EFFECT OF PREREQUISITE ON INTRODUCTORY STATISTICS PERFORMANCE

Askar Choudhury, Illinois State University
Don Robinson, Illinois State University
Ramaswamy Radhakrishnan, Illinois State University

ABSTRACT

Experience in teaching suggests that students' success is greatly affected by the prerequisite courses taken. Statistical Reasoning (introductory statistics) is a required course in most business schools. Students can choose one of several available prerequisites for this course. Some of these courses are more mathematically oriented than others. Therefore, the objective of this research is to observe if one prerequisite is more effective than the others on Statistical Reasoning.

This paper focuses on the students performance in introductory statistics course who took one of two prerequisite courses— i) Data & Chance, and ii) Finite Mathematics. Several parametric and nonparametric tests provide consistent conclusions about the effectiveness of prerequisite course on student's performance in Statistical Reasoning. Specifically, we have found that students who took the Finite Mathematics received significantly better grade in introductory statistics than did students who took Data & Chance. Thus, students with added mathematical orientation do have greater statistical proficiency. Furthermore, the analysis reveals that on average student's course grade is about half a point higher with Finite Mathematics than with Data & Chance.

INTRODUCTION

A continuing challenge for teachers and curriculum researchers is to identify the best possible prerequisite course. When several alternative prerequisite courses exist, identifying the most suitable one has been a source of continuous discussion among the academicians and academic advisors. This paper addresses the issue of prerequisite course that differentiates student performance in an introductory statistics course, primarily for business and economics students. Several different factors may affect students' performance (Dale & Crawford, 2000) in a course including student's background knowledge. Understanding (Choudhury, Hubata & St. Louis, 1999) and acquiring the basic knowledge is the primary driver of success (Bagamery, Lasik & Nixon, 2005; Sale, Cheek & Hatfield, 1999). Experience in teaching indicates that students' performance (Trine & Schellenger, 1999) is primarily affected by the prerequisite courses taken. The effect of these prerequisite courses on students' performance is important, because of their diverse level of preparedness and backgrounds. Literatures in this area of research offer little guidance, if any, as to which prerequisite is better suited for a specific course. Performance outcome of prerequisites have been measured and tested in various disciplines (Buschena & Watts, 1999; Butler, et. al., 1994; Cadena et. al., 2003). A remarkable discussion on prerequisite courses has been provided by Potolsky, et. al.(2003). Higgins (1999) among others, perceive that statistical reasoning should be considered an important component of an undergraduate program. Discussion on statistical reasoning can be found in Garfield (2002) and DelMas et. al.(1999).

For this study, data were collected from a Mid-Western university. At this University all students are required to complete one of the several middle-core quantitative reasoning courses. These quantitative reasoning courses accomplish several outcomes of twelve different general education objectives set by the university's undergraduate program. A specific quantitative reasoning course, Statistical Reasoning (MQM 100) is required for all business and economics majors. Statistical Reasoning course stresses application of statistical concepts to decision problems facing business organizations. All sections use a common textbook and cover the same basic materials. The course includes descriptive tools, probability concepts, sampling processes, statistical inference, regression, and nonparametric procedures. Any of the inner-core mathematics courses in the program can be used as prerequisite. These inner-core courses include Data & Chance, Finite Mathematics, Dimensions of Mathematical Problem Solving, and Calculus I.

This paper focuses on students' performance in Statistical Reasoning as measured by its final course grade due to the effect of a prerequisite. Specifically, this research addresses the question; does the level of mathematical maturity attained by students from Data & Chance (Math 111) or Finite Mathematics (Math 120) enhance their performance in Statistical Reasoning? Data & Chance includes data representations, curve fitting, interpretation of polls and experiments, central tendency, statistical reasoning, and applications of probability. Finite Mathematics covers linear functions, matrices, systems of linear equations, sets and counting, probability, statistics, and mathematics of finance.

There is a general perception that students frequently fear courses in statistics. Most likely, the fear may result from the lack of acquaintance of mathematics and its applications as suggested by Kellogg (1939). Toops (1934) in his review argues that mathematics courses should not be a blanket prescription as a prerequisite for statistics courses. Others perceive this argument as a result of non-relevance from the students' point of view, specifically non-specialist students (see, Pollock & Wilson, 1976; Higgins, 1999; Gober & Freeman, 2005; Moore & Roberts, 1989). Therefore, a proper prerequisite course could help alleviate some of these problems. A natural prerequisite course for an introductory statistics course would be an elementary (or basic) statistics course (see Roback, 2003 for similar discussion), such as, Data & Chance. But, on the contrary, anecdotal evidence suggests that students who took Data & Chance are not as well equipped for Statistical Reasoning as those who took Finite Mathematics. Although there are no specific topics covered that are absolutely necessary for Statistical Reasoning, we perceive that students obtain a higher level of "mathematical maturity" from Finite Mathematics than those who takes Data & Chance.

In this study, the authors analyzed the effectiveness of a prerequisite course on student's performance in introductory statistics. They found that students who took the Finite Mathematics received significantly better grades in introductory statistics than did students who took Data & Chance. This finding implies that this type of prerequisite would be more effective in similar courses in which quantitative reasoning is considered necessary.

DATA AND METHODOLOGY

Data were collected from the records of all students enrolled in introductory statistics course during fall 2002, spring 2003, and fall 2003 semesters. Students were grouped by the prerequisite courses completed prior to enrolling in introductory statistics course. All students who took Data & Chance as a prerequisite completed this course at the university. Most students with Finite Mathematics as a prerequisite completed the course at the university. Others transferred their credit for Finite Mathematics from junior colleges or other universities. In our sample, 507 students took Data & Chance as a prerequisite and all from this university. Total of 1509 students had Finite Mathematics as a prerequisite. Among these, 1306 took this from the university and others transferred from other institutions. There were no recruitment (or selection) attempts to draw students into either of these courses. As there is no indication presented to the student about the prerequisite course, nor there is any control for which students enrolled in which course. For these reasons, it will be assumed that the students are of comparable mathematical abilities when taking a prerequisite course.

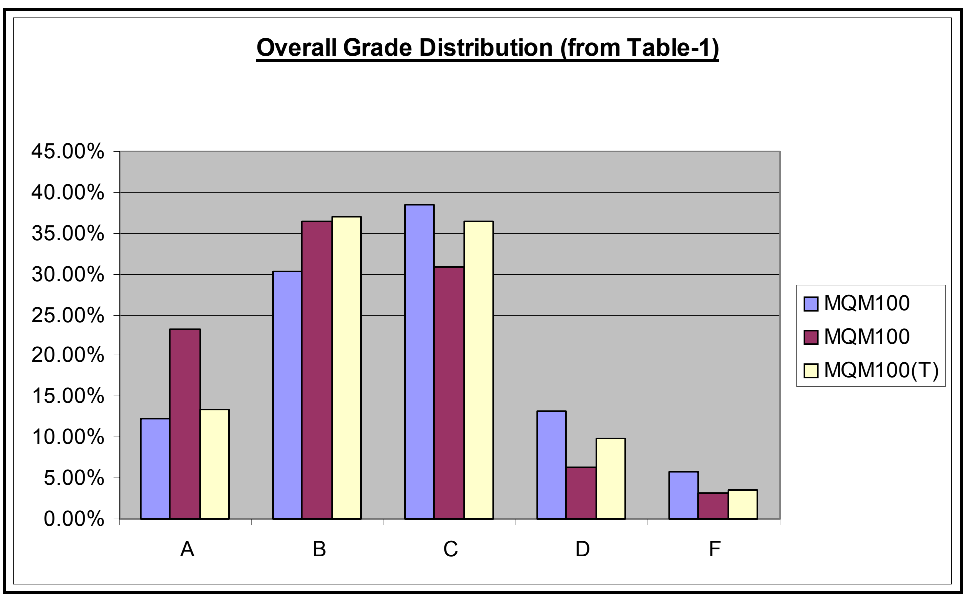
TABLE 1: Grade Distributions (in percentage) by Course and by Semester

Semester	Grade	MAT 111	MQM 100 [MAT 111]*	MAT 120	MQM 100 [MAT 120]*	MAT 120(T)	MQM 100(T) [MAT 120(T)]*
Fall 2002	A	21.62%	12.75%	17.11%	22.15%	15.85%	13.41%
	B	33.78%	30.20%	37.11%	39.47%	29.27%	37.80%
	C	33.11%	32.89%	32.00%	29.17%	51.22%	37.80%
	D	9.46%	15.44%	12.44%	5.26%	3.66%	6.10%
	F	2.03%	8.72%	1.33%	3.95%	0.00%	4.88%
Spring 2003	A	16.77%	12.50%	12.47%	24.32%	7.58%	15.15%
	B	37.72%	31.55%	32.56%	30.63%	45.45%	36.36%
	C	38.32%	36.90%	34.64%	33.33%	42.42%	31.82%
	D	6.59%	14.29%	16.86%	8.56%	4.55%	13.64%
	F	0.60%	4.76%	3.46%	3.15%	0.00%	3.03%
Fall 2003	A	27.13%	11.58%	22.17%	23.15%	22.22%	10.91%
	B	37.23%	29.47%	34.51%	39.16%	35.19%	36.36%
	C	28.72%	44.21%	31.49%	30.30%	37.04%	40.00%
	D	5.85%	10.53%	9.32%	4.93%	5.56%	10.91%
	F	1.06%	4.21%	2.52%	2.46%	0.00%	1.82%
Overall	A	22.07%	12.23%	17.11%	23.20%	14.85%	13.30%
	B	36.38%	30.37%	34.77%	36.37%	36.14%	36.95%
	C	33.20%	38.46%	32.73%	30.93%	44.55%	36.45%
	D	7.16%	13.21%	12.97%	6.28%	4.46%	9.85%
	F	1.19%	5.72%	2.42%	3.22%	0.00%	3.45%

* Introductory Statistics course grades with respective prerequisites; [MAT111]-Data & Chance, [MAT120]-Finite Mathematics, [MAT120 (T)]-Finite Mathematics (transferred).

Performance comparisons are made between these two prerequisite courses (Finite Mathematics and Data & Chance) using introductory statistics course grade. Course grades are classified in the usual manner: A, B, C, D, and F. For the purpose of comparing the average grades of the course in question, the grades assumed the standard quantitative values. An A was weighted at 4 points, a B at 3 points, a C at 2 points, a D at 1 point, and an F at 0. A variety of statistical tests were performed to compare students' performance using course grade in introductory statistics course. Students were grouped into three different groups— 1) Data & Chance, 2) Finite Mathematics at this university, and 3) Finite Mathematics transferred. The Mann-Whitney test (equivalent to the Wilcoxon Rank Sum test) does not make restrictive assumptions about underlying distributions. While two sample *t*-tests require normally distributed populations, the large sample sizes available in this study mitigate this requirement. Versions of the *t*-tests assuming equal population variances and the more conservative unequal variances are reported. In addition, *F*-tests to evaluate the equality of population variances assumption were conducted.

FIGURE 1



1st bar: MQM100 with Data & Chance (at the university).
2nd bar: MQM100 with Finite Mathematics (at the university).
3rd bar: MQM100 with Finite Mathematics (transferred).

EMPIRICAL RESULTS

We present grade distributions in Table 1 and summary statistics in Table 2 for each course by semester and also for all semesters combined (overall). The letter grade distribution in Table 1 reveals that higher percentage of students who took Finite Mathematics at the university received a better grade in introductory statistics course than those who took Data & Chance. As for example, in the fall of 2002, 22.15% of those who took Finite Mathematics at the university received an 'A' in introductory statistics course. In contrast, only 12.75% of those who took Data & Chance received an 'A' in the course. This difference is fairly consistent for all three semesters considered in this study. This difference reverses when we compare them for lower grades, such as C, D or F (see Figure 1). Overall, 18.93% of Data & Chance students received either a 'D' or 'F' in introductory statistics course while only 9.50% of the university's Finite Mathematics students received these low grades. This percentage difference in the higher grade (A & B) for introductory statistics course is roughly equal when we compare Finite Mathematics (transferred) and Data & Chance. As for the lower grades (C,D,F), these percentages for transferred Finite Mathematics are in between the university's Finite Mathematics and Data & Chance. Figure 1 also depicts this information clearly.

In Table 2, we present summary statistics on course grades. We observe that almost half a point difference in average grade points between students with Finite Mathematics at the university and students with Data & Chance. For example, in fall of 2002 those who took Finite Mathematics as a prerequisite received an average grade of 2.706 in introductory statistics course compared to 2.228 for those who had Data & Chance. These results suggest that Finite Mathematics leads to a substantially better grade in introductory statistics course. This improvement is not observed with the transferred Finite Mathematics students. This leads us to test two different hypotheses. First, does it matter which prerequisite is taken for introductory statistics course? Second, does it make any difference if Finite Mathematics is transferred from other institutions or taken at the university? Since, the outcome of prerequisite selection has a substantial payoff, it is important for us to test these hypotheses.

TABLE 2: Summary Statistics by Course and by Semester							
Semester	**Grade**	**MAT 111**	**MQM 100 [MAT 111]***	**MAT 120**	**MQM 100 [MAT 120]***	**MAT 120(T)**	**MQM 100(T) [MAT 120(T)]***
Fall 2002	Average	2.635	2.228	2.562	2.706	2.573	2.487
	Std	0.991	1.127	0.958	0.997	0.801	0.971
	N	148	149	450	456	82	82
Spring 2003	Average	2.634	2.327	2.337	2.644	2.560	2.469
	Std	0.859	1.023	1.010	1.038	0.704	1.011
	N	167	168	433	444	66	66
Fall 2003	Average	2.835	2.336	2.644	2.756	2.740	2.436
	Std	0.930	0.960	1.006	0.946	0.872	0.897
	N	188	190	397	406	54	55
Overall	Average	2.709	2.301	2.511	2.700	2.613	2.467
	Std	0.929	1.031	0.998	0.996	0.791	0.960
	N	503	507	1280	1306	202	203

Note: Maximum grade is 4 and minimum grade is 0, on a four-point scale.
* Introductory Statistics course grades with respective prerequisites; [MAT111]-Data & Chance, [MAT120]-Finite Mathematics, [MAT120 (T)]-Finite Mathematics (transferred).

Thus, both parametric and non-parametric tests on difference between two means (medians for the nonparametric tests) have been performed and reported in Table 3. As expected, both tests reveal that the difference in average grades obtained in introductory statistics course is highly significant when comparing Finite Mathematics (at this university) with Data & Chance (see, Table 3). When Finite Mathematics is transferred from an outside institution, they are only marginally significant at 10% level in the fall of 2002 and not statistically significant in spring or fall of 2003.

The similarity of parametric tests assuming equal and unequal variances is not surprising, since *F*-tests on the equivalence of variances (using sample variances) produced *p*-values ranging from 0.0581 to 0.8804 for individual semesters and at least 0.2380 for all semesters combined. A footnote to Table 3 contains the *p*-values for each semester and the combined semesters for the university's Finite Mathematics versus Data & Chance and for transferred Finite Mathematics versus Data & Chance.

One atypical result requires an additional comment. Comparing students who transferred Finite Mathematics from other institutions to the Data & Chance students, all three tests have higher *p*-values for individual semesters than for all semesters combined. These more-significant *p*-values for the combined groups result from the increased degrees of freedom obtained when combining all semesters.

These tests lead us to the conclusion that students with added mathematical orientation do possess greater statistical proficiency. Perhaps, this is resulted from the enhanced mathematical maturity due to a specific prerequisite leading to a better understanding of statistical reasoning and hence elevated performance in the introductory statistics course.

TABLE 3-A: *t*-tests for average differences in grades in introductory statistics ($\sigma_1^2 \neq \sigma_2^2$)

	Both prerequisites taken at the university		**Math 120 transfers versus Math 111 at the university**	
Semester	***t-value****	***p-value#***	***t-value ****	***p-value#***
Fall 2002	4.616 (456, 149)	0.0000	1.834 (82, 149)	0.0682
Spring 2003	3.402 (444, 168)	0.0008	0.967 (66, 168)	0.3352
Fall 2003	4.990 (406, 190)	0.0000	0.710 (55, 190)	0.4795
All Semesters	7.456 (1306, 507)	0.0000	2.038 (203, 507)	0.0422

* Positive *t*-values indicate better performance for those taking Math 120; values in parentheses are the number of students who took Math 120 and the number who took Math 111.

\# Assumes the population variances are not equal.

TABLE 3-B: *t*-tests for average differences in grades in introductory statistics ($\sigma_1^2 = \sigma_2^2$)				
	Both prerequisites taken at the university		**Math 120 transfers versus Math 111 at the university**	
Semester	***t-value****	***p-value#***	***t-value ****	***p-value#***
Fall 2002	4.913 (456, 149)	0.0000	1.757 (82, 149)	0.0802
Spring 2003	3.380 (444, 168)	0.0008	0.962 (66, 168)	0.3369
Fall 2003	5.017 (406, 190)	0.0000	0.684 (55, 190)	0.4946
All Semesters	7.572 (1306, 507)	0.0000	1.977 (203, 507)	0.0484

*Positive *t*-value indicates better performance for those taking Math 120; values in parentheses are the number of students who took Math 120 and the number who took Math 111.
Assumes equal population variances; *F*-tests for equivalence of variances produced the following p-values for Fall 2002, Spring 2003, Fall 2003, and All Semesters are 0.0581, 0.8380, 0.7996, and 0.3379 for both prerequisites taken at the university and 0.1397, 0.8804, 0.5681, and 0.2380, for Math 120 transfers and Math 111 from the university.

TABLE 3-C: Mann-Whitney test for equivalence of grade distributions in introductory statistics				
	Both prerequisites taken at the university		**Math 120 transfers versus Math 111 at the university**	
Semester	***W****	***p-value#***	***W****	***p-value#***
Fall 2002	146387.0 (456, 149)	0.0000	10294.0 (82, 149)	0.0934
Spring 2003	142328.0 (444, 168)	0.0009	8189.0 (66, 168)	0.3307
Fall 2003	130717.0 (406, 190)	0.0000	7066.0 (55, 190)	0.4905
All Semesters	1256407.0 (1306, 507)	0.0000	76828.5 (203, 507)	0.0476

* W is the sum of the ranks of the students who took Math 120; values in parentheses are the number of students who took Math 120 and number who took Math 111.
# p-value of the test adjusted for ties.

CONCLUSION

Findings of this study suggest that prerequisite is an important component in predicting academic performance in introductory statistics course. Our analysis illustrates the importance of selecting a proper prerequisite for introductory statistics course for business and economics majors. This selection matters in two ways. First, the prerequisite course provides students with necessary background knowledge needed to succeed in the subsequent courses, including other business and economics courses. Second, the course needs to have necessary components included, so that, students have better opportunity to improve their mathematical maturity needed for quantitative reasoning. Therefore, to reduce attrition and improve students' performance in introductory statistics course, Data & Chance may not be a suitable prerequisite. Specifically, we have found that students who took the Finite Mathematics received significantly better grades in introductory statistics than did students who took Data & Chance. Thus, students with added mathematical orientation from Finite Mathematics may have greater statistical proficiency. In addition, our analysis reveals that on average student's course grade is about half a point higher with Finite Mathematics than with Data & Chance.

REFERENCES

Bagamery, B.D., J.J. Lasik & D.R. Nixon (2005). Determinants of Success on the ETS Business Major Field Exam for Students in an Undergrduate Multisite Regional University Business Program. *Journal of Education for Business*, 81(1), 55-63.

Buschena, D. & M. Watts (1999). (How) Do Prerequisites Matter? Analysis of Intermediate Microeconomics and Agricultural Economics Grades, *Review of Agricultural Economics*, 23(1), 203-213.

Butler, J.S., T.A. Finegan & J.J. Siegfried (1994). Does More Calculus Improve Student Learning in Intermediate Micro and Macro Economic Theory? *The American Economic Review*, 84(2), 206-210.

Cadena, J., B. Travis & S. Norman. (2003). An Evaluation of Reform in the Teaching of Calculus. *Mathematics and Computer Education*, 37(2), 210-220.

Chapman, H.H. (1955). Instruction in Statistics in the Colleges and Universities of the South. *The American Statistician*, 9(2), 18-21.

Choudhury, A., Hubata, R. & R. St. Louis 1999. Understanding Time-Series Regression Estimators. *The American Statistician*, 53(4), 342-348.

Dale, L.R. & J. Crawford (2000). Student Performance Factors in Economics and Economic Education. *Journal of Economics and Economic Education Research*, 1,45-53.

DelMas, R.C., J. Garfield & B.L. Chance (1999). A Model of Classroom Research in Action: Developing Simulation Activities to Improve Students' Statistical Reasoning," *Journal of Statistics Education*, 7(3).

Garfield, J. (2002). The Challenge of Developing Statistical Reasoning. *Journal of Statistics Education*, 10(3).

Gober, R.W. & G.L. Freeman, (2005). Adjusting Business Statistics Grades for Anxiety. *Proceedings of the Academy of Information and Management Sciences*, 9(2), 15.

Higgins, J.J. (1999). Nonmathematical Statistics: A New Direction for the Undergraduate Discipline. *The American Statistician*, 53(1), 1-6.

Jenkins, S.J. & J.G. Nelson (2000). Program Evaluation and Delivery in Economics Education. *Journal of Economics and Economic Education Research*, 1, 100-109.

Kellogg, L.S. (1939). Some Problems in Teaching Elementary Statistics. *Journal of the American Statistical Association*, 34(206), 299-306.

Moore, T.L. & R.A. Roberts (1989). Statistics at Liberal Arts Colleges. *The American Statistician*, 43(2), 80-85.

Pollock, K.H. & I.M. Wilson (1976). Statistics Service Teaching in Universities. *The Statistician*, 25(4), 247-252.

Potolsky, A., J. Cohen & C. Saylor (2003). Academic Performance of Nursing Students: Do Prerequisite Grades and Tutoring Make a Difference? *Nursing Education Perspectives*, 24(5), 246-250.

Roback, P.J. (2003). Teaching an Advanced Methods Course to a Mixed Audience. Journal of Statistics Education, 11(2).

Sale, M.L., R.G. Cheek & R. Hatfield (1999). Accounting Student Perceptions of Characteristics Necessary for Success: A Comparison with those Cited by Professionals. *Academy of Educational Leadership Journal,* 3(2), 53-61.

Toops, H.A. (1935). Mathematics Essential for Elementary Statistics. *Journal of the American Statistical Association*, 30(190), 483-484.

Trine, J.A. & M.H. Schellenger (1999). Determinants of Student performance in an Upper Level Finance Course. *Academy of Educational Leadership Journal,* 3(2), 42-52.

ECONOMICS ARTICLES