Poku & Ampadu, 2020; Mohamed & Waheed, 2011; Thapa & Paudel, 2020), whose works also found that the students' attitudes towards were seen be positive.

The study also revealed that the differences in students' attitudes about gender were not meaningful. This finding contradicted some past research work conducted by Drzewiecki & Westberg. (1997), A.K. et al., (2006), and Hargreaves et al. (2008), whose studies indicated that male students had more positive general attitudes toward mathematics compared to their female counterparts. However, these studies' trends contradicted the research conducted by Adamu & Garba. (2018) found in their study that female students held a more positive view of mathematics than boys. Despite being contradicted to previously mentioned literature, however, the finding of this study provided similar evidence to the work of Anokye-Poku & Ampadu. (2020); Karjanto. (2017); Mohamed & Waheed. (2011); Opolot-Okurut. (2005); Siregar et al. (2019); Thapa & Paudel. (2020) & Yavuz Mumcu & Aktas. (2015). These latter studies found that despite holding positive attitudes toward mathematics, their attitudes were found to be of no significant difference in terms of the students' gender.

In terms of the students' BacII Math Grades, the present study found that the students' overall attitudes toward mathematics were significantly different in terms of their BacII. However, the differences were seen only with those who got BacII Math Grade A&E. With the extended analysis for Factor 2, which is related to the students' confidence in mathematics, the result also showed the variations existed among two pairs of BacII Math Grades, A&E and B&E. In relation to these findings, Opolot-Okurut. (2005) found that schools with high performance tend to have students with high attitudes toward mathematics. Although this study did not specifically mention mathematics background, their level of knowledge before entering university life or higher grades does play a particular role in their attitudes in higher education.

Past studies (Davadas & Lay, 2018; Marchis, 2011; Orozco-Guzmán et al., 2020) have been focused on factors influencing the students' attitudes toward mathematics, but those works focused on factors, such as parental factors, teachers' factors, school factors and students' mental or emotional factors, such as self-esteem, self-efficacy and self-confidence etc. This study found that the students' background knowledge in mathematics has contributed to their attitudes toward mathematics, though it was only with their confidence in mathematics. The relationship between the students' background knowledge in mathematics and their attitudes toward mathematics presented in this study was only a surface catch. A comprehensive analysis of this may be a valuable topic for future research.

Students' Attitude and Their Achievement

It was found that two factors of the students' attitudes toward mathematics were seen to have positive relations with their mathematics performance in probabilities and statistics, despite the fact that the relations were found to be weak, $rs = .293$, for their interest in mathematics and $rs = .210$, for the students' confidence in mathematics. However, negative relationship was expressed in terms of the students' fear of mathematics, $rs = -.119$. Without specifically referring to any attitude factors, it was evidenced that the more the students feel positive about mathematics; there was tendency they will perform better in mathematics. The finding was in consistent with several literatures whose findings also indicated the positive relationships between the students' attitudes toward mathematics and their achievement in this subject (Adamu & Garba, 2018; Capuno et al., 2019; Mensah et al., 2013; Moenikia & Zahed-Babelan, 2010; Subia et al., 2018) although there was inconsistent with the strength of the relation.

Comparing the strength of the relationship between the mentioned variables, the research conducted by Capuno et al. (2019) also found similar strengths in the relationship. However, this study used a different instrument compared to the present study. Capuno et al. (2019) used a tool measuring the students study habits, which they referred to as students' attitudes, and the result revealed that the relationship was weak ($r = .227$). About this, the studies conducted by Mensah et al. (2013) and Moenikia & Zahed-Babelan. (2010) found that the relationship between the students' attitudes toward mathematics and their performance was between .419 to .455. In addition to positive relation, Subia et al. (2018) found that the link

between the students' attitudes toward mathematics was strong, $r = .792$.

It should be noted that the relationship between Factor 3 (Math-Fear) and the students' achievement in probabilities and statistics was negative. From this relationship, we could deduce that negative feelings toward mathematics will affect their learning in mathematics in general, not to mention only the probabilities and statistics courses.

5. CONCLUSION

The study concluded that the students' background knowledge in mathematics in general education played a significant role in shaping the students' performance in probabilities and statistics in higher education. It shaped their achievement, but the students' mathematics background knowledge also played a significant role in their attitudes toward mathematics in general. High achievement students in BacII mathematics performed better in the probabilities and statistics course and had more positive attitudes toward mathematics. However, the results were not conclusive because a few pairs of their BacII Math Grades contributed to the findings. Gender has no significant contribution to the two variables or constructs of study, which may be due to the study context, ITC, where male and female students had similar learning capacity or attitudes toward mathematics.

Although the magnitudes were not high, the students expressed a certain level of interest and confidence in mathematics. Together with this, the participants also had some sense of fear toward mathematics. Moreover, the results proved that all three attitude factors had weak relationships with their achievement in probabilities and statistics. The results also indicated that the more positive the students felt about mathematics, the better they tended to perform in this subject.

Concerning the strength of the relationship, we may deduce that other factors could play specific roles in shaping the students' performance in this course or probably in mathematics in general. The students' participation in their learning processes, such as classroom engagement and their involvement in assignments or classwork should also be monitored when studying factors influencing their performance. Although other factors may play their roles in shaping the students' performance in mathematics, based on literature, the students' attitudes toward this subject have been regarded as the critical determinant of the students' success.

Limitation and Further Study

It should be noted that considering the conceptual framework of this study, the relationship between the students' attitudes toward mathematics needs to be carefully monitored as this relationship did not indicate the causal relationship between the two variables. Further research should focus on the causal relationship between these two variables with careful consideration of the direction of their relation, as highlighted in Lipnevich et al. (2011). In a practical sense, we could deduce that success (or failure) in mathematics may cause mathematics attitudes or that mathematics attitudes are causing mathematics achievement Lipnevich et al. (2011). Further research should also focus on the effects of other factors on the students' mathematics achievement.

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Tong LY

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Mr. LY Tong has years of extensive experience in teaching and research in education, mathematics education, and social science. He has advanced degrees in education and mathematics. Presently, he is a full-time researcher at the Department of Educational Research, Institute of Humanities and Social Sciences, Royal Academy of Cambodia. Mr. LY Tong also has some experience in designing and developing grant research projects for government and non-government institutions.

Research Interest:

- Student' Learning and Misconception
- Mathematics Education
- Machine Learning & Data Science

Sokhey PHAUK, PhD

Personal Profile (Scan Here)

Sokkhey PHAUK received his B.Sc. in Mathematics from Royal University of Phnom Penh, Cambodia, in 2010, and later received his M.Sc. in Applied Mathematics from Suranaree University of Technology, Thailand, in 2013. In 2021, he obtained his PhD in interdisciplinary intelligent system (majoring in data science) from University of the Ryukyus, Japan. He is currently a lecturer at Department of Applied Mathematics and Statistics at the Institute of Technology of Cambodia (ITC). His currently research include data analysis, machine learning, educational data mining, and data science.

Research Interest:

- Mathematics Education, Educational Data Mining
- Machine Learning & Data Science

Soth CHEA

Personal Profile (Scan Here)

Mr. Chea Soth has rich experience in both teaching and research. With advance degree in mathematics education from Hiroshima University, Japan, Mr. Chea Soth has worked as lecturer of mathematics and researcher in PTEC. Besides teaching, he also plays significant role in supervising thesis work to his students. Moreover, he has also been involved in Strengthening Teacher Education Program in Cambodia (STEPCam) project.

Research Interest:

- Students' Misconceptions
- Mathematical Knowledge for Teaching (MKT)
- Student Learning Assessment

APPENDIX

Students' Questionnaire

Questionnaire Code: .....

Purpose:

This study aims at assessing the mathematics performance in probability and statistics of engineering students at ITC with regard to different factors such as gender, their performance at high school, and their attitude toward mathematics. This survey questionnaire is part of the data gathering. It is divided into two parts: (i) ***General Questions*** and (ii) ***Attitude toward Mathematics.***

Please note that this study is subjective in nature and there is no "right" or "wrong" answer to your choice. The analysis from this study is exclusively for research and educational purposes where privacy of your information will be kept confidential.

(Your Cooperation is Highly Appreciated.)

Part 1: General Questions

Student's ID: _____

Gender: □ Female □ Male

Your Bac II Grades:

Overall Grade	☐ A	☐ B	☐ C	☐ D	☐ E
Mathematics Grade	☐ A	☐ B	☐ C	☐ D	☐ E

Part 2: Attitude toward Mathematics

How do you agree to the following statements?

Item	Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1	I always prepare myself well for my math classes, tests and quizzes.	☐	☐	☐	☐	☐
Q2	I often motivate myself to get a good score in math.	☐	☐	☐	☐	☐
Q3	I always pay full attention during my math classes.	☐	☐	☐	☐	☐
Q4	Mathematics is important for my study and future career.	☐	☐	☐	☐	☐
Q5	I feel confident in my abilities to solve mathematics problems.	☐	☐	☐	☐	☐
Q6	I can understand my math teacher's explanation easily.	☐	☐	☐	☐	☐
Q7	I spend lots of time to practice mathematics or work on assignments.	☐	☐	☐	☐	☐
Q8	I would prefer to write a math assignment than write an essay.	☐	☐	☐	☐	☐
Q9	I believe studying of math helps me with problem solving in other subjects.	☐	☐	☐	☐	☐
Q10	I like to solve new problems in	☐	☐	☐	☐	☐

	mathematics.					
Q11	I am happier in a math class than in any other classes.	☐	☐	☐	☐	☐
Q12	It would not bother me at all to take more math courses.	☐	☐	☐	☐	☐
Q13	I have usually been at ease during math test.	☐	☐	☐	☐	☐
Q14	I have usually been at ease during math course.	☐	☐	☐	☐	☐
Q15	I often feel tense and bored in my mathematics class.	☐	☐	☐	☐	☐
Q16	I always feel nervous in quizzes or exams of math.	☐	☐	☐	☐	☐
Q17	I don't like working on the homework given by my mathematics teacher.	☐	☐	☐	☐	☐
Q18	I am not eager to participate in discussions that involve mathematics.	☐	☐	☐	☐	☐
Q19	I get a sinking feeling when I think of trying hard math problems.	☐	☐	☐	☐	☐
Q20	My mind goes blank and I am unable to think clearly when working mathematics.	☐	☐	☐	☐	☐
Q21	Mathematics makes me feel uneasy and confused.	☐	☐	☐	☐	☐

Math Score:

Probability and Statistics