

Is Math Ability Beneficial to Performance in College Computer Science Programs?

Tai-sheng Fan & Yi-ching Li*

ABSTRACT

The purpose of this research is to investigate the relationship between math ability and academic performance. Students enrolled in five universities providing computer science programs were surveyed. A total of 940 valid questionnaires were collected, 796 males and 144 females. The results showed that performance of math courses taken both at high school and college level related significantly to the average score of core courses taken at the college computer science programs (CS-MAJOR, $r > .38$, $p < .001$). Average score of college math courses (C-MATH) was also found to significantly relate to performance in introductory computer science course (CS-INTRO) as well as average score of computer science core courses ($r > .35$, $p < .001$). The benefit of math ability to academic performance in college computer science programs was confirmed in this study.

However, correlation coefficient found between math score obtained in College Entrance Exam (CEE-MATH) and performance in college math courses did not reach significant level. More surprisingly, CEE-MATH was found to negatively correlate to CS-INTRO and CS-MAJOR in most cases. As a result, using CEE-MATH as a sole mean for prediction of performance in college computer science programs is considered not appropriate. The results of this research can be used as a means for better advice for high school graduates in

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choosing college majors. It can also be used as an additional screening tool during the college admission process.

Key words: Academic performance prediction, math ability, computer science education

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INTRODUCTION

Since computers have come into wide use in various industries, and increased numbers of high-paid-salary positions have become available in computer-related fields, computer science has evolved into an attractive field of study. Consequently, numerous universities have experienced problems of oversubscription wherein the number of eligible applicants has exceeded the number of available first-year positions in computer science programs. Faced with limited faculty and staff positions as well as computer facilities, processes for limiting the number of students have become necessary.

Thus, Campbell and McCabe (1984) suggested that if college counselors had access to more specific information regarding the predictive factors for student success in computer science, they might be able to more effectively advise students concerning the reality of pursuing a computer science major. With limited resources and high attrition rates, it has become increasingly important to identify more effective criteria for the classification of those students who are likely to succeed in the computer science major, thus making the best use of available computing resources.

Math ability has frequently been reported to positively relate to performance in the introductory computer science courses in studies among United States (US) subjects (Butcher & Muth, 1985; Dey & Mand, 1986; Dixon,

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1987; Goodwin & Wilkes, 1986; Konvalina, Wileman & Stephens, 1983; Oman, 1986; Ramberg & Caster, 1986; Renk, 1986; Thronson, 1985). Various measures for math ability were used in these studies, including the number of math courses taken in high school and college, performance in these math courses, or scores from the Scholastic Aptitude Test (SAT) math component. Although some researchers also used self-rating for measuring math ability, the validity of this measure is questionable without providing other supporting data. Moreover, none of the studies reviewed found a significant relationship between number of college math courses taken and performance in the computer science programs. Thus, the relationship of math proficiency to student overall performance in college computer science programs has not been conclusively demonstrated.

Little research regarding prediction of academic performance in college computer science programs was conducted in Taiwan. The only related study among subjects from this setting was focused upon finding the relationship between attitudes toward computers and performance in a computer science course, and was conducted at the high school level (Tsai, 1984). Due to the dramatic differences in culture as well as educational systems, the findings from studies in other western countries may not be adaptable to Taiwan.

To be admitted to a four-year college or university, most high school graduates in Taiwan must pass a competitive College Entrance Examination (CEE) held nationwide annually. Then they must complete a choice-of-major form in a ranking order. Afterward, a centralized placement is conducted based upon student total CEE scores, specific restrictions set by individual departments, and the ranking of choice-of-major as indicated by the students (College Entrance Examination Board, 1994).

However, without much research justification for the practice, certain universities have set minimum CEE math scores, besides total CEE scores, as corequirements for admission to computer science programs (College Entrance Examination Board, 1994). Therefore, an investigation of the relationship between math ability and performance in computer science courses may provide empirical evidence on the appropriateness of such a hypothesized relationship.

In addition, high school grade point average (GPA) has been reported to be

a good performance predictor for college computer science programs in many US studies. However, high school performance has never been taken into consideration for college admissions in Taiwan. It is of particular concern whether student high school performance in math courses can be used to predict college achievement. If a relationship between high school math performance and success in college computer science programs does exist, findings of this study may provide supporting evidence for future changes in college admission policies in Taiwan, as specifically related to the field of computer science.

In Taiwan, the college enrollment in computer-related programs has increased by more than 121% since 1985 (Hwang, 1990). From a sample university examined, only two students dropped from the program within the years between 1985 and 1989. However, changing academic majors in Taiwan is not as easy as in the US, and if a student reluctantly remains in an undesired program, then learning may become a painful and unproductive process for that individual. The student may ultimately leave the field of computer science upon graduation.

At the present time and for some years to come, Taiwan faces a shortage of information professionals (Chen, 1988; Wang, 1989). If computer science graduates do not work in the field for which they have been trained, then the productivity of the educational resources would be further limited. In addition, the failure to meet national needs for the information profession may create problems for the entire economy. Hence, the findings of this study may provide some insights in searching an adequate selection process of students for computer science programs.

Thus, the primary purpose of the present study was to determine the relationship between student math ability and student academic achievement in college computer science programs in Taiwan. However, the greater part of the research completed regarding academic achievement prediction has been directed at the predictability of performance in the introductory computer science courses. This study then focused primarily upon the prediction of overall performance in computer science programs, rather than achievement within a single computer science course.

LITERATURE REVIEW

During the past two decades, researchers in the US have sought to identify factors that can be used to predict academic achievement in college computer science programs. Some researchers reported the effectiveness of using scores from standardized aptitude tests such as SAT to predict college performance in computer science courses (Butcher & Muth, 1985; Dixon, 1987; Goodwin & Wilkes, 1986; Oman, 1986; Renk, 1986). Others suggested that mathematics background related significantly to student performance in college computer science courses (Butcher & Muth, 1985; Dey & Mand, 1986; Renk, 1986; Thronson, 1985). Still others indicated that high school performance was a good predictor for student academic achievement in college computer science courses (Butcher & Muth, 1985; Clarke & Chambers, 1989; Konvalina, Wileman & Stephens, 1983; Renk, 1986; Taylor & Mounfield, 1991; Thronson, 1985).

However, relatively little research has sought to determine the predictability of student performance in computer science programs beyond the introductory level. Butcher and Muth (1985) argued that student cumulative GPA, and not simply the grades earned in single computer science courses, should provide better measures of academic success. Among those that adopted this focus, Anyanwu (1988) found that high school performance, but not the matriculation test scores, related significantly to academic success in college computer science programs. Shoemaker (1986) reported that high school GPA and College Board Mathematics Achievement Test could reliably predict major GPA of the computer science programs. In addition, Sorge and Wark (1984) identified mathematical and verbal skills are of the first importance that affected student persistence in computer science programs.

Campbell and McCabe (1984) examined factors influencing student success in a first-year computer science program. By evaluation of Registrar records, it was found that successful completion of a first-year computer science program was a useful indicator of success in the major. Success was measured in terms of three consecutive semesters of enrollment as a declared computer science, engineering, or other science major. Primary research interest was

directed at determination of those factors that differentiated students who persisted in the major from those who changed their majors to disciplines other than computer science, engineering, or other science after one full year of study in the university.

The sample included 256 first-semester freshman computer science majors who enrolled in the first programming course for majors at a large midwestern university (Campbell & McCabe, 1984). Students with other courses in the university prior to enrollment in the programming course were excluded from the study. The factors examined included SAT scores, high school rank and size, and high school math background. Students remain in the computer science fields (CS group) were compared with students who switched to other majors.

The results indicated that students in the CS group scored higher in SAT math (621 versus 575, $p < .001$) than those who switched to other majors. The CS group was also found to rank higher in high school (88.3 versus 85.8, $p = .03$), had taken more high school math (8.72 versus 8.25, $p = .001$) and had received higher average grades in these courses. The results of discriminant analysis also identified SAT math scores and grades in high school math as the most effective predictors that could be used to differentiate potential successful computer science students from those who eventually withdrew from the majors (Campbell & McCabe, 1984).

From analysis of Registrar records of 1,323 computer science majors enrolled at Purdue University from 1978 to 1981, Sorge and Wark (1984) sought to identify the factors that could be used to predict student success in the computer science major. Most of the students had taken six or more high school math courses with grades of B or above. Most of the sample ranked in the top one-third of their graduating class in high school and the sample male-to-female ratio was about two to one.

Among these subjects, 1,071 students started with a traditional beginning course for computer science majors, CS 230, Introduction to Structured Programming. Finding that students with SAT-math scores less than 540 usually did not do well in the beginning calculus course (the corequisite of CS 230), the Computer Science Department used a SAT math score of 560 as the

safety factor for admission to CS 230. Enrollment in four consecutive computer science courses at a level higher than CS 230 was considered as the standard for success in the major (Sorge & Wark, 1984).

Regression analysis was used to determine the factors that effectively predicted if students achieved satisfactory progress in the computer science program. The results of various models with a combination of different variables were compared. When students who scored 560 or higher in SAT-math and 500 or higher in SAT-verbal, and achieved grades of B or higher in CS 230 and a score of five or more on the trigonometry placement test were compared to the sole use of SAT scores as a selection criteria, retention rates for the former dramatically increased from around 50% to 79% (Sorge & Wark, 1984).

Unexpectedly, 43% of those students who met the SAT scores selection criteria and earned grades of B or higher in CS 230, did not continue their studies in the computer science major. It was suggested that some factors other than academic ability might be involved which were responsible for the high attrition rate among these capable students (Sorge & Wark, 1984).

Butcher and Muth (1985) were interested not only in student performance in a single course, but also the overall success in college. They investigated the feasibility of predicting performance for precomputer science majors, using information available prior to enrollment in college, such as American College Test scores (ACT, included scores for mathematics, English, natural science and social science) and associated high school data. First-semester freshmen students who completed the introductory computer science course (CS 1) for computer science majors at West Virginia University during the academic year of 1981-1982 were the subjects of the study. Only data from 269 students (124 from the Fall, 1981 and 145 from the Fall, 1982) who completed the course were used. A questionnaire was used to obtain student background information, with all other information obtained from the Registrar's Office.

To test the effect of high school math (HS-MATH) on student academic performance, students were categorized into groups with no high school math course taken ($n = 17$), groups with completion of algebra ($n = 54$), and groups with completion of precalculus ($n = 198$). Significant mean differences

between groups with various levels HS-MATH were found ($p < .01$). It was suggested that course work in high school mathematics did "improve student performance in college" (Butcher & Muth, 1985, p.265).

The variables HS-GPA and ACT-Math appeared to have the highest correlation with performance in college computer science programs. Though the correlation coefficient was significantly different from zero, it was concluded that using any single variable to predict student performance was limited in value. Butcher and Muth (1985) concluded that performance in an introductory computer science course and in the first-semester in college could be predicted, based only upon information available prior to college enrollment, such as high school transcripts and ACT scores. The variables HS-GPA and ACT-Math jointly provided the best predictive equation for both GRADE and CGPA.

Some precautions for using the restrictive admission requirements were also made. First, more than 50% of the variation in college performance remained unexplained. Second, students without outstanding high school grade or standardized test scores such as from the ACT examination were still able to succeed. Finally, of those who had demonstrated their ability to handle college-level course work, it might be necessary to provide greater opportunities to them if they were to develop their full potentials (Butcher & Muth, 1985).

Shoemaker (1986) was interested in finding which preadmission measures could be used to predict college GPA for prospective engineering, and information and computer science (ICS) majors. The sample included 296 engineering students and 238 ICS majors, enrolled at the University of California at Irvine during Spring term 1982-1983.

Two predictors, scores from College Board Mathematics Achievement (MATHACH) and high school GPA, were included in the optimal prediction equations for the Information and Computer Science majors for both cumulative ($R^2 = .38$, $SE = .44$ grade points) and major GPA ($R^2 = .38$, $SE = .52$). It was concluded that the sample college GPA were predictable from the scores of math achievement tests and high school GPA (Shoemaker, 1986).

Anyanwu (1989) conducted a study in Nigeria to determine the relationship between student achievement in computer science programs at the college level and the test scores of the Joint Admission and Matriculation Board (JAMB), high school performance, and previous computer experiences. To ensure the representative nature of the sample population, five universities were randomly selected, based on the length of establishment and curriculum orientation. Eventually, 150 students (44 first-year, 62 second-year, and 44 third-year students) were included as subjects.

Test scores from the JAMB, high school records, and grades of university courses were all obtained from appropriate Registrar's offices (Anyanwu, 1989). To analyze the data, the subjects were categorized into three cohorts. Cohort I included 150 subjects who had complete first-year records, cohort II comprised 106 students who had complete second-year records available, and cohort III included only 44 junior students who had complete third-year records.

Surprisingly, no significant relation was found between the JAMB math component test scores and computer science achievements at any of the three year levels (r range from 0.02 to 0.08). A strong relationship between achievement in overall computer science program and achievement in the math component of the computer science program was found for all three cohorts ($r = .71, .72$, and $.51$, respectively). The result was not surprising, given the fact that math courses comprised 40% of the courses required by the computer science program. A similar result was reported between achievement in the overall computer science program and achievement in the nonmath components of the computer science program (r range from 0.52 to 0.69). However, it was suspected that the high correlation achieved was mainly due to self-correlation.

Though not significant, the strength of the relationship between the joint effect of high school GPA and high school math GPA and achievement in the computer science program was reported to increase with length of time in the computer science program (Multiple R range from 0.33 to 0.42). Anyanwu (1989) suggested that improvement in the math component of computer science programs would increase the overall computer science program achievement. Since achievement in the computer science program was highly correlated among the three class years ($r = .66$), it was also asserted that success in the

freshmen year was also very likely an indicator of success in later year.

However, subject to careful observation, most of the correlation coefficients were too low to have an important value for education. Though the correlation coefficients achieved were high in some of cases, such as between achievement in the math component of computer science courses and achievement in overall computer science program, those results were suspect for reason of self-correlation within the computer science courses tested.

METHOD

Based on the research reviewed, current study was designed to avoid the research weaknesses observed. There are many computer related programs offered at the college level in Taiwan, including electrical/computer engineering (ECE), computer science (CS), management information systems (MIS) and computer education (CED). Due to the differing curricular requirements among these programs, the variables investigated would be difficult to analyze and compare with one another among the different programs. For practical consideration, only computer science majors were chosen as the target population. As a result, all five universities (three were government-budgeted and two were private-funded) that provide computer science programs were surveyed. Due to the consideration that no information regarding college performance is available for entering college freshmen, freshmen students were excluded from the study. Hence, the study population consisted of 1,169 college computer science majors, including sophomore, junior and senior students currently enrolled at the participating universities.

On the day the questionnaire was administered, 974 students were available and were surveyed. A researcher-designed questionnaire was used to collect background information from subjects who volunteered to participate, each of whom completed a written, voluntary consent form. A total of 958 questionnaires were collected. Following careful and thorough examination, 18 questionnaires submitted by graduate students or non-computer science majors were identified and were excluded. The actual sample size thus consisted of 940 subjects, representing more than 81% of the population.

Among the participating subjects, 796 were males (85%) and 144 were females (15%). Gender information for the subjects, by university and class level, is provided in Table 1.

Scores from subject CEE and college computer science courses were obtained from appropriate college registrar offices. However, only those computer courses offered and required by all the participating universities for computer science majors were considered as computer science core courses. These core courses include (1) calculus, (2) linear algebra, (3) discrete math, (4) probability, (5) numerical methods, (6) introduction to computer science, (7) programming, (8) programming languages, (9) data structures, (10) assemblers, (11) introduction to digital systems, (12) electric circuits, (13) system programs, (14) operating systems, and (15) computer structures. The average scores of these computer science core courses (CS-MAJOR) were then computed, and were employed as college academic performance measure.

Significant results concerning the relationship between the number of high school math courses taken and final grades earned in introductory computer science courses have been reported in a number of studies completed in the US (Butcher & Muth, 1985; Dey & Mand, 1986; Ramberg & Caster, 1986; Renk, 1986; Thronson, 1985). Dey and Mand (1986) further indicated that the average grade of high school math courses taken related significantly to performance in college introductory computer science courses. Campbell and McCabe (1984) also reported a similar result, although the first year grade-point average (GPA) was used for the correlation analysis instead of the grade for an individual course. A significant relationship between high school math and overall performance in college computer science programs was also found in a Nigerian study (Anyanwu, 1988).

Since a uniform curriculum as determined by the Ministry of Education (1990, 1993) was used, all high school students in Taiwan took the same number of math courses. Based upon this consideration, for this study math ability is measured by scores of CEE math component (CEE-MATH), average scores of high school math courses (HS-MATH, rather than the number of math courses taken), and average scores of college math courses (C-MATH).

Pearson's product moment correlation coefficients (r) were calculated to

examine relationships between investigated variables. The level of statistical significance was set at 0.05 for all statistical analyses. Since incomplete items were observed in several questionnaires, a pair-wise deletion was used when dealing with missing values. While interpreting the results of the correlation coefficient analysis, statistical significance was not the only concern. The degree of the relationship was also examined for a possible indication of practical importance for education.

To determine the relationship between math ability and college performance, HS-MATH, C-MATH, and CEE-MATH were correlated with scores of introductory computer science courses (CS-INTRO) and CS-MAJOR accordingly. To generate results for CS-MAJOR, scores for math courses were also included to calculate average scores for all computer science core courses. However, in order to determine the relationship between C-MATH and other non-math computer science courses, a new variable, CS-NONMATH, was used to develop the correlation analysis.

RESULTS AND DISCUSSIONS

The results of an analysis of variance (ANOVA) in conjunction with findings from a multiple range test for the two variables, CS-INTRO ($F = 11.76$, $p < .001$) and CS-MAJOR ($F = 18.05$, $p < .001$), showed that there was a significant difference between class levels. Thus, statistical analyses were completed by grouping students within the same class level across universities as well as students in the same class level who enrolled at the same university. Table 2 presents a summary of the average scores for HS-MATH, CEE-MATH and the college performance variables (C-MATH, CS-INTRO and CS-MAJOR). The correlation coefficients relating to the hypothesis testing are summarized in Table 3 and Table 4.

Although HS-MATH was found to reach significance level in correlation with CS-INTRO for all combined class groups ($r = 0.20$, 0.12 and 0.20 , respectively, for sophomore, junior, and senior), all of the coefficients were at a level of 0.20 or lower. Such low coefficients, though significant, provide little of practical value that may be concluded for educational purposes. Moreover,

for the individual classes of each university, only the correlation coefficients for sophomores at university A ($r = 0.48, p < .005$) and for seniors at university E ($r = 0.31, p < .05$) were found to be significant. Therefore, the correlation coefficients achieved were too weak to provide evidence for the existence of a significant relationship between HS-MATH and CS-INTRO.

To the contrary, HS-MATH was consistently found to associated significantly with CS-MAJOR for almost all cases, with the exception of sophomore and junior classes at university C ($r = 0.29$ and 0.25 , respectively) and sophomores at university D ($r = 0.21, p = .05$). With respect to the correlation of HS-MATH with C-MATH, the coefficients for both sophomores and juniors at university C were not significant. However, for other classes as well as all combined class groups, HS-MATH was significantly correlated to C-MATH. Moreover, there was an increasing level in correlation coefficients by class level between HS-MATH and C-MATH (r increased from 0.41 to 0.46) and between HS-MATH and CS-MAJOR (r increased from 0.38 to 0.44).

HS-MATH was found to correlate significantly with both C-MATH (r range from 0.35 to 0.56) and CS-MAJOR (r range from 0.30 to 0.53), but not to CS-INTRO, for almost all the combined class groups as well as classes in individual universities. This finding supports results obtained by a number of studies conducted in the US, to the effect that math background related significantly to performance in college computer science programs. To summarize, course work in high school math seems to improve student college performance in Taiwan, just as was indicated in the study conducted in the US (Butcher & Muth, 1985; Dey & Mand, 1986; Dixon, 1987).

It was also of interest to note that a non-significant relationship between HS-MATH and college performance was found only for the students at university C. Upon closer examination of C-MATH by university, it was found that the students of university C obtained lower scores than those students from other universities. This low average score in C-MATH might be attributed to the low correlations obtained between C-MATH and CS-NONMATH, and the non-significant correlation found between HS-MATH and C-MATH, for the students at university C.

The findings for the relationship between C-MATH and CS-INTRO were

not anticipated insofar as a significant correlation existed between C-MATH and CS-INTRO for all class level groups (r range from 0.35 to 0.47, $p < .001$ for all cases) and for all individual classes. For the students of university A, the correlation coefficient for this relationship was in excess of 0.58 ($P < .001$).

A strong relationship was found between C-MATH and CS-NONMATH with a correlation coefficient in excess of 0.70 for several cases. The level of correlation increased by class level from the sophomore to the senior groups; that is, from 0.36 to 0.58 to 0.63, respectively ($p < .001$ for all three cases). The same pattern was also observed for almost all of the classes at the various universities included in the sample. However, this finding was not consistent with results reported in the US by Dey and Mand (1986), Konvalina, Wileman & Stephen (1983), and Thronson (1985). One possible reason for this incompatibility is that average scores were used for the present study, while the number of math courses taken in college was used in the other cited studies.

It was of interest to note that the students at university A obtained the highest coefficients by a substantial margin for all of the correlation between the math ability variables and the college performance variables in almost all cases. Moreover, the students from university A also had the highest HS-MATH scores from among subjects from all the universities. These findings also seem to imply that good math abilities can be of benefit to student performances in college computer science programs. It may be hypothesized that university A employs a stronger, math-oriented curriculum, especially for the introductory computer science courses, than do other universities for their respective computer science programs.

For the current study, test scores from the CEE math component (CEE-MATH) were found to have a significant relationship to overall performance in college computer science programs (CS-MAJOR) for all combined class levels, but only for the senior level group in relationship to performance in introductory computer science courses (CS-INTRO). Significant correlation coefficients were seldom found between CEE-MATH and CS-MAJOR for individual classes. Moreover, when the correlations were significant, they nonetheless did not account for an acceptable level of variance.

Rather, CEE-MATH correlated negatively with both CS-INTRO and

CS-MAJOR for most (65% or greater) individual classes. It was also observed that all of the significant correlation coefficients between CEE-MATH and college performance were negative. Fan, Li and Niess (1998) also reported similar findings between other CEE variables and college performance. These findings seemingly indicate that CEE-MATH may not be a valid instrument for the measurement of student math ability, suggesting that the use of CEE-MATH as a sole mean to predict student future achievement in college computer science programs is not appropriate in Taiwan.

This finding of negative relationships is a contradiction of results reported in a number of research studies conducted in the US, wherein math scores were found to correlate highly with course performance for college computer science programs (Butcher & Muth, 1985; Dixon, 1987; Goodwin & Wilkes, 1986; Oman, 1986; Renk, 1986). However, in the Nigerian study conducted by Anyanwu (1988), a non-significant relationship between test scores for the math component of the Joint Admission and Matriculation Board (JAMB) and overall achievement in college computer science programs was reported.

Though a significant relationship between HS-MATH and CS-INTRO could not be determined, the results obtained from this study supported the assumption that math ability can be correlated to performance in college computer science programs. Furthermore, the ascending pattern of relationships by class level between the math ability variables and college performance measures seems to suggest that as more computer science courses were taken, the importance of math ability became more evident.

From all of the findings regarding significant relationships between HS-MATH and college performance, and between performance in C-MATH and other non-math components, the role of math ability in supporting academic achievement in college computer science programs is seemingly confirmed. However, the use of HS-MATH by itself to predict college computer science program performance is recognized as inappropriate due to the reason that only less than 50% of the variance can be explained by the correlations. Comparisons of the findings for current study and related research are summarized at Table 5.

IMPLICATIONS FOR COMPUTER SCIENCE EDUCATION

The findings of this study indicated that CEE-MATH was closely correlated to CS-MAJOR in combined class groups. However, negative coefficients were observed in many individual class groups. These results failed to demonstrate the close relationship between CEE-MATH and college performance in computer science programs, as reported in a number of investigations reported in the US that scores from the math component of standardized aptitude tests effectively predict college performance in computer science programs (Butcher & Muth, 1985; Campbell & McCabe, 1984; Dixon, 1987; Goodwin & Wilkes, 1986; Oman, 1986; Renk, 1986; Sorge & Wark, 1984).

However, a strong relationship was determined to exist between course performance in college computer science programs and other math ability measures (i.e., HS-MATH and C-MATH). In addition, HS-MATH was also found to closely relate to C-MATH. Combining these findings, the effectiveness of the continued use of CEE-MATH to measure student math ability is questionable. Due to the lack of power for predicting student future achievement in computer science programs, as well as its incapability in measuring student math ability, the use of CEE-MATH as a major selection criterion for entering college computer science programs is considered to be inappropriate.

College admission in Taiwan is principally determined by CEE total scores. A score within the upper 50% percentile for CEE-MATH subjects is required as a co-requirement for computer science program admissions at some universities. High school performance has never been used for this selection purpose. However, high school performance in math courses was consistently found to correlate well with college performance in computer science programs. In consideration of this result, if a different admission process is employed in the future, it is suggested that high school performance be included as one of the admission criteria for the selection of potentially successful students for computer science programs.

Some of the inconclusive results of this research, in combination with findings from previously conducted studies, suggest that performance prediction findings should be viewed cautiously. Butcher and Muth (1985) pointed out that studies using standardized test scores all identify high school grades or GPA as important parameters, but nonetheless leave more than 50% of the variance unexplained. Chin and Zecker (1985) warned that the use of a mathematics pretest as the only success predictor for computer science courses was inappropriate. Since test scores tend to improve with practice, Sharma (1987) questioned the usage of test scores as the sole screening tool for college admissions. Sorge and Wark (1984) also suggested that factors other than academic ability were involved in succeeding in computer science programs. Therefore, as indicated by Oman (1986), the prediction model developed using pre-admission variables should be supplemented with other methods (e.g., personal interviews) if academic advice or selection for successful computer science majors is the principal purpose of such process.

One of the major purposes for identifying effective predictors of college performance is the intention to make better use of limited resources by helping students reach reasonable decisions for choices of college major. However, as Butcher and Muth (1985) indicated, some of those who have been classified as unlikely to succeed in beginning computer science courses have been found eventually to perform well in subsequent courses. Therefore, the practice of individual success prediction for academic performance should not be used to discourage students with high motivation in computer science studies. Instead, it would be more appropriate to use information from performance prediction as a means to better advise high school graduates in Taiwan in the process of choosing college majors.

LIMITATIONS OF THE RESEARCH

Several limitations of the present study were recognized. The primary limitation can be directly linked to the voluntary nature of participation in the survey. Though the sample represented in excess of 81% of the defined population, some students were absent from classes during administration of the questionnaire and were not contacted. Written consent to participate was not

obtained from these students. As a result, questionnaire information as well as registrars' records for these students were not available. Therefore, generalization of the findings from this study to the entire population of computer science programs must be approached with caution.

Because high school performance is not considered as a selection criterion for college admission in Taiwan, high school transcripts for the sample were not available in registrars' office. Consequently, all information regarding high school performance was self-reported by the participants during questionnaire administration.

As previously described, including all students in computer-related programs in Taiwan in the investigation was not encompassed within the present study. As a result, comparisons of differences between various programs (i.e., computer engineering, computer science and management information systems) were not undertaken. Hence, the ability to generalize the findings of this research to populations other than those within computer science programs is limited.

RECOMMENDATIONS FOR FUTURE RESEARCH

In this study, statistically significant correlations were found between CEE math scores and overall performance in college computer science for combined class groups. However, the predictive powers of these scores considered to be limited in the absence of supplementary information were found. Moreover, CEE-MATH was negatively correlated to performance, both in introductory computer science courses and overall course work, for the computer science programs of many individual classes. These results suggest that reassessing the predictive validity of CEE-MATH may be necessary.

The close relationship between math ability and overall performance in college computer science programs was confirmed by the present study. However, students in Taiwan take the same number of math courses at the high school level and it would be meaningless to examine the relationship between high school math and performance in college computer science using the number of high school math courses taken as a variable. Rather, the identification of certain mathematics courses as prerequisites or co-requisites to beginning computer science courses may be necessary. Moreover, the specific

mathematical knowledge that contributes to successful learning in subsequent computer science courses also needs to be identified through additional research.

Only computer science majors currently enrolled in a university in Taiwan, and not students in other computer-related programs, were included within the present study. Generalizing the results from this study to populations other than computer science majors is thus inappropriate. Therefore, future research should be conducted to determine if similar results can be found for students enrolled in other computer-related programs. Clarification of the predictability of student success in computer-related programs may be obtained if the results of such research can be combined or compared to the findings reported in this study.

Table 1. Subjects by Gender, University and Class Participating in the Study.

	Male Subjects	Female Subjects	Total
<u>Combined</u>			
SO ¹	318	70	388
JU	261	46	307
SE	217	28	245
Subtotal:	796	144	940
<u>Univ. A</u>			
SO	50	8	58
JU	31	8	39
SE	38	8	46
Subtotal:	119	24	143
<u>Univ. B</u>			
SO	80	15	95
JU	62	9	71
SE	48	2	50
Subtotal:	190	26	216
<u>Univ. C²</u>			
SO	32	7	39
JU	30	2	32
Subtotal:	62	9	71
<u>Univ. D</u>			
SO	74	20	94
JU	77	13	90
SE	68	9	77
Subtotal:	219	42	261
<u>Univ. E</u>			
SO	82	20	102
JU	61	14	75
SE	63	9	72
Subtotal:	206	43	249

Notes:

¹ SO = Sophomore, JU = Junior, SE = Senior.

² University C program recently established; thus, no senior-level students are included.

Table 2. Average Scores for Math-Related Variables and College-Performance Variables.

	CEE-MATH	HS-MATH	C-MATH	CS-INTRO	CS-MAJOR ¹
Combined	58.00	73.25	68.20	71.12	70.51
Univ. A	71.74	77.18	71.26	79.69	75.55
Univ. B	67.12	76.15	73.87	74.40	74.09
Univ. C	66.17	71.80	58.73	70.71	68.29
Univ. D	51.31	70.46	65.73	70.09	65.73
Univ. E	50.77	71.54	68.53	68.68	68.39

Notes:

¹ CEE-MATH = CEE mathematics; HS-MATH = high school mathematics; C-MATH = college mathematics; CS-INTRO = introductory computer science courses; CS-MAJOR = average scores of core courses for computer science majors.

Table 3. Correlation between Math Ability and Performance in College Computer Science Programs.¹

	HS-MATH			C-MATH ²	
	CS-INTRO	C-MATH	CS-MAJOR	CS-INTRO	CS-NONMATH
<u>Combined</u>					
SO ³	.20***	.41***	.38***	.35***	.36***
JU	.12*	.45***	.41***	.37***	.58***
SE	.20**	.46***	.44***	.47***	.63***
<u>Univ. A</u>					
SO	.48***	.51***	.53***	.68***	.71***
JU	-.02	.56***	.37*	.58***	.72***
SE	.24	.51***	.47**	.59***	.76***
<u>Univ. B</u>					
SO	.17	.33**	.36***	.25*	.32**
JU	.12	.39***	.33**	.31*	.56***
SE	.09	.38**	.42**	.48***	.70***
<u>Univ. C</u>					
SO	.17	.27	.29	.35*	.24
JU	.12	.24	.25	.59***	.58***
<u>Univ. D</u>					
SO	.02	.35***	.21	.28**	.21*
JU	-.01	.47***	.30**	.22*	.58***
SE	.10	.37***	.33**	.45***	.70***
<u>Univ. E</u>					
SO	.01	.43***	.31**	.37***	.54***
JU	-.07	.43***	.36**	.35**	.54***
SE	.31*	.44***	.51***	.34*	.62***

Notes:

1 * = $p < .05$; ** = $p < .01$; *** = $p < .001$.

2 HS-MATH = high school math; C-MATH = college math; CS-INTRO = introductory computer science courses; CS-MAJOR = average scores of computer science core courses; CS-NONMATH = average scores of computer science core courses with math courses excluded.

3 SO = Sophomore; JU = Junior; SE = Senior.

Table 4. Correlation between Scores of CEE Math Component (CEE-MATH) and College Performance (CS-INTRO and CS-MAJOR).¹

	CS-INTRO	CS-MAJOR ²
<u>Combined</u>		
SO ³	.10	.11*
JU	.06	.19***
SE	.22***	.31***
<u>Univ. A</u>		
SO	-.06	-.01
JU	-.27	-.19
SE	-.35*	-.25
<u>Univ. B</u>		
SO	-.03	-.01
JU	.03	-.06
SE	.16	.20
<u>Univ. C</u>		
SO	-.34*	-.30
JU	-.25	-.36*
<u>Univ. D</u>		
SO	-.24*	-.04
JU	-.35***	-.11
SE	.12	.10
<u>Univ. E</u>		
SO	-.06	.01
JU	.05	.17
SE	.06	.06

Notes:

¹ * = $p < .05$; ** = $p < .01$; *** = $p < .001$.² CS-INTRO = introductory computer science courses; CS-MAJOR = average scores of core courses for computer science majors.³ SO = Sophomore; JU = Junior; SE = Senior.

Table 5. Comparisons of related research findings

	Subjects	Sample size	Purpose	Findings
Campbell & McCabe 1984	CS freshmen	n = 256	Factors influencing persistency in CS	SAT-math, number of math courses taken and math scores significantly correlated to persistency in CS
Sorge & Work 1984	CS majors	n = 1323	Factors influencing persistency in CS	SAT-math and SAT-verbal scores are of the most importance for prediction of CS retention rate
Butcher & Muth 1985	Sophomore of CS majors	n = 269	Performance prediction for CS majors	High school math and ACT-math significantly correlated to college CS performance
Shoemaker 1986	Engineering and CS majors	n = 534	Performance prediction for CS majors	Score of College Board Math Achievement test significantly correlated to college CS performance
Anyanwu 1988	CS majors	n = 150	Performance prediction for CS majors	High school math significantly correlated to college CS performance. Improvement of college math performance significantly increased achievement in CS programs
Current study	CS majors	n = 940	Relationship of math ability and college CS performance	Achievement in college math-related courses significantly correlated to performance in high school math and college non-math CS courses. CEE-math negatively correlated to college CS performance in many cases

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數學能力對資訊科學系學生 學業表現之助益性

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摘 要

本研究針對資訊科學系的學生進行問卷調查，期能探究學生之數學能力對其大學整體學業表現之助益性。總計回收 940 份有效問卷，男性 796 人，女性 144 人。結果發現，學生高中數學課程的平均成績與就讀資訊科學系期間的數學課程之平均成績(C-MATH)及專業核心課程的平均成績間，皆呈顯著的正相關($r > 0.38$, $p < .001$)。而 C-MATH 與電腦入門課程的成績及非數學之專業核心課程的平均成績間，亦存有顯著的正相關($r > 0.35$, $p < .001$)。因此，學生的數學能力對資訊科學課程表現之助益性，在本研究中得到印證。

然而，大學聯考的數學成績與就讀資訊科學系期間的數學課程之平均成績的相關性卻不顯著。更令人意外的是，聯考的數學成績與電腦入門課程的成績及專業核心課程的平均成績間，在多數情形下皆呈負相關。因此，單獨以大學聯考的數學成績做為大學資訊科學系學生之學業成就預測指標並不適當。本研究的成果可協助高中畢業生在決定是否選擇就讀資訊科學系時，提供額外的參考；也可在推薦甄試過程中，做為決定申請者是否適合就讀資訊科學系的輔助評量或篩選工具。

關鍵詞：學業成就預測、數學能力、資訊教育

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