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The Importance of Mathematics Competency in Statistical Literacy

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Competence in mathematics and statistics are related, but are not the same thing. To measure the impact of mathematical competence on statistics performance, ACT math scores together with remedial and required math grades were analyzed together with final grades in a two-course sequence of undergraduate statistics. Results indicate that math competence is correlated with success in the first statistics course, but generally not the second. In addition, success in the first statistics course does not imply success in the second. These findings support the claims that mathematics and statistics are two separate disciplines, each deserving of its own pedagogy.

It is widely recognized that statistical literacy, statistical reasoning, and statistical thinking are key components of the skills needed by employees in various industries (Ben-Zvi and Garfield, 2004; Snee, 1993). To provide the skills, college degree programs in the United States require a course in introductory statistics. However, American college students often regard their statistical learning experience very negatively (Hogg, 1991). As a result, many students postpone taking statistics course(s) until the end of their degree programs (Onwuegbuzie and Wilson, 2003; Zeidner, 1991).

To understand the causes of such perceptions, various factors have been investigated including mathematical competence, mathematical anxiety and attitudes, statistics anxiety and attitudes, motivation, educational background, self-efficacy, instructional strategies, and technology. For example, according to Gal (2002), An adult's statistically literate behavior is predicated on the joint activation of five interrelated knowledge elements including literacy skills, statistical knowledge, mathematical knowledge, context knowledge, and critical questions, together with a cluster of supporting dispositional elements including beliefs, attitudes, and critical stance. As envisioned by Gal (2002), mathematical competence plays an integral role in the achievement of statistical literacy.

There has been a general consensus in the literature that students' statistical performance is positively related to their mathematical competence (Adams and Holcomb, 1986; Feinberg and Halprin, 1978; Galagedera, 1998; Galagedera and Woodward, 2000; Johnson and Kuennen, 2006; Lalonde and Gardner, 1993; Nasser, 1999; Wisenbaker et al. 2000). Moreover, there are intricate relationships among students' mathematical competence, mathematics attitude and anxiety, statistics attitude and anxiety, and statistics performance. Students tend to experience mathematics anxiety (Bessant, 1995; McLeod, 1992; Stodolsky, 1985), and mathematics anxiety is negatively related to statistical performance (Adams and Holcomb, 1986; Onwuegbuzie and Seaman, 1995; Wisenbaker et al., 2000; Zeidner, 1991). Mathematical competence has a positive effect on attitudes toward statistics (Carmona, 2004; Lalonde and Gardner, 1993; Schutz et al., 1999) and on anxiety toward statistics (Gal et al., 1997; Onwuegbuzie, 2003). Statistics anxiety is negatively related to statistics performance (Lalonde and Gardner, 1993; Zeidner, 1991), whereas positive statistics attitude is associated with better statistics performance (Lalonde and Gardner, 1993; Roberts and Bilderback, 1980; Wise, 1985). Silvia et al., (2008) examined these relationships. They found that students with poor math competence showed more sustained negative attitudes toward statistics throughout the semester; whereas students who did not fail the introductory statistics course had improved statistical attitudes. Moreover, anxiety toward statistics was found among the students that eventually fail the course. Nasser (2004) also found that mathematical competence, mathematical anxiety, attitudes toward mathematics and statistics, and motivation, together accounted for 36% of the variance in statistics performance.

It has been reported that mathematics and statistics are two distinct methodological disciplines (Gal and Garfield, 1997; Groth, 2007; Moore, 1988, 1992), and statistics education is a new and emerging

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discipline (Zieffler et al., 2008). Given the disciplinary differences between mathematics and statistics outlined by Gal and Garfield (1997), it seems rational that statistics education should shift its focus from mathematical computation and procedure to an emphasis on statistical literacy, statistical reasoning, and statistical thinking (Garfield, 2003; Jeffries, 2001; Moore, 1997; Tempelaar et al., 2007). To address whether statistics education is a new and emerging paradigm calling for vastly different pedagogies from mathematics education, the present study focuses on the relationship between mathematical competence and statistics performance. Specifically, this research investigates the relationship between undergraduate business students' mathematical competence measured by American College Testing ("ACT") math score, their grades in remedial and required mathematics courses and their performance (as measured by final grade) in required business statistics courses.

Since the authors work in a department offering the undergraduate degree in Management Information Systems ("MIS"), the primary interest was in determining the effects of mathematics preparation on statistics performance for students majoring in MIS. Therefore, this study investigates the following research questions:

1. Does an undergraduate MIS student's ACT math score have any effect on their final grades in business statistics courses?
2. Does an undergraduate MIS student's success in a remedial mathematics course have any effect on their final grades in business statistics courses?
3. Does an undergraduate MIS student's success in other required mathematics courses have any effect on their final grades in business statistics courses?

LITERATURE REVIEW

Lalonde and Gardner (1993) examined various factors in relation to statistics performance of psychology students in an introductory statistics course. Factors in three classes (aptitude, situational anxiety, and attitudinal-motivational characteristics) were used. Mathematical aptitude factors include mathematics background level ranging from low to high, and a 10-question test designed to measure basic mathematical ability. Their correlation analysis revealed that mathematical background was positively correlated ($r = +.37$) with statistics performance. Similarly, score on a basic mathematics test was also positively correlated ($r = +.29$) with statistics performance.

Galagedera (1998) investigated the influences of a remedial mathematics course on success in an elementary statistics course, where the remedial mathematics course was required by students who failed to satisfy the entry requirements for mathematics. Regression analysis suggested that the performance in the remedial mathematics course tended to be positively correlated with the statistic score. Musch and Broder (1999) conducted a study to determine the relative contribution of test anxiety, study habits, and math skills to the performance of 66 students on a statistics exam. Regression analysis revealed that all three variables together explained about 25% of the variance in the final statistics exam score, while math skills explained 17% of the variance and contributed significantly to exam performance.

Johnson and Kuennen (2006) conducted an ordered probit regression to identify factors that contributed to undergraduate students' success in an introductory business statistics course, as measured by final grade in the course. Independent variables included (1) whether the student had taken calculus or business calculus, (2) whether the student had taken compulsory remedial mathematics, (3) score on a basic math skills test, (4) ACT math score, and (5) ACT science/reasoning score. They identified that the most important determinants of student statistics performance are GPA, the ACT science score, the basic math quiz score, gender, and professor.

Silvia et al., (2008) investigated the factors linked to the difficulties encountered by 442 psychology students in introductory statistics courses, using a between-subject design: those who never failed the final exam and those who failed at least once before passing it. Factors investigated included math background, math competence, and attitude and anxiety toward statistics. From t tests, they found that students' math background and competence had a statistically significant effect on their final statistics performance. Moreover, students who enrolled in the course without an adequate level of mathematical

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competence showed more negative attitudes and high anxiety toward statistics learning, and such negative attitudes failed to change throughout the semester.

Tanner et al., (2009) examined the relationship between undergraduate business students' math skills and their performance in a business statistics course. The basic math/computational skills test with 40 basic questions was administered to a convenience sample of 174 students in statistics classes. Results suggested that math skills have some influence on final statistics grade. For example, students who earned a grade of A in statistics classes had significantly higher scores on the math skills than those with grades of C, D, or F.

The present study differs from previous studies in the following three aspects. First, unlike most of the studies (e.g., Lalonde and Gardner, 1993; Silvia et al., 2008) which used a convenience sample (e.g. the students taking the statistics course(s) taught by the researchers), the present study uses all students enrolled in MIS at the authors' university at the time the data were collected. Second, to investigate the effect of mathematical competence on statistics performance, some researchers measured mathematical competence by administering a basic math/computation skills test (e.g., Musch and Broder, 1999; Tanner et al., 2009). In this study, a student's mathematical competence is measured by a combination of ACT math score, grades in remedial math course(s), and grades in required math courses. And lastly, the present study measures performance differences in statistics based on four separate initial mathematics placement paths. For instance, one path is to take remedial math, followed by a basic math, then introductory statistics. A second path is to take basic math immediately followed by introductory statistics. These paths are explained further in the next section.

METHODOLOGY

Participants

The purpose of this paper is to study the relationships, if any, that exist between the performances (in terms of final course grade) in undergraduate mathematics classes, and the performances (also in terms of final course grade) in business statistics courses, for students majoring in MIS at a regional state university in the southern United States. The curriculum specifies that, in order to graduate, MIS majors need to pass various sets of mathematics courses depending upon their ACT math scores. In addition, these students must pass two statistics (called "quantitative methods" or "QMET") courses in sequence. See Table 1 and Table 2 for further demographic information on these MIS majors. Table 1 shows the distribution of students by gender and classification, as well as their ACT math scores.

Table 1: Student Demographics by Gender, Academic Classification, and ACT Math Score

Gender	% (n = 159)	Academic Classification	% (n = 159)	ACT Math	% (n = 135)
Female	15.7	Freshman	12.5	< 17	3.7
Male	84.3	Sophomore	17.6	17 or 18	13.3
		Junior	25	19 or 20	18.5
		Senior	44.9	21 – 24	38.6
				≥ 25	25.9
TOTALS	100.0		100.0		100.0

Table 2: Percentages of Grades in Mathematics and Business Statistics Courses

	% by Math Course					% by Statistics Course	
Grade	MATH 092	MATH 100	MATH 105	MATH 201	MATHh 250	QMET 251	QMET 252
A	22.7	9.1	14.7	23.4	17.5	24.5	12.3
B	31.8	34.1	51.6	36.9	25.8	43.6	49.2
C	31.8	52.2	31.6	28.9	45.4	25.5	32.3
D	9.1	2.3	0	9	8.2	4.3	4.6
F	4.6	2.3	2.1	1.8	3.1	2.1	1.6

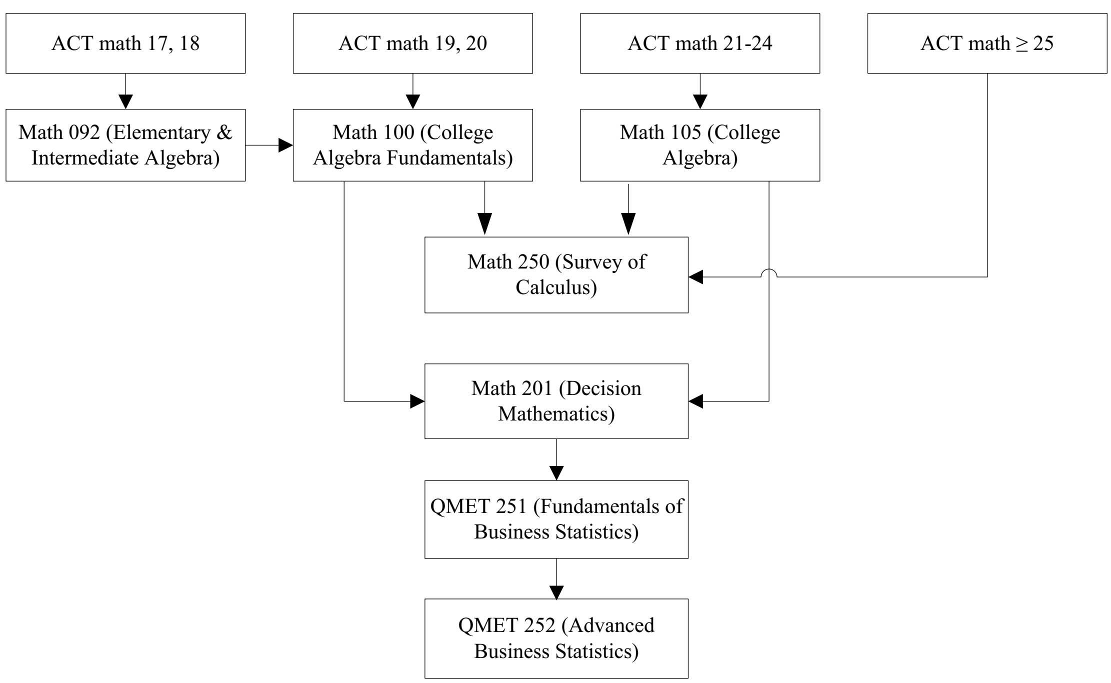
Table 2 shows the students' final grades on mathematics courses, some of which are remedial, and some of which are required of all business majors at the authors' university. Table 2 also shows final grades in the two business statistics courses, both of which are required of all MIS majors. Students most frequently earned a grade of B or C for all mathematics and business statistics courses. Descriptions of these courses appear below.

Initial Mathematics Placement

Students are placed into a mathematics course based on their ACT math score as follows. With an ACT math score less than 17, a student must take remedial mathematics course(s) at a community college, or pass a freshman placement exam. With a score of 17 or 18, a student will be placed in remedial MATH 092 (Elementary and Intermediate Algebra). With a score of 19 or 20, a student is placed in MATH 100 (College Algebra Fundamentals). All the afore-mentioned courses are remedial mathematics by nature. With a score between 21 and 24, a student is placed in MATH 105 (College Algebra). MATH 100 and MATH 105 are interchangeable for degree purposes. With a score of 25 or higher, a student receives credit for MATH 105 and proceeds directly to MATH 250 (Survey of Calculus).

Course prerequisites are shown in Figure 1. For example, MATH 100 or MATH 105 is the prerequisite for both MATH 201 (Decision Mathematics) and MATH 250 (Survey of Calculus). Only MATH 201 is required before taking QMET 251 (Fundamentals of Business Statistics). QMET 251 is a prerequisite for QMET 252 (Advanced Business Statistics). Other than MATH 105 which is a five-credit-hour course, all other courses mentioned above are worth three credit hours. Figure 1 depicts the recommended progression, or “path”, for mathematics and statistics courses at the college.

Figure 1: Mathematics and Statistics Courses Progression Paths



Data Collection

Each author of this research advises MIS majors for their course registration. The university allows faculty advisors online access to students’ academic records. The student’s campus identification number, provided by the MIS department secretary, was used to obtain grades, gender, academic classification, and ACT math score. Data was collected from all MIS majors at the end of the Fall 2010 semester, resulting in a total of 159 students. The grades were not identifiable to individual students. Data sources for the quantitative analyses included students’ gender, classification (freshmen, sophomore, junior or

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senior), ACT math score, the final grade received for remedial math (MATH 092), final grades from required math courses (MATH 100 or 105, MATH 201, and MATH 250), and final grades from statistics courses (QMET 251 and QMET 252). If a student failed course(s) multiple times, only the final passing grade was recorded.

Data Analysis

A scale ranging from 0 to 4 was used to code the grades achieved in all mathematics and statistics courses (F = 0; D =1; C = 2; B = 3: and A = 4). SPSS version 17 was used to conduct all statistical analyses. First, correlation analyses were conducted to investigate the relationships between the students' performance in mathematics courses and their grades in both business statistics courses. Second, as described earlier in the subsection of Initial Mathematics Placement, MIS majors were placed into different initial math classes based on their ACT math scores. One-way ANOVA tests were conducted to test for differences in students' business statistics grades, treating the four different initial math placement paths (see Figure 1) as independent variables. If the group difference was significant, the post-hoc multiple comparisons tests using Gabriel's procedure were conducted to compare all different combinations among the four ACT math paths. Third, a paired t-test was conducted to test the difference in mean grades between the two business statistics courses. The alpha level for all analyses was set at $\alpha = .05$.

RESULTS

Correlation Analyses

Table 3 shows 12 correlations, only four of which were positive and statistically significant between:

a) ACT math scores and fundamentals of business statistics (QMET 251) grades, $r = .231$, $p = .04$.
b) College algebra (Math 105) grades and QMET 251, $r = .263$, $p = .048$.
c) Math 105 and advanced business statistics (QMET 252), $r = .405$, $p = .012$.
d) Decision mathematics (Math 201) and QMET 251, $r = .266$, $p = .015$.

Other than MATH105, none of the other math-related scores or grades were statistically correlated to performance of QMET 252, the advanced business statistics course.

Table 3: Correlations between Mathematics Performance and Statistics Performance

Correlations Between	R (Coefficient of Correlations)	p-value**
ACT Math & QMET 251	.231	.040**
ACT Math & QMET 252	.031	.819
Math 092 & QMET 251	.221	.540
Math 092 & QMET 252	.423	.498
Math 100 & QMET 251	.120	.545
Math 100 & QMET 252	.258	.286
Math 105 & QMET 251	.263	.048**
Math 105 & QMET 252	.405	.012**
Math 201 & QMET 251	.266	.015**
Math 201 & QMET 252	.028	.833
Math 250 & QMET 251	.041	.737
Math 250 & QMET 252	.075	.607

**Significant correlation at $\alpha = .05$ (level of significance)

ANOVA on QMET Grades for Different Math Placement Paths

Analysis of variance (ANOVA) showed that initial mathematics placement and path of progression, as shown in Figure 1, had no statistically significant effect on performance in QMET 251, with $F(3, 75) = 1.272$, $p = .290$, and effect size $r = .22$. Similarly, initial mathematics placement and path of progression

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had no significant statistical effect on performance in QMET 252, with $F(3, 52) = .513$, $p = .0675$, and effect size $r = .17$.

Paired t Test

A paired t-test was performed on the mean difference of grades between QMET 251 and QMET 252 (each pair of values consisted of a single student's grade in each course). The results indicated a statistically significant difference with $t = 3.609$ and $p = .001$ in final grades between the two courses.

Discussion

The purposes of the study were to investigate the effects of ACT math scores, performance in remedial mathematics courses, and required mathematics courses on MIS majors' performance in two business statistics courses. Correlation analyses revealed statistically significant correlations only between ACT math scores and QMET 251, between MATH 105 and both business statistics courses; and between MATH 201 and QMET 251. These would seem to indicate that students' remedial mathematics grades (MATH 092), fundamental college algebra (MATH 100), and survey of calculus (MATH 250) have little or no effect on business statistics grades in either statistics course.

These results indicate that math performance is generally a significant indicator of performance in the first statistics course, but not the second one. In addition, success in the first statistics course is significantly different from success in the second course as indicated by the significant t-test result for mean difference in grades. Basically, QMET 251 is an introduction to statistics featuring one variable methods and QMET 252 is primarily concerned with multiple variable methods. Thus the content of the second statistics course is more statistical than mathematical. In fact, there is very little mathematics required in either of the two statistics courses. A very basic knowledge of algebra is all that is required. Calculus is not required in either statistics course, and probabilities for distributions are tabulated in statistical tables. This fact seems to support the previous research which indicates other factors such as anxiety and attitude are very important in both mathematics and statistics performance. Students who succeeded in math have overcome the math anxiety, and therefore succeeded in the first statistics course.

ANOVA analyses revealed that different mathematics preparation (i.e. whether remedial mathematics was required) had no effect on MIS majors' performance in both business statistics courses, similar to the research findings of Gnaldi (2006) and Johnson and Kuennen (2006). The present findings contradict the general consensus in the literature that students' statistical performance is positively related to their mathematical competence. Instead, these findings corroborate the claim that mathematics and statistics are two distinct methodological disciplines (Carmichael et al., 2009; Chance and Garfield, 2002; Groth, 2007; Johnson and Kuennen, 2006; Moore, 1992; Zieffler et al., 2008). According to Gal and Garfield (1997), statistics differs from mathematics in the following perspectives:

a) In statistics, data are numbers within a context. The context motivates procedures and is the source of meaning and basis for interpretation of results of such activities.
b) Context-bounded statistical problems usually do not have a single mathematical solution, but mathematics is characterized by precision and finiteness.
c) Mathematical concepts and procedures function only as a part of the attempt to solve statistical problems. Moreover, the computation or execution of mathematical procedures is being replaced by the use of sophisticated computer software programs.
d) A primary goal of statistics education is to enable students to render reasoned descriptions, judgments, inferences, opinions and interpretation of data with the help of mathematical tools when needed.

Statistics education is a new and emerging discipline (Zieffler et al., 2008). Given the disciplinary differences between mathematics and statistics outlined by Gal and Garfield (1997), it seems rational that statistics education should shift its focus from mathematical computation and procedure to an emphasis on statistical literacy, statistical reasoning, and statistical thinking (Garfield, 2003; Jeffries, 2001; Moore, 1997; Tempelaar et al., 2007). In the statistical literacy model that Gal (2002) proposed, mathematical knowledge is only one of five cognitive elements. According to Gal, statistical literacy involves knowledge elements including literacy skills, statistical knowledge, mathematical knowledge, context knowledge, and critical knowledge, and dispositional elements including beliefs, attitudes and critical stance. Furthermore, such disciplinary differences drive the Board of Directors of the American Statistical Association to endorse a set of six guidelines for teaching an introductory college statistics course (Franklin and Garfield, 2006). The guidelines specify that instruction should:

a) Emphasize statistical literacy and develop statistical thinking.
b) Use real data.
c) Stress conceptual understanding rather than mere knowledge of procedures.
d) Foster active classroom learning.
e) Use technology for developing conceptual understanding and analyzing data.
f) Use assessments to improve and evaluate student learning.

Note that none of these guidelines specify "mathematical" skills or competencies. These guidelines, together with the results of the present study, are in agreement with Gal's (2002) model which describes mathematical knowledge as only one of the seven elements in statistical literacy.

Future Research

Findings were based solely on a population of MIS majors, which were predominantly male. Consequently, generalizations of these results may be limited. Future studies should include a larger proportion of females. Other studies should also focus on majors outside MIS.

As reviewed by Zimmer and Fuller (1996), there are numerous factors that affect undergraduate students' statistics performance: statistics factors (statistics anxiety and statistics attitude), mathematical factors (math anxiety and math attitude), technological factors (computer anxiety, computer attitude, and ability to use calculators), and personal factors (GPA, test anxiety, gender, spatial ability, age, and personality). This study primarily examined the effect of mathematical performance on performance in business statistics courses. More research incorporating the other factors is warranted.

As indicated in the literature and confirmed by the present study, mathematics and statistics are two separate disciplines with separate pedagogy. Researchers should investigate instructional methods for success in statistics separately from those adopted in mathematics education.

Conclusion

In recent years a paradigm shift has occurred from traditional views of teaching statistics as a mathematical topic (which emphasizes computations, formulas and procedures) to the current view that statistics is a distinct methodological discipline from mathematics. Such disciplinary differences call for statistics education to emphasize statistical literacy, statistical reasoning, and statistical thinking. This study finds that undergraduate students' mathematical preparation and competence had very little effect on their performance in business statistics courses. This study supports the claim that statistics education is different from mathematical education. Consequently, instructors of statistics should adhere to the new guidelines of statistical teaching and learning as prescribed by the Board of Directors of the American Statistical Association.

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