The effects of preparatory year courses on students' performance in first calculus courses at university: The case of KFUPM

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Abstract

This paper presents the results of a longitudinal study conducted to investigate the effect of preparatory-year programme courses on students' performance in first calculus course. Another variable included in the study is the role of the semester in which students take the first calculus courses. The data consists of grade records of more than two thousands students tracked over seven semesters, and comes from bilingual Arab students studying at an English medium university. Analysis of this data reveals that all the variables contribute with varying degrees in explaining students' performance in first calculus courses. The implications of this finding for academic policy are discussed.

Background of the study

English language is gradually becoming the main language of instruction in higher education institutions within the Middle East. The trend is much more in area of sciences, medical, and engineering courses. However, the Arabic language remains the main language of instruction at the primary and secondary levels. At the university entry level, different Middle Eastern universities use different programmes to bridge the gap that this language switch may cause. The most common approach is a one-year preparatory programme. In addition to bridging the language barrier, the programme also aims at creating a conducive atmosphere for a smooth transition from secondary school to university.

King Fahd University of Petroleum and Minerals (KFUPM) is one of a few universities in Saudi Arabia in which the language of instruction is officially English. Consequently, all students admitted to KFUPM are required to complete a one-year preparatory programme before starting their undergraduate studies. This programme mainly consists of two courses of intensive English language instruction (ENGL 001

and ENGL 002), and a review of some basic secondary school mathematics comprising MATH 001 and MATH 002. In addition, students take courses related to graphics, a mechanical engineering workshop, and physical education during the preparatory year.

According to the Undergraduate Bulletin of KFUPM (2001), the main aim of the preparatory-year programme is to prepare students for undergraduate study, especially with regard to the new language of instruction.

The preparatory year programme at KFUPM is a two-semester programme. However, students are given a maximum of three semesters to complete the programme. The final grades earnt by the students in this programme are not considered in the calculation of the students' cumulative grade point average (CGPA) for the undergraduate programme. Nevertheless, the grades are recorded in the students' transcript together with the semester grade point average (GPA) and CGPA. More notably, a student's performance on the preparatory year programme is largely considered as a predictor of his success in the undergraduate programme (Al-Doghan, 1985).

It should be noted that though KFUPM is a science and engineering oriented university, it is not automatic for all admitted students to secure a place in engineering and computer science courses after 'successfully' completing the preparatory-year programme. For a student to go for any academic programme of his choice, he has to meet some minimum entry requirement based on the preparatory-year mathematics and English courses.

After passing the preparatory-year courses, students follow two different mathematics strands. Those students posted to the college of sciences, engineering, and computer sciences are required to take a more rigorous mathematics strand which begins with Calculus I, while others go for a different set of mathematics courses.

Our focus in this study is on students taking the Calculus I strand. The reason for choosing Calculus I is because it is largely considered as the backbone of the calculus series. On the other hand, the typical calculus sequence of courses is considered the nucleus of modern mathematics and vital for any science and engineering related courses, in which KFUPM specialises.

As in many other college algebra and pre-calculus courses, the aim of preparatory mathematics (MATH 001 and 002) at KFUPM is to prepare students for these calculus courses. However, not much is known about the level of students' preparedness for the calculus series after completing the preparatory-year programme. Therefore, the aim of this paper is to examine the effect of the four major preparatory-year courses (ENGL 001 and 002, MATH 001 and 002) on students' performance in the first calculus course at KFUPM. In addition, we intend to investigate the effect of the semester in which students take Calculus I.

Method

The participants whose grades formed the data of this study were male students with an average age of 19 years, mostly in the first year of university life after the completion of their preparatory-year programme. Almost all these students have Arabic as their first language as well as it being the language of instruction during their previous schooling. Most of them have had little English background at the time of admission.

Data

The data for this study was collected longitudinally from the Autumn 2002 semester to Autumn 2004 and comprised seven semesters in total. The number of students that took Calculus I in all the seven terms are presented in Table 1.

Year	Term	Frequency
Autumn 2002	21	561
Spring 2003	22	161
Summer 2003	23	104
Autumn 2003	31	450
Spring 2004	32	201
Summer 2004	33	114
Autumn 2004	41	491
	Total	2082

Table 1: Number of students from each Term.

Letter grades for all English and mathematics courses in the preparatory-year programme were recorded for each student, as well as that of Calculus I. All students who went through the orientation programme at KFUPM and progressed through Calculus I provided the data for this study.

Procedure

To investigate the relationship between orientation programme variables with students' performance in Calculus I at KFUPM, a multiple regression procedure was utilised in this study. The dependent variable for the analyses is the students' numerical grade in Calculus I. The number of students with these letter grades and corresponding numerical grades in the regression analyses are given in Table 2.

Grade		Frequency
Letter	Numerical	
DN or F	0.00	69
D	1.00	201
D+	1.50	221
C	2.00	385
C+	2.50	357
B	3.00	328
B+	3.50	227
A	3.75	197
A+	4.00	97
Total		2082

Table 2: Calculus I response profile.

The independent variables on the other hand, are the students' numerical grades in ENGL 001, ENGL 002, MATH 001, and MATH 002 (ordered as DN or F, D, D+, C,

C+, B, B+, A, and A+). Other independent variables include the academic Term (021, 022, 023, 031, 032, 033, and 041) in which the students took Calculus I.

Results and discussion

In the course of this investigation several models were developed using regression analysis. However, only the pertinent models are reported here. Table 3 gives three of these models and variables therein. The results of the three models are summarised in Table 4 in descending order. The table also reports the models, the multiple correlation R-values, R^2-values, Adjusted R^2-values with associated degrees of freedom, F-values and p-values.

Model 1	Model 2	Model 3
T21	T21*	T21
T22	T23*	T23*
T23	E2*	E2*
T31	M1*	M1
T32	M2*	M2*
T33		M1M2*
E1		M2T21*
E2*		M2E1T32*
M1*		E1E2T32*
M2*		

M1 = MATH 001, M2 = MATH 002, E1 = ENGL 001,
E2 = ENGL 002, T21 = Term 21 and likewise,
M1M2 = interaction of M1 and M2,
M2T21 = interaction of M2 and T21,
M2E1T32 = Interaction of M2 and E1 and Term 32,
E1E2T32 = Interaction of E1 and E2 in Term 32.
*= significance at alpha 0.05.

Table 3: Summary of the variables in the best three models.

As can be noticed from Table 4, all three models are statistically significant at alpha 0.05, and very close to each other in terms of their accuracy. However, Model 3 is the best model and explains about 36 per cent of the total variance in the Calculus I grade.

Model	R	R^2	R^2 (adj)	df (Model)	df (Error)	F statistic	p
1	0.5959	0.3551	0.3516	11	2070	103.6	<0.0001
2	0.5945	0.3534	0.3518	5	2076	226.88	<0.0001
3	0.5998	0.3598	0.3570	9	2072	129.39	<0.0001

Table 4: Multiple regression model summary.

Table 5 shows the summary of the best model and the variables that contributed significantly in the model. The first column of Table 5 is the name of the variable, followed by degree of freedom, the estimate of the parameter, standard error, and the associated t-value, and p-value. The best model seems to suggest that the academic subjects of the preparatory year are important predictors of Calculus I performance. Of the academic variables, ENGL 002 and MATH 002 provide a significant contribution to the best prediction model. Among the academic terms, semester 023 appears to be the only significant term when compared to the reference term 041. This simply means that from the perspective of the model, students taking Calculus I in different semesters, were not very different in ability except for those taking the course in term 023.

Variable	DF	Parameter Estimate	Standard Error	t-value	$\Pr > \|t\|$
Intercept	1	0.5155	0.2603	1.98	0.0478
T23	1	0.2576	0.0814	3.16	0.0016
E2	1	0.0658	0.0319	2.07	0.0390
M2	1	0.3062	0.0904	3.39	0.0007
M1M2	1	0.0840	0.0305	2.76	0.0059
M2T21	1	−0.1311	0.0523	−2.51	0.0122
M2E1T32	1	−0.0609	0.0301	−2.02	0.0432
E1E2T32	1	0.0763	0.0299	2.56	0.0106

Note: Only the significant variables are reported here.
The non-significant variables were reported in Table 3.

Table 5: Summary of the value of each coefficient with standard error, t-statistics, and p-value.

There are also several significant interaction effects in the best model. First important interaction is M1M2 (interaction of MATH 001 and 002). Although MATH 001, which was crucial in Model 1 and 2, is surprisingly not significant in the best model, its joint effects with MATH 002 appear significant as a predictor of Calculus I performance in the best model. In addition to the M2 effect, the interaction effect of the variables M1 and M2 implies that, beyond that already explained by M2, the common core concepts and skills found in the preparatory-year mathematics curriculum as represented in both mathematics courses are crucial as a predictor of Calculus I performance. This also indicates that some knowledge and skills in MATH 001 reinforce the knowledge and skills in MATH 002 to provide a better prediction of Calculus I performance. Another significant interaction effect is M2T21 (that is, the joint effects of MATH 002 and Term 021). This interaction appears to subtract from the gradient of the regression line representing MATH 002 at Term 021. That is, for Term 021, the profile of Calculus I student performance is better explained by a gradient that is smaller than what is represented by MATH 002 effects alone. The third interaction effect M2E1T32, is the three-way interaction effects of MATH 002, ENGL 001 and Term 032. Although neither ENGL 001 nor term 032 were significant by themselves, their joint effects with MATH 002 show that the prediction should be discounted by 0.0609 numerical grade units. This implies that the student's ENGL 001 skills and MATH 002

knowledge, when applied to the context of the semester in which they took Calculus I, Term 032, requires a smaller predicted numerical grade than in other Terms. Lastly, the interaction effects E1E2T32 is also significant. This effect represents the common knowledge and skills that are in the preparatory-year English curriculum as represented in both English courses that students carry into the context of semester term 032. This joint English knowledge and skills in term 032 requires a higher predicted Calculus I score than in other terms beyond those already warranted by the ENGL 002 effect.

Variable when added last	R^2 improvement
E1	<0.010
E2	0.030
Both E1 and E2	<0.030
M1	0.070
M2	0.100
Both M1 and M2	0.270

Note: The added last analysis was conducted with only the academic variables in the model.

Table 6: Summary of the contribution of preparatory-year courses in predicting Calculus I performance.

For completion of the analyses, a regression model with only the academic variables in the model was fitted with each of the variables in Table 6 added in last to see the effect of the course in question when other academic variables are already used as predictors of Calculus I performance. The four academic subjects in the preparatory year (ENGL 001, ENGL 002, MATH 001, and MATH 002) together explain slightly above 33 per cent of the total variance. Contrast this with total variance explained by the best models (36 per cent). This has shown that adding other variables (including academic Term) in the model add only around three per cent to the model. In these analyses along with the remaining academic variables, MATH 001 explains only seven per cent, MATH 002 ten per cent, ENGL 001 less than one per cent, and ENGL 002 three per cent. On the other hand, jointly, the two mathematics courses explain twenty-seven per cent of the total variance, while the two English courses explain barely more than three per cent.

As noted earlier, surprisingly ENGL 001 and MATH 001 did not contribute significantly to the best model as stand-alone effects, but their joint effects with other variables can be readily seen as crucial predictors of success in the Calculus I course. This means, the intact curriculum of MATH 002 is needed more as a pre-requisite of Calculus I than that of MATH 001. Furthermore, MATH 001 as a pre-requisite for MATH 002 can be seen as providing more of a supportive role to MATH 002 as the main pre-requisite of Calculus I. This should give some empirical support to the new policy in the preparatory year that for a student to go to either an engineering or a computer-related course, he should get at least a passing grade of D in MATH 001 and C in MATH 002 as a placement requirement.

Limitation of the study

The results of this study should be interpreted with caution due to a number of factors. Firstly, our data collection method and analysis are quantitative in nature. So, no attempt was made to qualitatively (through interviews or classroom observations) investigate the same problem. Had this approach been used, a different result may have been obtained. Therefore, future research may possibly look into this factor to corroborate the result. Secondly, participants were Arab male students only, with little background in English. It would be interesting to determine whether the findings would be replicated in a women's university in Saudi Arabia. Thirdly, the variables examined here are certainly not exhaustive and other factors such as student reading habits, level of motivation, etc. could also be included in a future study.

Conclusion

As the preparatory-year programme is becoming the main bridge between secondary school and the university due to students' language constraints, not much is known about the effect of such a programme on students' performance in higher mathematics courses, which are largely considered as the backbone of science and engineering oriented courses.

In this paper we have investigated using multiple regression analysis on the effect of the preparatory-year academic courses, and the term in which students took Calculus I, on the students' performance in the first calculus course at KFUPM. The three models reported earlier seem to suggest that the academic subjects of the preparatory year are important predictors of Calculus I performance with the best model explaining about 36 per cent of the students' numerical grade in Calculus I. However, MATH 002 and ENGL 002 seemed to contribute more than other main effects variables. Other factors that contributed significantly in the best model included some interaction of the preparatory-year courses. However, it is interesting to note that ENGL 001 and MATH 001 alone did not contribute significantly to the final model. They have an effect only when they interact with other variables. On the other hand, the variable term is also not significant with the exception of term 023. A plausible explanation for this might be the superior mathematics abilities of the student cohort in this summer semester compared to the other semesters.

The findings in this study tend to indicate that as far as science and engineering oriented courses are concerned, the students' mathematics background is very critical, and therefore should be given attention. This result corroborates with many studies in the literature (Begle, 1979; Tuli, 1980; Jamison, 1994; Kelly, 1999; Soares, 2001; Yushau, 2005). Furthermore, the variation found in the role of MATH 001 and MATH 002 in predicting Calculus I grades seems to suggest that if the aim of the preparatory-year mathematics programme is to prepare students for the calculus series, then there is a need to streamline the syllabus, and emphasis should be given more to MATH 002, as it plays a greater role in predicting students' performance in Calculus I.

Similarly, students' proficiency in English – the language of instruction plays some positive role in predicting students' performance in Calculus I. Many studies have corroborated this finding (Taole, 1981; Ferro, 1983; Al-Doghan, 1985; Cuervo, 1991; Maro, 1994; Han, 1998; Lim, 1998; Yushau, 2005). Therefore, language issues should

be taken into consideration whenever students are learning mathematics in a second language.

It is our hope that, due to lack of research in this area, the data presented in this study will serve as a starting point, and hopefully contribute to the field of mathematics education. Furthermore, the findings in this study may help university administrations in policy making regarding student placement into academic programmes after completing the preparatory year, and in streamlining and prioritising the syllabus. It can also be useful for other universities with similar preparatory-year programmes.

References

AL-DOGHAN, A. A. (1985). The predictive validity of selection measures used by the University of Petroleum and Minerals in Saudi Arabia, *Dissertation Abstract International*, **47**(2), 466.

BEGLE, E. G. (1979). *Critical variables in mathematics education: Findings from a survey of the empirical literature*. Mathematical Association of America, National Council of Teachers of Mathematics: Washington, DC.

CUERVO, M. M. (1991). Bilingual instruction in college mathematics: Effects on performance of Hispanic students on CLAST mathematics competencies examination, *Dissertation Abstract International*, **52**(12), 4253.

FERRO, S. F. (1983). Language influence on mathematics achievement of Capeverdean students, *Dissertation Abstract International*, **43**(12), 3879.

HAN, Y. A. (1998). Chinese and English mathematics language: The relation between linguistic clarity and mathematics performance, *Dissertation Abstract International*, **59**(7), 2405.

JAMISON, M. G. (1994). An exploration of extra and classroom variables for three measures of college mathematics achievement (academic achievement), *Dissertation Abstract International*, **55**(9), 2753.

KELLY, L. (1999). A longitudinal study measuring the ability of two South African mathematics tests to predict mathematics performance of Grade 9 high school pupils, *South African Journal of Education*, **19**(2), 100–108.

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS (2001). *Undergraduate bulletin*. KFUPM: Dhahran.

LIM, B. S. (1998). Factors associated with Korean-American students' mathematics achievement, *Dissertation Abstract International*, **59**(6), 1955.

MARO, R. A. (1994). The effect of learning mathematics in a second language on reasoning ability, *Dissertation Abstract International*, **33**(6), 1647.

SOARES, B. (2001). Can student aptitude and attitude assist in placing students in appropriate advanced placement mathematics courses?, *Dissertation Abstract International*, **62**(3), 953.

TAOLE, J. K. (1981). A study of effect on pupils' achievement of studying a selected

secondary school mathematics topic in the vernacular, *Dissertation Abstract International*, **42**(5), 2009.

TULI, M. R. (1980). Mathematics creativity as related to aptitude for achievements and attitude towards mathematics, *Dissertation Abstract International*, **42**(1), 122.

YUSHAU, B. (2005). *The predictors of success of computer aided learning of precalculus algebra*. Unpublished PhD thesis. University of South Africa: Pretoria.