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IMPACT OF MATHEMATICS ON THE THEORETICAL COMPUTER SCIENCE COURSE UNITS IN THE GENERAL DEGREE PROGRAM IN COMPUTER SCIENCE AT SRI LANKAN STATE UNIVERSITIES

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ABSTRACT

Aim/Purpose	The purpose of this study is to identify how Advanced level Mathematics and Mathematics course units offered at university level do impact on the academic performance of theoretical Computer Science course units.
Background	In Sri Lankan state universities, students have been enrolled only from the Physical Science stream to do a degree program in Computer Science. In addition to that, universities have been offering some course units in Mathematics to provide the required mathematical maturity to Computer Science undergraduates. Despite of this it is observed that the failure rates in fundamental theoretical Computer Science course units are much higher than other course units offered in the general degree program every year.
Methodology	Academic records comprised of all 459 undergraduates from three consecutive batches admitted to the degree program in Computer Science from a university were considered for this study.
Contribution	This study helps academics in identifying suitable curricula for Mathematics course units to improve students' performance in theoretical Computer Science courses.
Findings	Advanced level Mathematics does not have any significant effect on the academic performance of theoretical Computer Science course units. Even though all Mathematics course units offered were significantly correlated with academic performance of every theoretical Computer Science course unit, only the Discrete Mathematics course unit highly impacted on the academic performance of all three theoretical Computer Science course units. Further this study indicates that the academic performance of female undergraduates is better than males in all theoretical Computer Science and Mathematics course units.

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Future Research Identifying other critical success factors contributing to the students' academic performance of the theoretical Computer Science through empirical studies

Keywords theoretical computer science courses, academic performance, discrete mathematics

INTRODUCTION

BACKGROUND OF THE STUDY

Due to a huge demand of Computer Science professionals in early 90's, Sri Lankan universities started to offer Computer Science as a subject at faculty level (Faculty of Science) with Mathematics and another subject from the basket of Physics, Chemistry, and Statistics. As computer science has grown and matured, and some of its technology dependent fields became independent disciplines of their own, universities started to establish new departments or faculties to offer undergraduate degree programs in Computer Science at the beginning of the 21st century. As a consequence the number of courses in mathematics has been decreased in this Computer Science curriculum. This badly affects the Mathematical maturity required for students to learn, understand, and appreciate the fundamental theories of computer science.

University Grants Commission (UGC) has been admitting students to state universities in Sri Lanka to follow a degree program in Computer Science only from Physical Science stream based on the Z-score of a very competitive advanced level (A/L) examination in which students must have obtained at least "C" grade in Mathematics among three subjects. At the same time there has been a pressure to make Computer Science curriculum less Mathematical in order to give opportunity for students from the Biological Science stream also. According to the literature, no studies have been conducted to assess the impact of A/L Mathematics on the academic performance on theoretical Computer Science courses at the degree level in Universities of Sri Lanka.

The importance of mathematics in learning computer science has been highlighted in ACM Computing Curricula 2001 (ACM (CS 2001), 2001), which emphasizes, "Theory is one of the three primary foundations of computer science. It depends on mathematics for many of its definitions, axioms, theorems, and proof techniques. In addition, mathematics provides a language for working with ideas relevant to computer science, specific tools for analysis and verification, and a theoretical framework for understanding important computing ideas." It seems natural to expect that by the time students get to the theoretical courses they have received the adequate mathematical background that will allow them to handle these courses without any difficulty.

There has been a debate on what would be the appropriate Mathematical background needed for a degree program in Computer Science. Since Computer Science curriculum is heavily loaded already, it would be impossible to introduce additional new courses in Mathematics. In spite of this it is important to take actions and find an acceptable and reasonable solution to the problem.

PROBLEM IDENTIFICATION AND OBJECTIVE OF THE STUDY

Most of the state universities in Sri Lanka established a new Computer Science department under the faculty of Science to offer a degree program in Computer Science in addition to the existing degree programs in Science. Here Computer Science students have to take some Mathematics course units offered by the department of Mathematics in their first and second year of studies in a rigorous way with other students who are doing Mathematics as their main subject.

Up to now only two state universities have established a new faculty to offer a degree program in Computer Science. The faculty has to design some course units in Mathematics in order to give the required Mathematical maturity for students to follow the theoretical Computer Science courses with confidence. Also the faculty has to find their own staff to teach these Mathematics units. Students who are entering to this faculty are also coming with the mindset that they do not have to follow any serious Mathematics courses in the degree program in Computer Science. For this study, one of the leading state universities among these two state universities was selected. Around 175 students are entering to this university to do a degree program in Computer Science every year.

Theoretical Computer Science Courses are heavily math-flavored. To be able to handle these courses, students require all the Mathematical abilities of rigorous reasoning, abstract thinking, algorithmic thinking, and precision because textbooks are written in formal mathematical language and all concepts are defined formally, all results have mathematical proofs, all algorithms and techniques are presented with the help of formal mathematical notation. Based on Mathematical abilities theoretical Computer Science courses can be categorized into two groups:

Group I: Heavily math-flavored fundamental theoretical Computer Science courses such as Foundations of Computer Science, Automata Theory, and Theory of Computation come under this group. These courses need strong rigorous mathematical reasoning ability together with other mathematical abilities to learn, understand, and appreciate the theories presented in these courses.

Group II: Courses in data structures & algorithms and courses in computer programming come under this group. These courses need strong Mathematical skills such as abstraction ability and algorithmic thinking but do not require strong rigorous mathematical reasoning skill. These courses are generally offered in all degree programs in computing.

Table 1: Course units that have more than 10% overall failure rate

Course unit	2011/2012 Failure rate	2012/2013 Failure rate	2013/2014 Failure rate	Overall Failure rate
1. Programming Language Concepts	**42.9%**	**46.6%**	**28.0%**	**38.9%**
2. Foundations of Computer Science	**36.5%**	**39.4%**	**28.7%**	**34.8%**
3. Automata Theory	**22.6%**	**19.0%**	**43.6%**	**29.0%**
4. Database II	**27.4%**	**32.6%**	**14.1%**	**24.5%**
5. Mathematical Methods I	**17.5%**	**7.4%**	**35.7%**	**20.9%**
6. Statistics	**10.3%**	**20.3%**	**22.9%**	**17.8%**
7. Programing II	**18.2%**	**10.3%**	**13.7%**	**14.1%**
8. Software Engineering II	**22.4%**	**9.0%**	**9.2%**	**13.6%**
9. Programing IV	**14.9%**	**24.2%**	**2.1%**	**13.3%**
10. Database 1	**20.8%**	**5.1%**	**12.2%**	**12.8%**
11. Computer Networks I	**9.6%**	**14.9%**	**13.5%**	**12.6%**
12. Computer Systems	**15.2%**	**11.7%**	**10.8%**	**12.5%**
13. Software Engineering I	**12.2%**	**10.3%**	**14.5%**	**12.3%**
14. Discrete Mathematics	**16.3%**	**11.7%**	**7.9%**	**11.9%**
15. Data Structures and Algorithms II	**2.7%**	**5.1%**	**25.7%**	**11.1%**
16. Data Structures and Algorithms III	**16.7%**	**10.5%**	**3.9%**	**10.2%**
17. Mathematical Methods III	**7.0%**	**14.5%**	**9.2%**	**10.1%**

It is observed that the failure rates in theoretical Computer Science course units of Group I, such as Foundations of Computer Science, Programing Language Concepts and Automata Theory are very high every year compared to all other courses offered in the first and second year of studies at a general degree program in Computer Science at the Sri Lankan state Universities. Table 1 shows the percentage of the students those failed (less than 50 marks) in course units which have more than 10% overall failure rate in the decreasing order of failure rate from the last three batches out of twenty five compulsory course units offered in the first and second year of studies for the degree program in Computer Science at the University. Course units in the third year of study were not considered because the second semester of the third year of study is fully allocated for industry placement and the first semester of the third year of study has several optional course units to choose.

Several studies have been conducted in foreign universities to establish the importance of Mathematics in Computer Science & Software Engineering education (e.g. Asabere, Acakpovi, Torgby, Mends-Brew, & Ampadu, 2016; Devlin, 2001; Sidbury, 1986). Also a number of studies have been carried out to show the relationship between success in Mathematics and computer programming & algorithm courses (Group II) (e.g., White, 2003; White, & Sivitanides, 2003).

There is very little information available in the literature regarding why students need strong mathematical background to be successful in fundamental theoretical Computer Science courses. Paulson (2002) pointed out that when he taught Theory of Computing in one of the universities in USA with significantly less mathematical curriculum, the grade in Theory of Computing of 60.9% students was at least one letter grade lower than other relatively hard courses (group II). When he taught Theory of Computing in another university with mathematically charged CS curriculum, he could not see any significant difference.

The main objective of this study is to investigate whether and how Mathematics courses being offered impact on students' academic performance on fundamental theoretical Computer Science courses (Group I) individually and collectively and then to recommend appropriate modifications that could be made to the existing Mathematics courses in order to improve students' performance in fundamental theoretical Computer Science course units.

Because of the biased stereotyped belief that Mathematics is meant for boys and Biology is meant for girls, the physical science stream is dominated by males. Due to this more than 70% of the students who have been admitted to do a degree program in Computer Science at this university are males (e.g. Camp, 1997). This study also compares students' academic performance in Mathematics and theoretical Computer Science courses gender wise.

Brief Description about the Mathematics and Theoretical Computer Science Course Units (Group I) Considered in this Study

Mathematical Methods – I [MM I] (Offered in first year first semester):

This course is similar to an elementary Real Analysis (calculus) course in continuous Mathematics offered by department of Mathematics for the Physical Science students at the first year of study. This covers the concepts of limit, continuity, and differentiability of real functions together with first order ordinary differential equations.

Mathematical Methods – II [MM II] (Offered in first year second semester):

This is a common elementary course in algebra generally offered for the Physical Science students at the first or second year of study. This course introduces finite dimensional vector spaces, liner transformations defined on them, basis of vector spaces, matrices, and its applications.

Discrete Mathematics [DM] (Offered in first year second semester):

Discrete Mathematics is the backbone of Computer Science. This course covers propositional and predicate logic, arguments, and proof techniques under logic together with basic discrete structures sets, relations, and functions.

Foundations of Computer Science [FCS] (Offered in first year second semester):

This course emphasizes an analytical reasoning approach to the study of models of computation, algorithms and their complexity, automata and game theory. Emergent areas such as natural computation and quantum computation are also introduced.

Mathematical Methods III [MM III] (Offered in second year second semester):

This course introduces some basic concepts in three different areas: calculus, algebra, and number theory. This course initially covers some numerical methods used in calculus together with convergence of sequence and series of real numbers. Then it provides an introduction to number theory including modular arithmetic. Finally, this introduces discrete structures groups, rings, and fields.

Programming Language Concepts [PLC] (Offered in second year second semester):

This course provides the key features of programing languages. It covers programing domains, language evaluation criteria, influences on language design, implementation methods, syntax and semantics of programing languages, properties of variables, control structures, data types, sub-programs, and object oriented programing.

Automata Theory [AT] (Offered in second year second semester):

This course introduces students to the mathematical foundations of computation including automata theory, the theory of formal languages and grammars, and the notions of algorithm, decidability, and computability.

METHODOLOGY

SAMPLING AND PROCEDURE

The participants for the study comprised of all 459 undergraduates from three consecutive batches admitted to the degree program in Computer Science offered by the University. Among these students 71.2% were males and 28.8% were females with average Z score of M = 1.60, SD = 0.126 obtained in General Certificate Education in Advanced Level (GCE (A/L)) examination. Among these registered undergraduates, 38.8% of students had "A" grade, 46.8% had "B" grade and 14.4% had "C" grade in combined mathematics subject at GCE (A/L) examination. The majority of the students (93.9%) did the GCE (A/L) examination in Sinhala medium, followed by English medium (3.3%) and Tamil medium (2.8%). Participants' demographic and educational characteristics considered for this study across three academic years are summarized in Table 2.

Academic performance data on all courses offered in the first and second year of studies were collected for all 459 undergraduates from the academic records (database) of the Department of Examination. Scores of each course unit ranges from 0 to 100. If a student was absent for the final examination of a course unit, his or her score in that course unit was considered as missing data in the analysis.

DATA ANALYSIS

IBM SPSS Statistics 23 was used for the statistical analysis of the data. The whole set of data comprising three academic years was analyzed using stepwise regression model in order to select the best grouping of predictor variables that account for the most variance in the outcome. Thus, stepwise regression models were fitted for the data to assess the impact and importance of mathematics course units on the performance of each theoretical computer science course unit (Group I) offered in first two years of study. Analysis of variance was used to explore the effect of Combined Mathematics at the GCE (A/L) on the performance of Mathematics courses and theoretical computer science courses offered in the first and second year of studies. Table 3 shows the description of all the variables considered in this study. Independent sample t-test was used to examine the gender differences on the academic performance on mathematics courses and theoretical computer science courses offered in the first and second year of studies.

Table 2: Participants' demographic and educational characteristics across the three academic years

Characteristics	Academic Year		Frequency	Percentage
Gender	2011/2012	Male	115	74.7%
		Female	39	25.3%
	2012/2013	Male	107	74.8%
		Female	36	25.2%
	2013/2014	Male	104	64.2%
		Female	58	35.8%
Grade on Combined Mathematics at GCE (A/L) Examination	2011/2012	A	69	44.8%
		B	63	40.9%
		C	22	14.3%
	2012/2013	A	54	37.8%
		B	62	43.4%
		C	27	18.9%
	2013/2014	A	55	34.0%
		B	90	55.6%
		C	17	10.5%

Table 3: Description of variables used in the study

Name of the variable	Nature of the variable	Measurement of the variable	Scale of Measurement
AL_Grade	Predictor	Performance in Combined Mathematics at the G.C.E (A/L)	Grades: A, B, C
MM I	Predictor	Performance in **Mathematical Methods I (MM I)** course unit	Score: 0 - 100
DM	Predictor	Performance in **Discrete Mathematics (DM)** course unit	Score: 0 - 100
MM II	Predictor	Performance in **Mathematical Methods II (MM II)** course unit	Score: 0 - 100
MM III	Predictor	Performance in **Mathematical Methods III (MM III)** course unit	Score: 0 - 100
FCS	Criterion	Performance in **Foundations of Computer Science (FCS)** course unit	Score: 0 - 100
PLC	Criterion	Performance in **Programming Language Concepts (PLC)** course unit	Score: 0 - 100
AT	Criterion	Performance in **Automata Theory (AT)** course unit	Score: 0 - 100
Gender	Predictor	Gender of an undergraduate	Male, Female

RESULTS AND DISCUSSION

EFFECT OF COMBINED MATHEMATICS ON THE ACADEMIC PERFORMANCE OF MATHEMATICS COURSES AND THEORETICAL COMPUTER SCIENCE COURSES

A series of one-way between-groups analysis of variance were conducted to explore the effect of performance of combined mathematics at GCE (A/L) on the performances of mathematics courses (MM I, DM, MM II, and MM III) and theoretical computer science courses (FCS, PLC, and AT) offered in the first and second year of studies of the degree program in Computer Science at this university. Participants were divided into three groups according to their grades of the Combined Mathematics obtained at the GCE (A/L) examination (Group 1: Grade A, Group 2: Grade B, and Group 3: Grade C). The results of Analysis of Variance shown in Table 4 indicated that there was no statistically significant differences among the three groups on the performances of the mathematics courses and theoretical computer science courses at the 5% level significance.

Table 4: Descriptive Statistics and results of ANOVA

Courses offered in 1st and 2nd Year	Grade in Combined Mathematics			Overall	F-value	p-value
	A	B	C			
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*		
Mathematical Methods I (MM I)	59.15 (11.97)	56.16 (12.47)	56.45 (13.04)	57.36 (12.42)	F(2, 433) = 2.890	0.057
Discrete Mathematics (DM)	65.71 (14.81)	64.56 (14.86)	65.63 (13.42)	65.17 (14.62)	F(2, 433) = 0.323	0.724
Mathematical Methods II (MM II)	72.70 (12.56)	72.24 (13.11)	69.83 (12.69)	72.07 (12.84)	F(2, 431) = 1.201	0.302
Foundation of Computer Science (FCS)	52.26 (15.32)	52.29 (14.74)	57.06 (12.82)	53.00 (14.77)	F(2, 420) = 2.880	0.057
Mathematical methods III (MM III)	64.52 (12.19)	61.70 (13.40)	61.44 (10.81)	62.77 (12.61)	F(2, 413) = 2.626	0.074
Programming Language Concept (PLC)	52.75 (18.20)	53.10 (17.15)	57.66 (15.93)	53.65 (17.44)	F(2, 410) = 1.958	0.142
Automata Theory (AT)	56.98 (15.15)	54.29 (15.60)	58.44 (15.76)	55.96 (15.50)	F(2, 418) = 2.306	0.101

Up to the advanced level, students are mostly covering the routine manipulations of formulas to solve standard problems in Mathematics. Even though students are enrolled for degree programs in Computer Science from the advanced level Physical Science stream, the lack of experience in rigorous reasoning with purely abstract objects and structures in the A/L Mathematics may be considered as one of the important reasons for their poor performance in theoretical Computer Science courses.

It can been seen from the Table 4 that 15% of the students who got a 'C' grade in the A/L Combined Mathematics perform little better than the 39% of the students who got an 'A' grade in all three theoretical Computer Science courses. This clearly indicates that there is a reasonably large number of students, who did well at the advanced level examination, are following the degree program with less interest. This is due to the frustration caused by the fact that they did not get the degree program (Engineering)/ university they desired. Such students can be identified using available data and have to be motivated through academic counseling.

Impact of Mathematics Course Units on the Academic Performance of Foundation of Computer Science (FCS) Course Unit

Stepwise linear regression was performed to assess the ability of three mathematics courses to predict the performance of FCS. The predictors were the scores of the three mathematics courses, MM I, MM II, and DM, while the criterion variable was the scores of FCS. Table 5 summarizes the results of regression analysis. As can be seen in Table 5 each mathematics course scores is positively and significantly correlated with the criterion, indicating that those with higher scores on these variables tend to have higher score on FCS.

The results of stepwise regression analysis indicates DM was entered at step 1 and it was significantly related to the scores of FCS with R 2 = 42.9%, F (1, 408) = 306.16, p < .000. The overall model to predict the scores of the FCS was fitted at step 2 with the entry of one additional predictor, MM II. The total variance explained by the final model with the two predictors DM and MM II fitted at step 2, as a whole was 44.4%, F (2, 407) = 162.54, p < .000. Of these two predictors, DM made the largest unique contribution (B = .564), and MM II, although statistically significant, made much smaller contribution (B = .182). MM I did not make a significant unique contribution in predicting the scores of FCS. Further it can be concluded that the only useful predictor is the DM. It alone accounted for 42.9% of the variance in the scores of FCS, while the other predictor, MM II contributed only an additional 1.5% (0.444 – 0.429 = 0.015 x 100 = 1.5%).

Table 5: Bivariate Correlations and results from the stepwise regression analysis

Variable	Correlation with FCS	Results of Stepwise Regression at Step 1			Results of Stepwise Regression at Final Step		
		Regression Coefficients			Regression Coefficients		
		B	SE *B*	*β*	*B*	SE *B*	*β*
DM	.655***	*.663*	*.038*	*.655****	*.564*	*.048*	*.557****
MM II	.504***				*.182*	*.054*	*.158***
MM I	.400***						
Model Summary		**Model 1**			**Overall Model**		
F for Model		*F(1, 408) = 306.16****			*F(2, 407) = 162.54****		
R^2		*.429*			*.444*		
Adjusted R^2		*.427*			*.441*		
Change in R^2		*.429*			*.015*		
F for change in R^2		*306.16****			*11.24***		

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Impact of Mathematics Course Units on the Academic Performance of Programming Language Concept (FCS) Course Unit

Stepwise linear regression was performed to evaluate how well the mathematics courses offered in the first two years predicted the performance of PLC. The predictors were the scores of the four mathematics courses, MM I, MM II, DM, and MM III, while the criterion variable was the scores of PLC. Table 6 summarizes the results of regression analysis.

As can be seen in Table 6, each mathematics course scores is positively and significantly correlated with the criterion, indicating that those with higher scores on these variables tend to have higher scores on PLC. Two models were fitted by the stepwise regression procedure to predict the scores of PLC. DM was selected as the first predictor from the four predictors at step 1 and then MM III was added with DM at step 2 to predict the scores of PLC. Both MM I and MM II were not selected as predictors in predicting the performance of PLC.

The results of stepwise regression analysis presented in Table 6 indicates that DM was significantly related to the scores of PLC with R^2 = 31.1%, F (1, 382) = 172.52, p < .000 and the final model with the two predictors DM and MM III significantly explained the variation in the scores of PLC, as a whole was 38.0%, F (2, 381) = 116.51, p < .000. Of these two predictor, DM made the largest unique contribution (B = .543) in predicting the scores of PLC, although MM III also made a considerable unique contribution (B = .415) in predicting the scores of PLC. Both MM I and MM II did not make a significant contributions in predicting the scores of PLC. Further it can be concluded that the most influential predictor is the DM. It alone accounted for 31.1% of the variance of the scores in PLC, while the other predictor, MM III contributed an additional 6.9% of the variance.

Table 6: Bivariate correlations and results from the stepwise regression analysis

Variable	Correlation with PLC	Results of Stepwise Regression at Step 1			Results of Stepwise Regression at Final Step		
		Regression Coefficients			Regression Coefficients		
		B	SE *B*	*β*	*B*	SE *B*	*β*
DM	*.558****	*.720*	*.055*	*.558****	*.543*	*.059*	*.421****
MM III	*.490****				*.415*	*.064*	*.295****
MM II	*. 426****						
MM I	*.354****						
Model Summary		**Model 1**			**Overall Model**		
F for Model		*F(1, 382) = 172.52****			*F(2, 381) = 116.51****		
R^2		*.311*			*.380*		
Adjusted R^2		*.309*			*.376*		
Change in R^2		*.311*			*.069*		
F for change in R^2		*172.52****			*41.99****		

*$p < 0.05$, **$p < 0.01$, *** $p < 0.001$.

Impact of Mathematics Course Units on the Academic Performance of Automata Theory (AT) Course Unit

Stepwise linear regression analysis was conducted to evaluate how do MM I, MM II, DM, and MM III influence the performance of AT. Table 7 summarizes the results of regression analysis. As can be seen in Table 7, scores of each mathematics course is positively and significantly correlated with AT, indicating that those with higher scores on these variables tend to have higher scores on AT.

Three models were fitted by the stepwise regression procedure to predict the scores of AT. DM was selected as the first predictor at step 1 and MM III was added with DM at step 2. The multiple regression model at step 2 with the two predictors DM and MM III produced R^2 = .376, F (2, 377) = 113.44***, change in R^2 = .0.087 with F (1, 377) = 52.71*** indicating that these two predictors significantly explained 37.6 % of the variance in the scores of AT in which DM alone accounted for 28.8% of the variance and MM III contributed an additional 8.8% of the variance.

The overall model to predict the scores of AT arrived at step 3 with the three predictors DM, MM III, and MM I significantly explained the variation in the scores of AT, as a whole was 39. 9% in which 2.5% of the variations in the scores of Automata theory was explained by MM I. Of these three predictors, MM III made the largest unique contribution (B = .363) followed by DM (B = .316) and MM I (B = .226) in predicting the scores of AT. MM II did not make a significant contribution in predicting the scores of Automata theory. Further it can be concluded that the most influential predictor is the MM III followed by DM, and MM I.

Table 7: Bivariate correlations and results from the stepwise regression analysis

Variable	Correlation with AT	Results of Stepwise Regression at Step 1			Results of Stepwise Regression at Final Step		
		Regression Coefficients			Regression Coefficients		
		B	SE *B*	*β*	*B*	SE *B*	*β*
DM	*.537****	*.576*	*.047*	*.537****	*.316*	*.054*	*.295****
MM III	*.516****				*.363*	*.055*	*.305****
MM I	*.456****				*.226*	*.059*	*.184****
MM II	*.336****						
Model Summary		**Model 1**			**Overall Model**		
F for Model		$F(1, 378) = 153.21$***			$F(3, 376) = 83.33$***		
R^2		.288			.399		
Adjusted R^2		.287			.395		
Change in R^2		.288			.023		
F for change in R^2		153.21***			14.81***		

*$p < 0.05$, **$p < 0.01$, *** $p < 0.001$.

Discussion on Impact of Mathematics Course Units on the Students' Academic Performance of Theoretical Computer Science Course Units

Mathematical Methods – I

This course is generally offered when the CS degree program is housed in the engineering faculty or in the Science faculty. This course includes far more material than is generally needed for any of the CS courses offered in the general degree program. The main purpose of offering this course is to develop mathematical maturity and clarity of mathematical thinking at the beginning of the degree program. Even though this course is positively correlated to all three theoretical CS courses, it is not significantly contributed to the academic performance of any one of the three theoretical CS course units.

Mathematical Methods – II

This is a common elementary course in algebra generally offered for the Physical Science students at the first or second year of study. Even though most of the contents of this course are not necessarily a requirement for all CS courses offered in the first and second year of studies, this is very useful for some advanced courses such as computer graphics offered for the Honors degree program in the fourth year of study. That is why, even though this course is positively correlated to all three theoretical CS courses, it did not significantly contribute to the academic performance of all three theoretical CS courses.

Discrete Mathematics

Discrete Mathematics is the backbone of Computer Science. Almost all the undergraduate degree programs in Computer Science include this course in their curricula. This course includes materials such as propositional & predicate logic and proof techniques which are essential for understanding of theoretical CS courses (Group I). Statistical relationships indicate that Discrete Mathematics course unit not only positively correlated to all three theoretical CS courses but also significantly contributed to the academic performance of all three theoretical CS courses.

Mathematical Methods – III

Basic numerical methods taught in this course are not directly relevant to the theoretical CS courses PLC or AT, which are offered parallel with this course in the second semester of the second year of study. This course contains also some sections from discrete Mathematics such as discrete structures groups, rings, and fields together with basic number theory (modular arithmetic). Due to this we can say that Discrete Mathematics and Mathematical Methods – III are not totally independent. Note that even though Mathematical Methods – III was selected as the second predictor in the multiple regression model at step 2 with Discrete Mathematics, it was identified as most influential predictor in predicting the scores of Automata Theory than Discrete mathematics.

To understand definitions and theorems about the concepts of limits, continuity, and differentiability of real functions that are covered in Mathematical Methods I, the knowledge of logic (propositional and predicate) and proof techniques are very important, which are not covered in A/L Mathematics. Also good basic knowledge in logic is very useful for the two course units Data Structure and Algorithms I, and Programming I offered in the first semester of the first year of study. So, it would be very useful for students, if we could offer Discrete Mathematics in the first semester and offer the course unit Mathematical Methods- I after it.

As it was mentioned in the ACM guidelines for the CS curricular (ACM CS2013, 2013) that courses in calculus and algebra include far more material in these areas than is generally needed for most of the Computer Science under graduate courses. That is why ACM CS2013 only specifies mathematical requirements from Discrete Mathematics that are directly relevant for the large majority of all Computer Science undergraduates. Basic counting techniques (Combinatory), graph theory, and elementary number theory are three topics among the six topics from Discrete Mathematics, recommended by ACM CS2013 that are not covered in the existing curricular. So, it is highly recommended to offer another two credits course in Discrete Mathematics covering necessary items from topics counting techniques, elementary number theory, and graph theory in the second semester of the first year of study. Basic theorems covered in these areas provide the much needed experience of rigorous Mathematical reasoning skills with purely abstract objects and discrete structures which is essential for understanding theoretical Computer Science Courses.

Only around 10% of the students are selected at the end of the second year of study to do an honors degree program of four year duration in Computer Science based on their academic performance in the first and second year of studies. Mathematics course units covering calculus and algebra from the continuous Mathematics can be moved to third year of study as optional courses. So, students who have been selected to do an honors degree in Computer Science of four year duration or students who are willing to do a higher studies in Computer Science can take these courses if they want. Some technology dependent Computer Science courses that are very useful for the majority of the general degree students (90%), who are going to industry as programmers or software engineers, can be introduced in the first and second year of studies.

Gender Difference on the Students' Academic Performance of Mathematics Courses and Theoretical Computer Science Courses

A series of Independent samples t-tests were conducted to explore the gender difference on the academic performances of four mathematics course units (MM I, DM, MM II, and MM III) and three theoretical computer science course units (FCS, PLC, and AT) offered in the first and second year of studies of the degree program in Computer Science at this University. Results of Independent samples t-tests are summarized in Table 8. Even though the percentage of female students entering to this university to do a degree in Computer Science is less than 30%, statistical relationships shown in Table 9 show that their academic performance in Mathematics and theoretical Computer Science course units are significantly higher than that of males.

Table 8: Descriptive Statistics and results of Independent samples t - test

Courses offered in 1st and 2nd Year	Gender		t-value	p-value
	Male	Female		
	M (SD)	*M (SD)*		
Mathematical Methods I (MM I)	56.33 (12.52)	59.87 (11.86)	t(434) = - 2.719	0.007**
Discrete Mathematics (DS)	62.05 (14.54)	72.67 (11.85)	t(434) = - 7.320	0.000***
Mathematical Methods II (MM II)	69.42 (13.09)	78.32 (09.76)	t(432) = - 6.945	0.000***
Foundation of Computer Science (FCS)	50.21 (14.59)	59.57 (13.05)	t(421) = - 6.223	0.000***
Mathematical methods III (MM III)	60.20 (11.84)	68.95 (12.31)	t(414) = - 6.734	0.000***
Programming Language Concept (PLC)	52.21 (17.30)	56.95 (17.39)	t(411) = - 2.554	0.011*
Automata Theory (AT)	54.31 (15.36)	60.01 (15.16)	t(419) = - 3.463	0.001**

Table 9: Gender difference in students' academic performance

Course unit	Students' performance							
	Marks < 40		$40 \leq marks < 70$		Marks ≥ 70		Total	
	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N	Female N
MM - I	27 (8.7%)	3 (2.4%)	236 (76.4%)	94 (74%)	46 (14.9%)	30 (23.6%)	309	127
DS	24 (7.8%)	1 (0.8)	180 (58.4%)	55 (43%)	104 (33.8%)	72 (56.3%)	308	128
MM - II	6 (2%)	1 (0.8%)	137 (44.9%)	17 (13.2%)	162 (53.1%)	111 (86.0%)	305	129
MM - III	13 (4.4%)	1 (0.8%)	218 (74.0%)	56 (45.9%)	63 (21.4%)	65 (53.3%)	294	122
FCS	67 (22.6%)	7 (5.6%)	200 (67.3%)	91 (72.2%)	30 (10.1%)	28 (22.2%)	297	126
PLC	69 (24.0%)	23 (18.4%)	161 (55.9%)	66 (52.8%)	58 (20.1%)	36 (28.8%)	288	125
AT	46 (15.4%)	9 (7.4%)	198 (66.2%)	78 (63.9%)	55 (18.4%)	35 (28.7%)	299	122

CONCLUSION AND RECOMMENDATIONS

Discrete Mathematics is the only course unit among the four Mathematics course units offered by the faculty that is significantly contributing to the academic performance of all three fundamental theoretical Computer Science course units. Two Mathematics course units Mathematical Methods I & II covering sections mainly from continuous Mathematics are not significantly contributing to the academic performance of all three fundamental theoretical Computer Science course units. So, by introducing more topics from Discrete Mathematics that have not been covered in the available Mathematics course units, students' academic performance can be improved in theoretical Computer Science courses.

Even though there was no significant difference statistically among the three groups of students (students who got grades "A", "B", & "C" in the Advanced level Mathematics) on the performance in the mathematics courses and theoretical computer science courses at the 5% level significance, there is no way to verify that the entry requirement of at least "C" grade in Mathematics from the advanced level (A/L) examination from the Physical Science stream is necessary for a degree program in Computer Science. However, since advanced level Mathematics is not a pre-request for Discrete Mathematics course units, as a trial, a few students can be recruited from the advanced level Biological stream also. Since the Biological stream is dominated by female students, this will help to improve the gender balance in the Computer Science degree program.

RECOMMENDATIONS

- Offer the existing two credit course unit in Discrete Mathematics in the first semester of the first year of study.
- Offer an additional two credit course unit in Discrete Mathematics covering necessary elements in number theory, counting techniques, and graph theory in the second semester of the first year of study.
- Move Mathematics course units covering calculus and algebra from continuous Mathematics to third year of study as an optional courses.
- Recruit at least twenty five students from the Biological Science stream to see how they are performing at the general degree program in Computer Science.

FUTURE RESEARCH

At present, only around 40% of the total variance of the students' academic performance in all three fundamental theoretical Computer Science course units is explained by the four Mathematics course units offered. After making necessary changes in the curricula of the existing Mathematics course units, we have to reassess the contribution of every Mathematics course unit in predicting the academic performance of theoretical Computer Science courses. Also other critical success factors contributing to the students' academic performance of the theoretical Computer Science courses have to be identified through empirical studies.

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