Mathematics as a Performance Predictor in Information Technology Management

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Abstract

This paper considers admission requirements and their relationship to performance in a university level Bachelor of Commerce program in Information Technology Management (ITM). It examines assumptions underpinning admission requirements - in particular, the emphasis on mathematics as a predictor of performance. Subject to the limitations of our sample, results reveal that the average grade in their Best 6 Grade 12 courses is the best predictor of final University cumulative grade point average. Despite the emphasis placed on mathematics by Universities and information technology scholars, final cumulative grade point average showed no significant correlation with calculus, algebra and finite mathematics. Separate multiple regression analyses revealed that (i) calculus and English were weak predictors of overall cumulative grade point average and calculus was only marginally more important than English; and (ii) neither calculus nor finite credits (grade over 60) predicted University graduation success although algebra was shown to have some impact in this regard.

Keywords: mathematics, management education, English, information technology

1. INTRODUCTION

In recent years, the information technology industry has focused attention on the need to increase the supply of qualified professionals to meet its demand. Internationally government and industry reports have warned of impending shortages (e.g. Oates 2004; ITAC 2002; SHRC 2001) and the need to increase enrolments in IT programs. At the same time, studies have focused attention on the evolving nature of jobs and skills needed for success and their implications for

education. (e.g. Kruck & Lending 2003; Crum & Landry 2002).

Leaders in the field have proposed the need to consider a broader definition of "IT Professional" to encompass emerging areas of focus and skills (Denning 2001; Bailey & Stefaniuk 2003). Recent studies have stressed the importance of a balance between technical and management skills (Lee, Trauth, & Farwell 1995). Industry respondents have reported that it is most important for Information Systems graduates to be able to retrieve and evaluate information, participate and work cooperatively in a team, develop critical and reflective thinking, and self-motivate (Snoke & Underwood 1998). Numerous industry studies have emphasized that 'soft' skills, such as interpersonal communication, teamwork, and business knowledge are just as important as technical skills (Freeman & Aspray 1999; Shawyun 1999; Wynekoop & Walz 1999; McGuire & Randall 1998; Van Slyke et al. 1998; Lee et al. 1995; Todd et al. 1995).

In an effort to respond to industry needs, university programs which combine technology and management have emerged. Many have required at least one advanced high school mathematics course for admission. However, based on our review of the literature, we believe that the assumptions underlying these admission standards, and in particular, the strength of mathematics proficiency as an indicator of success in information technology/business hybrid programs, invite further investigation.

The largest technology/business hybrid program in Canada is Ryerson University's Information Technology Management (ITM) program with approximately 2000 full time students. The program includes a core of business management courses as well as required information technology management courses. After two years of foundation courses, students specialize in one of five areas: (i) telecommunications and network management, (ii) applications development, (iii) enterprise systems management, (iv) knowledge management, or (v) digital media management. Students also have the option to focus on professionally related courses to obtain a minor in a business subject area (e.g. marketing, finance, etc.). Of note is the fact that math courses, in the direct form of calculus, algebra, or finite are not part of the ITM curriculum. This differs slightly from eight IT major curriculums examined by Crum and Landry (2002) of which two reported inclusion of calculus as one of their core courses.

The ITM program was launched in 1999 following the merger of two pre-existing programs – the Bachelor of Applied Arts in Administration and Information Management and the Bachelor of Commerce in Business Information Systems. Students are admitted to the ITM program directly from high school, as opposed to applying after foundational undergraduate work in another field. The program does not require any standardized test scores for admission. Rather, applicants submit their best 6 grades in advanced grade 12 (final year of high school) credits. While a math course need not be one of the best 6, applicants must attain at least 60% in at least one of the three mathematics courses offered in grade 12: calculus, finite, and algebra. In other Ontario universities, most undergraduate business programs also require completion of at least one advanced mathematics course, and computer science programs require at least two. All such programs additionally require an advanced grade 12 English course. For admittance into ITM, students must obtain at least 60% in English.

In attempting to further understand the discourse around mathematics pre-requisites, the case of Information Technology Management at Ryerson is worthy of some focused consideration. In the year 2000, changes were introduced to the program. Its name was changed from 'Administration and Information Management' to 'Information Technology Management'. An advanced high school mathematics requirement was added as an entrance requirement and a compulsory programming course was added to the curriculum. Given that the mathematics requirement was largely influenced by the need to "legitimize" the BComm designation (Shortt et al. 2003), it seems warranted that it be evaluated in terms of its ability to predict success in the program.

2. REVIEW OF LITERATURE

High School and Post Secondary Performance

Existing research on the relationship between high school and post secondary performance has suggested that many factors come into play. For example, it has been suggested that the SAT (formerly known as the "Scholastic Aptitude Test"), the American College Test (ACT) or other achievement scores and high school performance are good predictors of college performance (Camara & Echternacht 2000; Garton, Dyer, & King 2000). In the United States, where SATs are used, research has shown that the SAT is a strong predictor of success for both men and women (Camara & Echternacht 2000). Other research has focused on additional variables. For example, Grabe and Latta (1981), and Cote and Levine (2000), concluded that motivation was a stronger predictor of college achievement than IQ scores. In a large sample study, Schmitz et al. (2001) found that high school GPA and verbal SAT scores were much better predictors of freshman college GPA than math SAT scores, although it was not reported how many students in the sample were from business or information technology programs.

Predictors of Success in Management Education

Previous research investigating academic performance in management education has been focused on the graduate level, specifically the Masters in Business Administration (MBA). While the literature here is valuable, MBA students often come from varied academic backgrounds, some of which do not include mathematics as a requisite to graduation. For example, Wright and Palmer (1994) found that while the GMAT and undergraduate GPA were associated with performance in an MBA program, they were not useful in segmenting moderately poor and very poor performers. Bieker (1996) sought a more predictive model, finding that 49% of the variation in academic performance could be explained by GMAT scores, grade point averages for 11 prerequisite courses, race, age (used as a proxy for work experience), and gender. Extending upon this work, Yang and Lu (2001) concluded that age and gender had no predictive utility in explaining academic performance in MBA programs. Their study used only four precedent variables, namely language (English or foreign), GMAT quantitative score, GMAT verbal score, and undergraduate GPA. Of note was that, although undergraduate GPA was the best predictor of academic performance, the GMAT quantitative score was a larger contributor than the GMAT verbal score. Similar studies have also examined other populations of interest. For example, Koys (2005) found that for non-U.S. students, total GMAT score could predict 41% of academic performance in an MBA program. Unlike previous studies, however, GMAT scores for this population of interest were not considered in the admission decision, presumably eliminating much of the survivor bias characterizing the earlier studies; that is, those students who had been admitted into MBA programs in previous studies must have at least met a minimum GMAT standard set by the admissions committee. As such, the GMAT was a more significant predictor than undergraduate GPA.

With regards to undergraduate business, there are three notable studies which examine admission criteria. Most recently, Morgan, Tallman, and Williams (2003) examined whether GPA for a set of core (or required) courses could explain upper-level GPA better than the GPA attained in non-core courses. They concluded that a combination of these measures provided a better standard for admission than did either alone. Clark and Sweeney (1985) formulated a discriminant model which was able to form accept/reject groups based on a student's GPA at 45 semester hours, college mathematics grade, and English composition grade. The overall accuracy of this model was reported to be 78%, meaning that these three variables could be used at a 78% accuracy to predict who would attain at least a 2.3 GPA in their final 21 hours of accounting courses. The level of accuracy rose to 90% when only considering the "reject" group. Pharr and Bailey (1993) composed a similar study, in which five required "predictor" courses were found to be better estimators of success in a collegiate business school than general measures such as ACT scores, SAT scores, and sophomore GPA. While these studies are valuable, all three examined multi-tier

Table 1 - Summary of Predictive Research in Student Performance for Information Systems Education

Study	Key Predictive Findings
Butcher and Muth (1985)	High school GPA and ACT scores can predict 36.6% of variation in grade for introductory computer science course.
Campbell and McCabe (1984)	Students who continued in a computer science major (or switched to a related field) had significantly different SAT math scores, SAT math scores, high school rankings, and mathematical and scientific backgrounds than students who did not.
Driscoll et al. (2000)	Required prerequisites for Information Systems major should be International Economics, Economic Price Theory, and Information Systems (all at the university level)
Kruck and Lending (2003)	Motivation and GPA can predict performance in introductory information systems course. Performance in prior related courses cannot.
Wilson (2002)	Comfort level was more important than mathematical background in an introductory computer science course.
White and Sivitanides (2003)	Success in freshman (university level) math course is positively correlated with success in Visual Basic course.

admission programs, which only admit students into the business program after some foundational college coursework in other areas. As explained, ITM considers only high school work in admission decisions.

Although research on the impacts of specific variables on certain business subjects such as marketing (Borde 1998), accounting (Danko-McGhee & Duke 1992; Norton-Welsh & Reding 1992), finance (Fox & Bartholomae 1999) and management science (Brookshire & Palocsay 2005) is rather abundant, research into the impact of math courses on future performance has been less definitive. As an example, first year university calculus classes tend to be associated with performance in economics (Butler, Finegan, and Siegried 1994). In addition, others (i.e. Westerman, Nowicki, & Plante 2002) have suggested that student-classroom environment fit is a significant predictor of both performance and satisfaction in university management courses. This body of research reveals that there is much concern over performance after admission. It is posited here that determining optimal admission criteria can aid in this cause by selecting students who are more likely to perform well.

Predictors of Success in Information Systems Education

Literature examining contributory factors to success in an information systems degree is limited, somewhat fragmented, and considerably more focused on programming than other IT skills sought in the workforce (see Lee et al. 1995). For example, Wilson (2002) studied a variety of factors and their impact on performance on a mid-term computer science examination, finding that comfort level in the computer science class (measured by a survey) was a stronger predictor than math background. A similar study determined that the combination of high school grade averages and ACT math score (similar to SAT) were the best predictors of performance in computer programming courses but "most of the variation in the examination grades remains unexplained" (Butcher & Muth 1985). A summary of these and other closely related studies with key findings can be found in Table 1 above.

Given the nature of the study of ITM, which emphasizes the *management* of technology, it is clear that research on performance in programming courses is only partially relevant, as only two programming courses are included in the ITM curriculum - one in HTML/Javascript and one in Visual Basic. The literature includes some related discussion. White and Sivitanides (2002) concluded that success in a college level mathematics course was a good predictor of success in a Visual Basic programming class. Rather than programming, process-related courses are more abundant in ITM. Specific to non-programming IS courses, some studies have considered computer skills or learn-

ing styles to predict performance (Chamillard & Karolick 1999), while others (i.e. Kruck & Lending 2003) added that performance is a function of a number of variables but motivation, as measured by self reported surveys, was most significant in predicting performance in an introductory computing course. Amidst these abstract predictors, others (Sexton et. al. 2001) rejected the hypothesis that prior courses in IS predict success in college IS courses. Driscoll et al. (2000) not only demonstrate an implicit rejection of Sexton et al. (2001) but also suggest that the traditional correlation procedures used to determine prerequisites for IS programs is not the ideal method. Rather, the "effect" method which employs independent samples t-tests implicate better courses as prerequisites as they are able to highlight differences in performance between those who had taken foundational courses and those who had not. However, they further noted that data of this nature is difficult to acquire, as students are naturally inclined to complete courses in their major in a logical order.

The Function of Mathematics as an Admissions Criterion

Mathematical admissions criteria for computer science, computer engineering, business management, and information systems have remained quite constant. Yet another body of literature suggests that mathematics may often serve a symbolic rather than practical purpose. For example, Mendick (2005) and Grundy (2000) questioned the effectiveness of using mathematics as an entry requirement for computer science. In short, Grundy (2000) describes that those who were proficient with matriculation level mathematics were not necessarily equipped to deal with non-mathematical abstractions in computing, and vice versa. Grundy further argues that that a political dimension influences the use of mathematics: that it serves the credibility/status/legitimacy value of the computer science profession rather than its practical value. Some also believe that math has been used as a "weeder" to limit program enrolment. Similarly, a professor of mathematics at the University of Toronto claimed in 1980 that its main function is to sustain social stratification through the selection of well disciplined students (Hacker 1990).

There are many reasons why it is important to consider the extent to which admission requirements are linked to academic performance. One is clearly the danger of exclusion of those qualified for program success and admission of those who may not be suitable for the program. Such irregularities would dilute the reputation of the University and its students (Steindl 1990). Reliability of the admission basis, then, serves practical and principle-based purposes for the University, for the industry's health, for the students themselves and for the robust security of societal values such as meritocracy and distributive justice.

When considered in the context of management education, the issue of mathematics as an entry point has been called into question. For example, Ahuja (2002) suggests the requirement may serve to reinforce certain gender expectations. Institutional theory suggests that these ideals may propagate in society through isomorphic (imitative) behaviour between like organizations. In fact, entry requirements may be based on this behaviour (whether it be blind or rational) as much as on actual skill requirements (Meyer & Scott, 1994). As noted above, questions have been raised about mathematics' practical versus symbolic value. In this regard, Becker (1995) notes that mathematics pedagogy is analogous to universal-level truths being handed down by non-human forces.

Recently, studies of the employee shortage in information technology have emphasized the need for a combination of technical and "soft skills". Carole Stephenson, formerly president of Lucent Technologies and currently Dean of the Ivey School of Business at the University of Western Ontario said, "the soft skills are hard". Ryerson describes its ITM program as providing a combination of technology and management or "hard" and "soft" skills. The website adds that: "today's organization wants business specialists oriented towards Information and Communication Technology (ICT) and the "new economy". Therefore, the ITM graduate receives "advanced management and decision-making training while developing skills with the latest technology" (Ryerson University 2004).

In spite of inconclusive empirical evidence, undergraduate business programs, computer

science programs and information technology management programs tend to stress the importance of formal preparation in mathematics as an admission requirement, and the discourse concerning information technology management tends to privilege mathematics and quantitative approaches.

3. HYPOTHESES

Based on the existing literature, our study commenced with four hypotheses.

Although ITM is a BComm degree that heavily integrates IT, the literature review suggests that only programming was definitively correlated with mathematical performance. From these precursors, we arrived at H1:

> H1. That high grades in mathematics are not the best predictor of overall performance for Information Technology Management majors.

Data ideally suited to the recommendations put forth by Driscoll et al. (2000) were unattainable; however, we assumed that the marginal benefits gained by a second math class would mirror that of the first class.

> H2: That students who completed more than one grade 12 mathematics course performed as well in ITM as those who completed only one.

Given a good fit for the general model, H3 is hypothesized to follow from H1.

> H3. That high grades in English are as good a predictor of overall performance in ITM as high school mathematics.

H4 was derived from the assumption that interdisciplinary degrees such as ITM are a good fit for the well-rounded student with an aptitude for a variety of subjects.

> H4. That the best 6 marks in grade 12 advanced courses are better predictors of overall ITM performance than performance in a single subject.

4. METHOD

This preliminary study examines student performance (measured by both CGPA and graduation success) in the four- year degree in Information Technology Management in the Faculty of Business at Ryerson University and the relationship (if any) to their grades in high school mathematics, English, their best 6 subjects and their overall GPA.

Data were collected from records for students admitted in September 2001 and from their university transcripts. Of the 309 students admitted to ITM in 2001, there were 84 females (27%) and 225 males (73%). Of these, 86 did not graduate in 2005 (26 females and 60 males). These students may have dropped out, changed programs, participated in co-op (short for "co-operative education", an option which integrates 20 months of work experience into the curriculum) or slowed down their progress for other reasons. Of the 223 students who graduated, 154 had taken high school calculus and achieved a grade of 60% or more, while the remaining 69 had another math credit (finite or algebra). Students could also elect to take more than one math in high school, as demonstrated by 102 students who achieved 60% or better in two math courses, and 39 students who achieved 60% or better in three math courses.

Of 154 students who had taken calculus, best 6 subject grade averages ranged from 72.3% to 89.0%. Their English marks ranged from 60% to 95%. Their calculus marks ranged from 45% to 96%. Their university graduating CGPAs ranged from 1.86 to 3.89 where 1.86 is equivalent to about 62% and 3.89 is equivalent to about 89%.

Six measures of high school performance were used as independent variables (Final, best 6, English, calculus, finite, and algebra). A multiple regression against Ryerson Cumulative GPA (the Dependent Variable) was carried out. In noting that the significance of the overall model does not infer the significance of each of the independent variables, further analysis was conducted. An examination of each coefficient demonstrates the magnitude and significance of each factor in the overall model.

Table 3 - Coefficients in the Regression Model[a]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	-3.900	1.843		-2.116	.040
	All Final	-3.830	4.774	-.255	-.802	.427
	Best 6	12.769	4.635	.736	2.755	.009
	English	.255	1.526	.027	.167	.868
	Algebra	-4.06E-03	.893	-.001	-.005	.996
	Calculus	.259	1.303	.034	.199	.843
	Finite	-1.401	1.218	-.191	-1.151	.256

a. Dependent Variable: CGPA

Considering H2, the students were divided into those who had completed only one mathematics course (n=116), and those who had completed more than one (n=141). Two independent-samples t tests were used to evaluate the mean difference in CGPA between the two groups.

5. RESULTS AND ANALYSES

The resulting model (R=.517) reveals a model that is a very good fit (i.e. the 6 independent variables as a group are a good predictor of CGPA) with 26.7% of the variance explained. An ANOVA (F=2.671, p=.027) verified that the regression model is significant to the p<.05 level. The model is summarized below in Table 2.

Table 2 – Summary of Multiple Regression Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.517[a]	.267	.167	.66193

a. Predictors: (Constant), Finite, English, Algebra, Calculus, Best 6, All Final

The Beta values in Table 3 show which factors (IVs) have the most effect as predictors in the overall model. 'Best 6' is the only significant predictor of CGPA (t=2.755, p<.01) and is shown to have the greatest impact. Although no other factor is significant, others are shown to have some influence, namely calculus and English, both as very weak and not-significant predictors. Three additional regressions were performed with graduation success (yes or no) as the dependent variable and each of calculus, algebra, and finite as independent variables. The models for calculus (R=.001, F=.571, p=.450) and finite (R=.000, F=.076, p=.763) show no support for either calculus or finite as predictors of University graduation. Conversely, the model for algebra (R=.095, F=2.796, p=.096) was significant at the p<.1 level showing some support for algebra as a predictor of University graduation.

The results shown in Table 4 are the means and standard deviations of students who completed only one mathematics course and students who completed more than one. The dataset included only mathematics grades over 60%. Thus, a student may have completed other math courses and achieved less than 60% but would not have received credit for the course in our study. Further, each student had at least one mathematics course. Results support H2 that there is no real difference in ITM performance between the two groups (t=.379, p=.705). A subsequent test measuring the difference in graduation success (Yes/No) between the groups also supported H2 (t=.628, p=.531). It could be that the skills learned in one class provide much of the foundation a student needs, or that there are few benefits to any mathematics courses for an ITM student. Considering the results from our regression model, we suspect the latter.

Table 4 – Group Statistics

Group	N	Mean of CGPA	Std. Deviation	Std. Error Mean
One Math Course	116	2.6821	.50314	.04672
More than one Math Course	141	2.6522	.71548	.06025

Our results show that performance in any of the high school math courses was not necessarily a strong predictor of performance in the ITM program, thus supporting H1. Even if math was shown to have some impact, it was no different than English (supporting H3) and much smaller than the impact of the best 6 (supporting H4). We also found that completion of more than one math course was of no, or little, benefit to ITM success.

One could perhaps infer that "the overall student" (all competencies) is a better choice as an entrance requirement for ITM. Of course, all students in the program have a minimum of 60% in one math credit so we considered the possibility that completion of one mathematics course might be correlated with performance. Given that no students without a minimum of 60% in high school mathematics are admitted to the program from high school, there is the possibility of survivor bias in our sample.

We also considered the link between completion of a particular high school mathematics course and graduation from the program. Only algebra appeared to predict success in this regard, with both calculus and finite having negligible impact as predictors of graduation. Of note is the fact that most of the students had calculus; only 24 students did not have calculus and the relevance of our analysis was limited in this regard.

In our brief and preliminary analysis we found little interaction among any of the variables considered. While further investigation is required, it seems that gender and high school performance have little impact on CGPA performance in ITM. Nor were the variables related to the likelihood of graduating from the program.

6. LIMITATIONS AND FUTURE RESEARCH

We recognize that this analysis is limited from a number of perspectives. All students in the sample had a minimum of 60% in English and 60% in one of calculus, algebra, or finite mathematics. There was no process for examining the performance of students without math or English; therefore the relevance of the findings is limited. Further, most of the students in the sample took calculus, so the sample of students without calculus was quite small. When all missing cases were taken out, only 24 students were left who did not have calculus. The sample disparity – 196 versus 24 – makes deduction unreliable. Data were not collected on the high schools of each student, so the general difficulties of assessing dissimilar high school environment factors such as different texts, assessments, and teachers that have been previously identified (in White 2003) are relevant here. Students who dropped out, switched programs, or did not graduate in the four years as expected were excluded. This includes the performance of co-op students who tend to have higher CGPAs but take longer to complete the program.

The context to test the difference in performance between students who do not complete any math courses as opposed to those who do was not present here. This is an area for future research. In addition, we want to further explore these relationships in the other three schools in the Faculty of Business with particular examination of factors affecting performance in different majors, for example Human Resources versus Finance. As well, we want to explore the impact of other factors affecting choice of majors and performance, including attitudes and behaviours. Finally, building on U.S. studies, which show that the strongest predictor of college performance in successive years is current college CGPA (Sexton, Hignite, Margavio & Satzinger 2001; Marcal & Robert 2000; Eskew & Faley 1988), we want to look at interactions between individual courses and overall GPA.

7. CONCLUSIONS

Our study is limited and preliminary. Nevertheless, it raises questions about a number of assumptions regarding admission requirements and performance in information

technology management programs. We found that while overall high school performance is significantly related to performance, no single course was, although calculus and English do have a minor impact on performance. Further, there was evidence that having algebra was related to graduation success, yet the completion of more than one math course was not.

We do not want to overstate the significance of our findings. Our overall conclusion, however, is that, at the very least, the assumption that mathematics is a good predictor of performance in information technology management programs needs to be re-examined. Not only does the evidence suggest that it is not a good predictor but also that other subjects, such as English, are at least as good (or as bad).

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