Examining the Effect of Position in the Program on Performance in Discrete Mathematics

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ABSTRACT
The discrete mathematics component common to computer science programs is often a source of difficulty for students. Two common approaches have been to integrate the mathematics with computer science in a computer science course or requiring students to complete a discrete mathematics course from the mathematics department. Different approaches to instruction have been attempted with varying success.

This paper reports the result of an investigation of student performance in discrete mathematics on the basis of the position in the program at which the student first attempts the discrete mathematics course offered by the mathematics department. The major sample includes 739 students over an 8-year period who first attempted the mathematics course in their first year, second year, or third year of the program. The analysis of the data indicated that there was a significantly better performance record for students who first attempted the course in their second or subsequent year. Analysis including 52 students in Spain found no significant difference between performance of first-year students in that country as compared to Canada.

The conclusion reached is that position in the program is important and the increased maturity of students in second and subsequent years would indicate that the discrete mathematics course might best be placed in the second year rather than in the first.

Keywords
Curriculum, discrete mathematics, sequence.

1. INTRODUCTION
Discrete mathematics is considered as a core subject for undergraduate programs in Computer Science. Computing Curriculum 1991 and 2001 include the discrete mathematics component with subtopics with a specification of 43 class hours of instruction; see [1] and [7]. The discrete mathematics component has been integrated in various ways, either as a single specific mathematics course offered in the first year or second year, or integrated course with discrete mathematics and computer science in a single or in two computer science courses.

Marion [6] points out that there is a difficulty in placing discrete mathematics in the first year since the students often have inadequate mathematics preparation. This is supported by Warford [9] who states a definite preference for including discrete mathematics in the second year. A study by Stein [8] that compared student performance in computer science courses found that students do as well in second year with a calculus course as a discrete mathematics course in first year. A recent Working Group [2] found that High School performance in mathematics was a significant predictor of success in university calculus and linear algebra courses, but the predictive ability was not obvious with respect to the discrete mathematics course. It was noted that the sample of students included those who completed a discrete mathematics course in year 1 and another portion who completed the discrete mathematics course in year 2. Mathematical maturity was thought to be a possible factor. There is support for this as indicated in [4], [5], [7], [8] and [9].

Looking at the mathematics that is generally required in Computer Science programs, most of the first courses in mathematics are in the continuous category. This is also true of the mathematics that students take in High School. Rather than look at the content, sequence, and instructional format of discrete mathematics, the hypothesis is that there is some degree of sophistication that is required for success. The study reported here examined the position in the program when the student first attempted discrete mathematics to see if there was a difference if students waited until they had completed some continuous mathematics and computer science before attempting the discrete mathematics course.

2. THE RESEARCH QUESTION

The basic question asks whether or not there is a difference in student performance in discrete mathematics depending on the position in the program at which the student takes the discrete mathematics course for the first time. Examining the performance of students by checking mark distributions for a particular course section is misleading since many of the students in the course are repeating and this skews the results positively.

Stated as a null hypothesis, the question is:

> **H_0**: There is no significant difference in the number of students who successfully complete the discrete mathematics course on the basis of the year in which they first attempted the course.

3. THE SAMPLE

Students in the study received instruction in discrete mathematics from the Department of Mathematics. This course is required for all majors in Computer Science and the program is designed so that the discrete mathematics course is normally taken in the first year.

The initial sample included all students who have taken the discrete mathematics course for the first time between 1996 and 2003 resulting in an N=741. The year in which the student first attempted the course was taken as the basis for grouping the data. A grade of 'C' or better is required for successful completion of the course. Students obtaining a grade of 'D', 'F' or 'W' (withdrawal) were retained in the data only if they had repeated the course.

An additional group of 50 was added to the sample as part of a secondary analysis. This consisted of students in the Computer Science program at the Universidad Politécnica de Madrid (UPM). At this institution, students are required to take a discrete mathematics course offered by the Department of Mathematics in their first year and also take calculus. Following the analysis of the North American group, a comparison was made to see if there are similarities between the first-year students in another country.

4. ANALYSIS OF THE DATA

The grades obtained, grouped by the year of first attempt are shown in Table 1. Students at UPM are shown as the fourth group, but all of these students attempted discrete mathematics for the first time in their first year. However, the grading scheme does not allow a break-down of the unsuccessful grades in the same fashion as the North American system to indicate the marginal students and those who failed outright. A 'D' column includes both 'D' and 'F' equivalents and withdrawals are shown in the 'W' column.

For groups 1, 2, and 3, it is obvious that the number of students who successfully complete the course on their first attempt decreases dramatically given the year of the first attempt. Failure rate for first-year Mathematics and Computer Science courses tends to be in the range of 35 percent at this institution. A rate of 55 percent is substantially higher than this for discrete mathematics. This drops to a value similar to other first-year courses when students attempt the course for the first time in the second year and to much lower failure rate if it is attempted after the second year. More importantly, the number of computer science majors who must repeat the course is reduced substantially by deferring the course until year two. Those who successfully complete the discrete mathematics course in their first attempt at UPM make up about the same proportion as the first attempt students in North America; in fact the differences are minimal.

A univariate analysis of variance was performed on the original group of 741 to test the null hypothesis that there was no difference in performance for students on the basis of the year of their first attempt at discrete mathematics. The result was an $F=12.11$ with 2 and 739 degrees of freedom. This is significant beyond 0.0001. Multiple comparisons using a Scheffe statistic indicate that there is a significant difference at the 0.001 level between student performance in year 1 and year 2. This is also the case for year 1 and year 3. There is a significant difference between year 2 and year 3 but at a level of 0.27. A similar analysis was conducted to see if there was a significant difference in total GPA for the students in the different groups and this proved to be insignificant at a level of 0.21. The null hypothesis is therefore rejected.

A second comparison including the UPM data to test the null hypothesis resulted in an F of 8.26 with 3 and 789 degrees of freedom. Once again this is significant beyond 0.0001. Post-hoc comparisons using a Scheffe statistic indicate that there is a significant difference at the 0.001 level between student performance in year 1 and year 2. This is also the case for year 1 and year 3. There is no significant difference between the performance of North American students and UPM students in their first attempt (significance level 0.99). Post-hoc comparisons of the UPM group with groups 2 and 3 were not attempted since the UPM data only covered the attempt in the first year. Once again, the null hypothesis is rejected.

Table 1.

SUMMARY OF GRADES BY YEAR OF FIRST ATTEMPT

Yr. Of Year of First Attempt	Description	A	B	C	D	F	W	Total
	number	50	58	97	45	64	79	393
	% of total	12.7	14.8	24.7	11.5	16.3	20.1	100.0
	no repeat				17	36	19	72
1	1 repeat				28	28	60	116
(Group 1)	2 repeats				1	6	14	21
	3 repeats				0	2	4	6
	total repeats				29	36	78	143
	repeat % of total				7.4	9.2	19.8	36.4
	initial fail % of total							54.7
	number	67	60	67	28	31	37	290
	% of total	23.1	20.7	23.1	9.7	10.7	12.8	100.0
	no repeat				11	15	1	27
2	1 repeat				17	11	33	61
(Group 2)	2 repeats				0	4	2	6
	3 repeats				0	1	1	2
	total repeats				17	16	36	69
	repeat % of total				5.9	5.5	12.4	23.8
	initial fail % of total							33.1
	number	15	8	22	4	5	4	58
	% of total	25.9	13.8	37.9	6.9	8.6	6.9	100.0
	no repeat				2	4	0	6
3	1 repeat				2	1	4	7
(Group 3)	2 repeats				0	0	0	0
	3 repeats				0	0	0	0
	total repeats				2	1	4	7
	repeat % of total				3.4	1.7	6.9	12.1
	initial fail % of total							22.4
	number	3	8	16	11		12	50
	% of total	6.0	16.0	32.0	22.0		24.0	100.0
	no repeat				3		12	15
	1 repeat				6			6
UPM first year	2 repeats				3			3
(Group 4)	3 repeats				2			2
	total repeats				11			11
	repeat % of total				22.0			22.0
	initial fail % of total							52.0
Total Students								791

5. CONCLUSIONS

For a large group over an 8-year period, the results indicate that there is a significant difference in performance depending on the year in which the student first attempted discrete mathematics. During the time period, different approaches, textbooks, instructors and sequences were undoubtedly used and fluctuations on the general performance of students in any given time frame likely did exist. These generally result in some smaller

differences, but not in the significant difference that is shown for this study. Performance of the UPM group is a reasonable indicator the factors which affect performance are also operative internationally and not local to the North American scene. This would suggest that to maximize student performance the discrete mathematics course taught by the Mathematics Departments the course is best placed in at least the second year. Other factors may still be operative, for example, the inclusion of a logic course in the first year, either before or concurrently with the discrete math course may change the performance in discrete mathematics. Taking other continuous mathematics courses may also affect performance. These variations were not examined and may modify the results found in this study.

6. REFERENCES

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