From Research to Practice: Basic Mathematics Skills and Success in Introductory Statistics

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Abstract

Based on previous research of Johnson and Kuennen (2006), we conducted a study to determine factors that would possibly predict student success in an introductory statistics course. Our results were similar to Johnson and Kuennen in that we found students' basic mathematical skills, as measured on a test created by Johnson and Kuennen, were a significant predictor of student success in the course. We also found a significant professor effect. These results have prompted us to evaluate and modify the teaching of our introductory statistics course.

1. Introduction

Faced with high failure rates in our introductory statistics course (roughly 40% of students not completing the course with a C or better), we sought explanations for our students' lack of success and potential remedies to improve their success.   In 2006 we read an interesting paper in this journal which examined basic mathematical skills of introductory statistics students and their subsequent success in the course (Johnson and Kuennen, 2006).   In that paper Johnson and Kuennen documented a gap in the literature regarding basic mathematical skills as a predictive variable for success in introductory statistics. To address that gap they conducted a study to identify student characteristics that may be associated with success in their introductory business statistics course. In addition to variables such as gender, GPA, professor, and self-reported hours of study and work, they included several measures of mathematics skills. These were ACT subject scores, previous mathematics courses the students had taken, and scores on a very short and basic test of mathematical skills that was developed and administered by the authors.

Johnson and Kuennen found "the most important determinants of student performance include student gender, GPA, ACT science score, and score on a quiz of basic math skills." Of interest to us was the fact that the basic skills mathematics score was consistent as a predictor of success even when controlling for course format and professor. While there is no magic bullet for predicting success in introductory statistics, we were interested in an instrument that could be administered quickly and would potentially help us identify students who may have problems. Johnson and Kuennen suggested that their results "may be widely applicable to other instructors and at other universities" and we decided to see if this was the case.

Johnson and Kuennen's research concerned an introductory level business statistics course with a precalculus prerequisite. By contrast, our course is a general education statistics course with no mathematical prerequisite. However, it still made sense to us that success in introductory statistics would be associated with students' mastery of basic mathematical skills including performing simple algebra and working with ratios and area. We wondered how our introductory students would perform on Johnson and Kuennen's basic skills test and if we would see similar results as those authors. Thus we embarked on a similar research project whereby we used, and modified, the basic skills mathematics test developed by Johnson and Kuennen. In addition to seeing if we would obtain similar results as those authors, we also had the following goals:

- o We wanted to have an instrument that would be a quick predictor of student success in the class and would give us an easy and early way to identify students who were likely to have problems in the class.
- o We wanted to determine if regularly attending the free tutoring in the Longwood Learning Center (LC) had a positive association with student success in the course.
- o We hoped the results of this project would provide information about our students' basic mathematical skills that would possibly suggest ways to improve our teaching of introductory statistics and ultimately, increase student success in the course.

Our data collection spanned two academic years and included five professors and 760 students. While our study used more students than Johnson and Kuennen's it was also simpler in that it did not consider as many predictors of success. We did not consider as many explanatory variables as Johnson and Kuennen in our models because we hoped to obtain results that would be useful yet involve a minimal amount of data collection for instructors with heavy teaching loads. Thus for each student in our introductory statistics classes we collected data on their basic skills test score, professor, and attendance at tutoring in our university learning center. Despite the fact that our study was simpler, analysis of our data did give similar results to those obtained by Johnson and Kuennen.

2. Course Description and Objectives

Statistical Decision Making (MATH 171) is a general education mathematics course at Longwood University and thus it has no mathematical prerequisites. This three-hour course is a non-calculus based introduction to statistics. Topics covered in the course are relatively standard and include descriptive and inferential statistics. The course is mostly taken by students

majoring in the liberal arts or social sciences although we are starting to see more science majors in the course. In the last five years our teaching philosophy for this course has evolved to better reflect the American Statistical Association (ASA) endorsed Guidelines for Assessment and Instruction in Statistics Education (GAISE) (http://www.amstat.org/education/gaise/index.cfm):

1. Emphasize statistical literacy and develop statistical thinking;
2. Use real data;
3. Stress conceptual understanding rather than mere knowledge of procedures;
4. Foster active learning in the classroom;
5. Use technology for developing conceptual understanding and analyzing data;
6. Use assessments to improve and evaluate student learning.

During the first academic year of the study we used the textbook Introduction to the Practice of Statistics (IPS) (Moore and McCabe, 2006) and during the second year we used the textbook The Basic Practice of Statistics (BPS) (Moore, 2007). Our main reason for switching texts was that we believed the level of exposition in BPS was more appropriate for the majority of our students in MATH 171. However, both textbooks have a similar teaching philosophy.

3. Data Collection

We collected data over the course of two academic years starting in the Fall of 2006 and ending in the Spring of 2008. We did not collect data for any classes taught during the summer sessions. Each semester, in every section of MATH 171, the basic skills test was administered on the first day of class. Students were not allowed to use a calculator on the test. Students were told that this test "counts" so they would have a vested interest in performing well on the test. How it counted was determined by individual instructors. For instance, one professor counted the test as a quiz score while another used it to determine bonus points on the final exam. The answers for each student on each question of the basic skills test were recorded into a spreadsheet. The test was not returned to the students.

During the two academic years of our study the course was taught by five different professors whom we will refer to as Professor 1 through Professor 5. All but one of these professors taught multiple sections throughout the two years of the study. Table 1 shows which semesters each professor taught and how many students took the basic skills test in their classes.

Table 1. Number of Students Taking the Basic Skills Test for Each Professor and Each Semester

	Fall '06	Spring '07	Fall '07	Spring '08	Totals
Professor 1	68	32	69	82	251
Professor 2	66	63	67	0	196
Professor 3	33	0	27	25	85
Professor 4	35	0	0	0	35
Professor 5	0	0	80	55	135
Totals	202	95	243	162	702

In the Fall of 2006 we used the basic skills test developed by Johnson and Kuennen. Starting in the Spring of 2007 we added five additional questions to the basic skills test. Most of these questions were problems involving percents, ratios and proportions. A copy of the modified test is in Appendix A. However, for this article we only conduct our analysis with the 15-question basic skills test developed by Johnson and Kuennen.

3.1 Independent Variables

We collected data for several independent variables for our analysis. For each student we have the score (number correct) on Johnson and Kuennen's fifteen-question basic skills test. We also recorded which semester the student was enrolled in the course and which professor the student had for the course. In addition we collected data on how many hours each student spent getting tutoring at the LC. Because so few of our students took advantage of the LC tutoring (only 13% attended more than two hours during their semester) we made the variables associated with the LC categorical. In Table 2, we list the independent variables we collected for each of the students.

Table 2. Independent Variables

Variable Name	Description
Score15	Score on the 15 point basic skills test, integer values from 0 to 15
I1, I2, …, I20	An indicator variable for each question which determined if the student had answered the question correctly. For instance, I1=1 if the student answered question 1 correctly, otherwise I1=0. We also recorded the students' answers to each question of the basic skills test.
Semester	Which semester the student was enrolled: F06, S07, F07, S08
Professor	Which professor the student had for the course: P1, P2, P3, P4, P5
P1, P2, P3, P4, P5	Indicator variables for Professor 1, Professor 2, etc. So for example P1=1 if Professor=Professor 1 otherwise P1=0.
I_LC1	An indicator variable determining if the student spent over 1 hour (I_LC1 =1) in the LC or not (I_LC1=0).
I_LC2	An indicator variable determining if the student spent over 2 hours (I_LC2 =1) in the LC or not (I_LC2=0).

3.2 Dependent Variable

Our dependent variable is "success" in the course. Our goal was not to predict grades but to get a quick measure, via the basic skills test, of the likelihood of a student being successful in completing the course and to have an easy and early way to identify students who might have problems. Clearly many factors determine a student's success in a course including previous exposure to statistics and mathematics and individual motivation. However, based on the research by Johnson and Kuennen we hoped that the basic skills test would give us a coarse, but quick, measure of our students' basic mathematical skills and likelihood for success in the

course. Thus we decided to use an indicator variable for "success" in completing the course as our dependent variable.

In order to determine the value of the "success" variable we first recorded the letter grade in the course for each student. We used the letter grade because different instructors use different numerical systems. A student had a success value of 1 if they made an A, B, or C in the course and a value of zero otherwise. We also kept track of two types of withdrawals. A student with a grade of EW is considered an early withdraw student. This means the student withdrew from the class during the drop/add period of the semester, which occurs during the first week of classes, and consequently did not appear on the professor's final roll. A grade of W means the student stayed in the class after the drop/add period and thus was on the professor's final roll. However, the student dropped the class by the withdraw date and received an official grade of W in the class. We note that we did not include the 19 students who received an EW in our analysis since they withdrew from the course within the first week of classes. However, students who received a W were included in our analysis and had a success indicator value of zero. At Longwood University the last day to withdraw generally occurs at the midterm of the semester. We argue that these students had invested some time in the course and, for whatever reasons, were not successful in completing the course with a grade of C or better.

3.3 Issues in the Data

There were a few small issues with our data. First, we had twenty-four students who did not take the basic skills test. Although these students received a grade in the course they were not included in our analysis. Second, we had students who repeated the course (37 students or 76 records) and thus appeared in our data set more than once. We debated whether to include these extra attempts in the analysis, and as it made very little difference in the outcomes, we left out the 39 repeated attempts (2 students took the course three times). Note that Table 1 does not include the 58 students (EW and repeated attempts) of our initial 760 students on which we collected data.

4. Data Exploration and Analysis

Our analyses below only include the 702 students (i.e. no repeats) whose final grade was an A, B, C, D, F, or W.

4.1 The Basic Skills Test

Our 702 students had a mean score on the 15-point basic skills test of 9.449 with a standard deviation of 2.532. Johnson and Kuennen's 292 students had a mean score of 11.10 with standard deviation 2.31. A quick two sample t-test shows strong evidence that our students tended to score lower, on average, on the 15-point basic skills test $\left(t = -9.97, df = 593, p \ll 0.001\right)$. This is not surprising to us and was in fact what we suspected since Johnson and Kuennen worked primarily with business statistics students who had a mathematics prerequisite before taking their statistics course whereas our students had no mathematics prerequisite and were mostly liberal arts and social science majors.

A one-way ANOVA showed that there was no significant difference in the mean score on the 15-point basic skills tests among the different instructors $\left(F(4,697)=0.769, \ \text{p-value}=0.546 \right)$. In Figure 1, box plots show no major differences in students' basic skills score among the five professors.

Figure 1. Students' Scores on Basic Skills Test Versus Professor
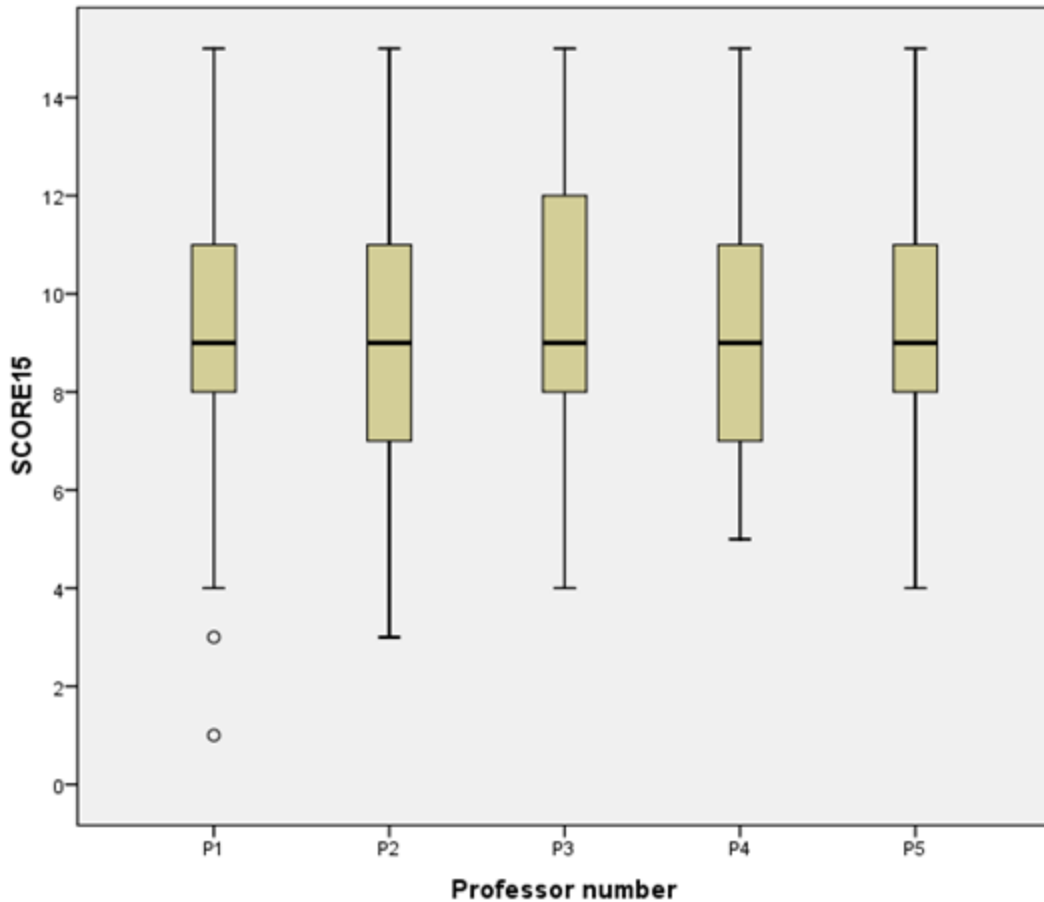
However, when plotting the score on the 15-point basic skills test versus the student grade in the class we observed a significant difference in means $\left(F(5,696)=22.216, \ \text{p-value}\ll 0.001 \right)$. Students with lower grades in the class tended to have lower basic skills test scores. This can be seen in Figure 2.

Figure 2. Students' Scores on the Basic Skills Test Versus their Final Grade
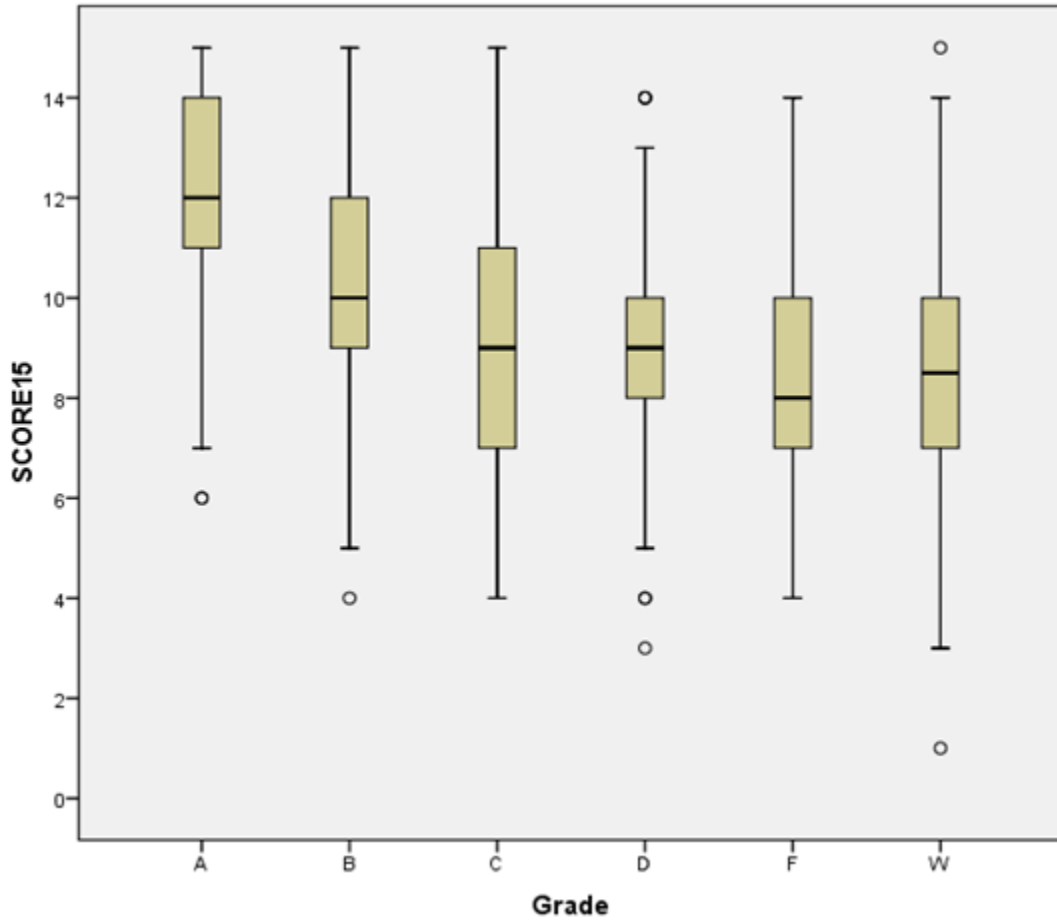
4.2 The Simple Regression Model

We first performed a binary logistic regression with our response variable, Y, being "success" in the class and the explanatory variable, X, being the score on the 15-point basic skills test. If we let $\pi(x) = P(Y = 1 \mid X = x) = 1 - P(Y = 0 \mid X = x)$ then our logistic regression model is given by:

$$\text{logit}[\pi(x)] = \log \frac{\pi(x)}{1 - \pi(x)} = \alpha + \beta x$$

The logit function is just the log of the odds of "success." We note that the interpretation of the coefficient β is different than for linear regression. In particular, if we consider an increase in $X = Score15$ by k points then we have:

$$\frac{\left[\pi(x+k)/\left(1 - \pi(x+k)\right) \right]}{\left[\pi(x)/\left(1 - \pi(x)\right) \right]} = \exp(\beta k).$$

The ratio $\dfrac{\left[\pi(x+k)/\left(1-\pi(x+k)\right)\right]}{\left[\pi(x)/\left(1-\pi(x)\right)\right]}$ is called the odds ratio and gives the ratio of the odds of

success at $X = x + k$ divided by the odds of success at $X = x$. Please see Agresti (2002) for more discussion of binary logistic regression.

We fit the model to get

$$\text{logit}\left[\hat{\pi}(x)\right] = -1.706 + 0.212x$$

where both of the coefficients are significant at the 1% level (see Table 3). We can say that an increase of one point on the 15-point basic skills tests increases the odds of getting a grade of C or higher in the class by approximately 24% since $\exp(0.212) = 1.237$.

Table 3. Binary Logistic Regression

	B	S.E.	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
					Lower	Upper
SCORE15	0.212	0.033	0.000	1.237	1.159	1.319
Constant	-1.706	0.315	0.000	0.182		

We note that for odds ratios greater than one but less than 1.5 the odds ratio is a reasonable estimate of relative risk (see Davies (1998)). Thus we could say that the proportion of students who are successful in the class increases by approximately 24% for each increase of one point on the 15-point basic skills test. The 15-point basic skills test is a strong predictor of success in the course with higher test scores corresponding to higher chances of success.

4.3 Adding the Effect of the Professor

We improved our model conceptually by adding the effect of the instructor. Our new model is a multiple binary logistic model with both quantitative and categorical explanatory variables. Using Professor 1 as the reference professor and including our indicator variables for the other professors we found two of the professor coefficients for our model were significant at the 5% level and the other two had *p*-values that were slightly above 0.10 (see Table 4).

**Table 4. Binary Logistic Regression with Professors Added**

	B	S.E.	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
					Lower	Upper
SCORE15	0.218	0.034	0.000	1.243	1.164	1.329
P2	-0.323	0.199	0.105	0.724	0.490	1.070
P3	0.916	0.295	0.002	2.500	1.403	4.457
P4	0.845	0.419	0.044	2.327	1.023	5.294
P5	-0.364	0.222	0.100	0.695	0.450	1.073
Constant	-1.731	0.345	0.000	0.177		

The interpretation of the coefficient for the *Score15* variable is similar to above, i.e. for a given professor, each additional point in basic skills test score corresponds to an increase in the odds of success by 24% since $\exp(0.218) = 1.243$.

Clearly the professor also had a significant effect. Using Professor 1 as a reference we see that for a given score on the basic skills test, the odds of success for students who have Professor 3 are 2.5 times the odds of success for students who have Professor 1 since the odds ratio of success for Professor 3 is $\exp(0.916) = 2.500$. Similarly, the odds of success for students who have Professor 4 are 2.3 times that of students who have Professor 1 since $\exp(0.845) = 2.327$. The odds of success for students who have Professor 1 are about 1.4 times that of Professors 2 and 5 since $\left(\exp(-0.323)\right)^{-1} = \left(0.724\right)^{-1} = 1.381$ and $\left(\exp(-0.364)\right)^{-1} = \left(0.695\right)^{-1} = 1.439$, respectively. We note that Johnson and Kuennen also found a professor effect.

In Figure 3, we see graphs of the predictive logistic models for the probability of success for students with each professor as a function of basic skills score. For each instructor, we see a positive relationship between math skills as measured by the basic skills exam and success in the course but the extent of this relationship varies across the professors. Students who have a score of 10 on the basic skills test have a 52% chance of passing the course with Professor 5, a 53% chance with Professor 2, a 61% chance with Professor 1, a 78% chance with Professor 4 and an 80% chance with Professor 3. Conversely, to have an approximately 60% chance of passing the course students would need a score of approximately 6 or higher with Professors 3 and 4, approximately 10 or higher with Professor 1, and approximately 12 or higher with Professors 2 and 5.

**Figure 3. Probability of Success with Each Professor
given the Score on the Basic Skills Test**
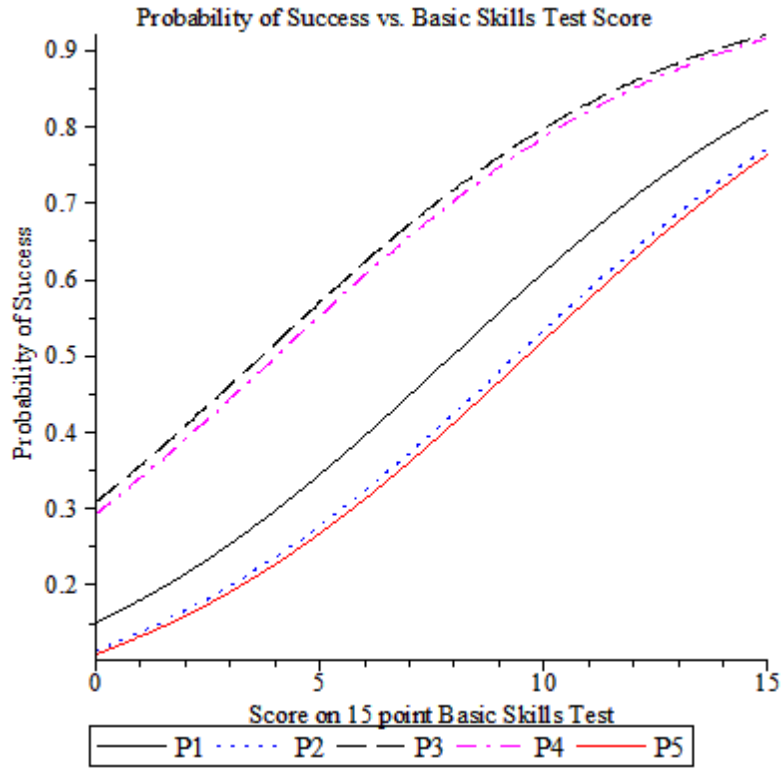
We note that while all of the professors who taught the course during the study used the same textbook each semester, their methods of teaching, use of technology, and methods of assessment varied. All instructors, except Professor 5, used a statistics calculator such as the TI-83 or TI-84. Professor 5 required a basic four function calculator and used statistical tables. Professor 5 also only gave in-class tests for their assessment. However, this professor regularly used in-class worksheets on which students worked problems. All of the other professors used methods of assessment such as graded homework, in-class quizzes, and/or a project in addition to in-class exams.

4.4 Adding the Effect of the Professor and Hours Spent at the Learning Center

Unfortunately only a small number of students actually went to the learning center for tutoring. Of the 702 students who remained in the class after the initial drop/add period, only 117 (or 16.7%) attended the free tutoring at the learning center for a total of more than one hour for the entire semester and only 89 (12.7%) attended the free tutoring at the learning center for a total of more than two hours over the entire semester. When we added the indicator variable for whether the student had spent more than one hour in the lab during the entire semester to our regression model in Section 4.3 it had a positive coefficient of 0.313 with a p-value that of 0.164. When we added the indicator variable for whether the student had spent more than two hours in the LC

during the entire semester, it had a positive coefficient of 0.291 with a *p*-value of 0.241 (see [Table 5](#)).

Table 5. BLR with Professor and Learning Center

	B	S.E.	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	Upper
SCORE15	0.221	0.034	0.000	1.247	1.166	1.333
I_LC2	0.291	0.248	0.241	1.337	0.822	2.176
P2	-0.352	0.201	0.079	0.703	0.474	1.042
P3	0.940	0.296	0.001	2.561	1.433	4.576
P4	0.875	0.420	0.037	2.398	1.053	5.460
P5	-0.331	0.224	0.138	0.718	0.463	1.113
Constant	-1.800	0.351	0.000	0.166		

While we were disappointed with these results we also discovered that there was a potential problem with adding the hours spent in the LC as a new variable to our regression model because whether the student attended tutoring or not in the LC was *not* independent of professor. In [Table 6](#) we see the number of students who attended the LC for more than 2 hours by professor. A chi-square test for independence showed a definite association between professor and use of the LC $\left(\chi^2 = 39.5, df = 4, \text{p-value} < 0.001 \right)$. A similar result holds for the use of the LC for more than 1 hour. We also tried investigating any possible interaction between professor and hours spent in the LC by adding the appropriate interaction terms to our model. The results were insignificant.

Table 6. Hours Spent in the Learning Center

	Hours Spent in Learning Center During the Semester 0=At most Two 1=More than Two	
Professor	**0**	**1**
P1	218	33
P2	150	46
P3	79	6
P4	34	1
P5	132	3

We note that Professor 5, who did not use a statistics calculator, had very few students attend the LC tutoring. We believe this may be because most of the tutors hired by the LC had learned statistics using a statistics calculator and were not proficient at using tables. Also, it is clear from

Table 6 that students in classes with Professors 1 and 2 were more likely to use the LC tutoring than those with other professors.

4.5 Analysis of the Basic Math Skills Quiz

Table 7 shows the percent of the 702 LU students who answered each question correctly versus the percent of the 292 Johnson and Kuennen students.

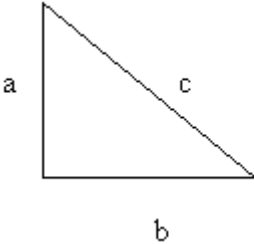**Table 7. Percent of Students Who Answered Each Question Correctly**

Question	1	2	3	4	5	6	7	8
% LU correct	96.01	75.93	98.43	88.46	70.66	50.85	38.60	54.99
% J&K Correct	96.99	84.89	97.53	92.35	77.87	61.6	68.32	76.10

Question	9	10	11	12	13	14	15
% LU correct	51.85	39.03	60.68	10.54	86.47	50.00	72.36
% J&K Correct	69.42	45.86	72.10	22.93	90.11	66.3	82.54

We refined our model in Section 4.3 by replacing the score on the 15-question basic skills test with 15 indicator functions, one for each question, where a value of one for the indicator function corresponds to a correct answer for that question. Thus we are considering the *independent* effect of each question. We realized that this may not be completely valid as some of the questions measure similar mathematical skills.

In Table 8 we give the question text for questions with a positive coefficient and a *p*-value less than 0.20. See Table 9 in the Appendix B for the full results.

Table 8. Questions With a Positive Coefficient and *p*-value Less Than 0.20.

Question Number	Question Text	*p*-value
7	Find the area of the right triangle drawn below The length of side a = 3 and the length of side b = 4, and the length of side c = 5.	0.001
4	Suppose that $x = \dfrac{a}{b}$. Then if $x = 4$ and $b = 2$, solve for a.	0.012
6	Perform the following division: $\dfrac{1/2}{1/3}$	0.013
13	In a group of 900 voters, two-thirds said they would vote for the incumbent in the race for Governor. How <u>many</u> of the 900 voters said they would vote for the incumbent?	0.041
1	Solve the following system of equations for *x*: $x = y - 6$ $y = 10$	0.107
2	Solve the following system of equations for x: $y = 2x + 3$ $y = 3x$	0.175

We found it interesting that questions 4, 6 and 13 involve using ratios, question 7 is a very basic question about finding the area of a right triangle when the leg lengths are given, and questions 1 and 2 involve basic algebraic manipulation (but not using ratios). In general all except one of the questions (Question 7) that we found significant at the 5% level were questions involving ratios and percents. This suggests that basic facility with ratios have a positive association with our students' success in introductory statistics. We note that Johnson and Kuennen found questions 2, 4, 6, 10, and 12 to be significant at the 10% level. Even though they had a different student population, we find it interesting that we both found questions involving ratios (4 and 6) significant. Lastly, in preliminary analysis of the modified basic skills test (with our five added questions) we found that question 19 ("Approximately 5.3% of Americans are color blind. Thus the ratio of the number of color blind Americans to the total number of Americans would result in the proportion…") was significant at the 1% level, questions 6, 7, and 20 ("Six hundred forty five adults out of 1000 randomly chosen adults said they "hate math." What percent of these 1000 adults hate math?") were significant at the 5% level, and questions 4 and 13 were significant at the 10% level.

We conjecture that the basic mathematics skills represented in the questions we found significant correspond to skills needed to be successful in our introductory statistics course. Even though our course is very algebraically light, it is conceptually heavy. Our emphasis in the course is on the correct use and interpretation of statistical procedures. While the use of formulas in the course is kept to a minimum, we do expect students to understand concepts and work appropriately with symbols. It is important for our students to be able to reason using basic statistical concepts. Many of these concepts derive from elementary mathematical constructs such as ratios. For instance, the ability to convert from counts to proportions to percents and conversely is needed for descriptive and inferential statistics for a single categorical variable. Questions 13, 19 and 20 cover mathematical skills of this nature. We found it interesting that questions 4 and 6 were also significant. Granted being able to manipulate ratios does not imply understanding of them, but not being able to do this probably indicates some fundamental misunderstanding. We were saddened to discover that many of our students did not recall how to divide fractions (question 6). Even if they did not remember arithmetic with fractions, we would hope that they could reason their way to the answer in question 4 by understanding the meaning of the symbols (i.e. if they understood the symbols they should be able to reason "what number divided by 2 equals 4?" and thus answer the question correctly). We believe question 1 was also a question in which students should be able to reason their way to the answer by understanding the symbols even if they don't remember how to solve an equation. One of the most important concepts in introductory statistics is the z-score (or standardized score). Students need to be able to understand the meaning of this concept and make reasonable conclusions based on it (i.e. in inference). The z-score is fundamentally a ratio that arises via conversion from the units of the variable to the location of the variable from the mean in terms of number of standard deviations. When reasoning using z-scores it is also important for students to be able to visualize the normal curve and compare areas. Although question 7, which involves finding the area of a right triangle given its side lengths was significant, we are not sure how well this corresponds to being able to reason with area. We do think that many of our students did not remember the area of a triangle. Most of our students answered (d) for this question (45%, more than those who answered it correctly). Perhaps this is because even though they knew to multiply two numbers, they really did not understand that they were getting the area of the square and hence the area of the triangle would be half that.

The bottom line is that even when teaching a conceptually heavy but computationally light statistics course, basic mathematics skills, such as the ability to work with ratios, are important. We believe that these skills are needed for the ability to reason using simple statistical symbols and concepts. If we are trying to teach statistics to students who cannot work with, let alone reason with symbols or ratios, then they are probably going to have a difficult time in the course.

5. Discussion and Future Work

The results from this study have not only reinforced the results of Johnson and Kuennen (2006) but have also given us valuable information. Because this study has informed us about potential factors leading to success in our introductory statistics course it has prompted us to start implementing changes that will, hopefully, improve our students' success.

First we have learned more about the mathematical background of our population of students who take MATH 171 which has altered how we teach the course. We were surprised at the level of the basic mathematics skills of our students and now no longer assume our students have basic knowledge of ratios, algebra, and area. Instead of a review at the beginning of the semester of basic mathematics concepts, we opt for a "just in time" approach where we review basic mathematical concepts that are fundamental to a statistics concept before or as we introduce the statistics concept. This is also in line with what Johnson and Kuennen recommended in their paper. We now review converting from counts to proportions and percents when we teach descriptive statistics for a single categorical variable. Several times during the semester we will review (or sometimes as we like to say "refresh our students' memory") on the relationship between decimals and percents since most of our computations are done using decimals but our interpretations use percents. We spend more time interpreting histograms and especially relative areas in histograms. For instance we ask our students to tell us which of two events are more likely based only on the graph of the histogram without doing any number crunching. This leads to a more natural transition to understanding the probability of events represented by area under a density curve. Before we start linear regression we review basic concepts about lines including the equation of a line, the meaning of the slope, and how to graph a line. And though it seems obvious to us now, we show every step when doing any algebraic manipulation. Although these techniques seem to improve our students' immediate understanding of the statistical concept, we are not sure how much our brief review compensates for fundamental lack of knowledge.

Second, we continue to use the Basic Skills Test on the first day of class to identify students that will potentially have a difficult time succeeding in the course. The test takes no more than 20 minutes to administer and we find it worthwhile for quick identification of these students. We usually give the test on the first day of class. On the second day of class we discuss the scores with the students. We let the students know that if they score less than 50% (on the 20 point basic skills test) then they are missing some mathematics skills that will be important for the class. We emphasize to them that students with a low score generally do not do as well as those with higher scores (we also are careful to acknowledge that a high score does not imply the class will be easy for the student). However we do stress to them that it is certainly possible to do well in statistics even if they had a low basic skills test score provided they are willing to work very hard. For students who want to remain in the class (and most of them do) we recommend that they start attending the LC regularly. We also recommend that they start to use our office hours on a regular basis. Lastly, we encourage our students to come talk to us if they are worried about staying in the class or are not sure if they should stay in the class. For students who are not required to take statistics and decide not to remain in the class, there are other general education mathematics courses they can take.

We note that although the LC was not associated with success in the course via our study, we are not ready to discount it, and in fact we highly recommend it to our students. We think there are several reasons for not seeing LC attendance as a predictor of success in the course including individual motivation and the fact that very few of our students actually used their services. We believe that if the choice of which technology to use (statistics calculators, etc.) was more consistent across sections of the course then it would be easier for LC tutors to work with all students in the course, not just those in sections that use the technology they are familiar with. Our university does not offer remedial courses in mathematics so we have been in discussion

with the LC about possible remediation sessions for students who lack fundamental mathematical skills. Because our introductory statistics course is a general education course, any student admitted to the university can take it. Thus we were not able to use many of the recommendations given by Johnson and Kuennen regarding placement and remediation.

Third, this study has led us to question our assessment methods in the class and, in particular, the potential need for regular assessment in addition to in-class tests. Many of us have begun to use on-line homework systems to help students keep up with the material. While the data is not in on these systems, some of us believe that these regular homework assignments with instant feedback contribute positively to student success in the class.

So, have these changes resulted in a better success rate for our students? One of us has kept track of their student success rate in MATH 171 over the years and has noticed that since the end of the study, student success has increased from 61.5% of students (279 out of 454) earning a C or better (Fall 2004 to Spring 2008) to 68% of students (187 out of 275) earning a C or better (Fall 2008 to Fall 2010) which is statistically higher $\left(p = 0.037 \right)$. Clearly it is not possible to establish a causal relationship but we believe that our changes in pedagogy, early intervention, and assessment have contributed to this increase. This fall semester (2010) this professor taught three sections of MATH 171. Of the 103 students who took the basic skills test and did not withdraw within the first week of class, 16 scored less than 50% on the test. The grades earned by those students were 2 B's, 8 C's, 1 D, 3 F's, and 2 W's. Six of those students attended the LC for more than two hours during the entire semester. Of those six, five completed the course with a C or better. Of the remaining ten students who did not attend the LC for more than two hours, five were successful and five were not. In particular, two of the students with very low basic skills scores (they both had 30% correct) were the two who earned B's in the course. These two students attended the LC for 16.5 and 18 hours each. Certainly it is hard to account for individual motivation and our sample size is small, but we believe that by giving these students an early warning regarding their mathematical skills many of them took our advice about working hard and attending the LC. Hopefully our early intervention was a contributing factor in their success.

Lastly, like Johnson and Kuennen we also found a significant professor effect which we were both surprised and disappointed to see. We believe that a general education course at this level should be more uniform across sections, i.e. two students with the same basic mathematical skills should have essentially the same chance of success regardless of professor. While our department has a strong history of academic freedom, there is increasing pressure to standardize the general education offerings at the institution. In reaction to our results and as part of a different assessment initiative not related to this study, we created a set of multiple choice questions to be used on all professors' final exams. Last academic year (2009/10) we started implementation of these assessment questions and will analyze and refine them over the next few academic years. Several of the faculty would like to see a common final exam in MATH 171 but there is no consensus on this at this time. We plan to conduct a follow-up study in the future to gauge how well, if at all, common final exam questions or a common final exam alleviate the professor effect.

Appendix A: Modified Basic Skills Test

The first fifteen questions are from Johnson and Kuennen (Johnson and Kuennen, 2006) and used with permission; the last five questions were added by the authors. The analysis in this paper was done using only the first 15 questions.

Basic Skills Mathematics Quiz

Answer the following mathematics questions to the best of your ability. Please do not use a calculator.

1. Solve the following system of equations for x:
$$x = y - 6$$
$$y = 10$$

(a) -60   (b) 10/6   (c) 3   (d) 4   (e) -4

2. Solve the following system of equations for x:
$$y = 2x + 3$$
$$y = 3x$$

(a) 0   (b) 3   (c) 3/5   (d) -3/2   (e) none of the above

3. Suppose that $x = \dfrac{a}{b}$. Then if $a = 6$ and $b = 2$, solve for x.

(a) 12   (b) 8   (c) 3   (d) 4   (e) 1/3

4. Suppose that $x = \dfrac{a}{b}$. Then if $x = 4$ and $b = 2$, solve for a.
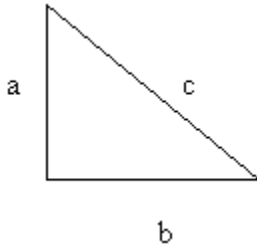
(a) 1/2   (b) 2   (c) 4   (d) 8   (e) 16

5. Suppose that $x = \dfrac{a}{b}$. Then if $x = 4$ and $a = 8$, solve for b.

(a) 1   (b) 2   (c) 32   (d) 4   (e) 1/2

6. Perform the following division: $\dfrac{\frac{1}{2}}{\frac{2}{3}}$
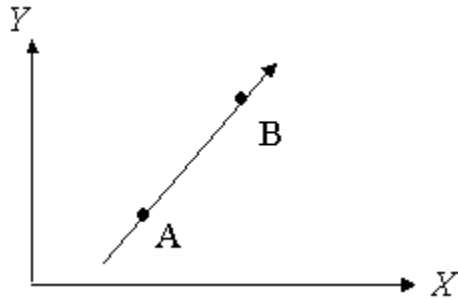
(a) 3   (b) 3/2   (c) 3/4   (d) 4/3   (e) 1/3

7. Find the area of the right triangle drawn below.

The length of side a = 3 and the length of side b = 4, and the length of side c = 5. The area of the triangle is:

(a) 3   (b) 4   (c) 6   (d) 12   (e) 25
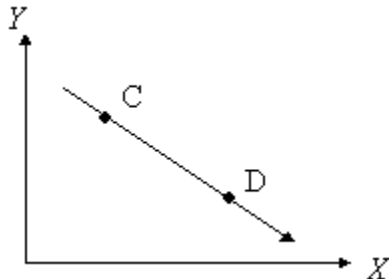
8.

The coordinates of point A are (1,2) and the coordinates of point B are (2,4). Find the slope of the line.

(a) 1/2   (b) 1   (c) -1 (d) 2   (e) -2

9.

The coordinates of point C are (1,4) and the coordinates of point D are (5,2). Find the slope of the line.

(a) 1/2   (b) -1/2   (c) 2   (d) -2   (e) 5/4

10. Suppose you want to carpet a rectangular room that is 6 *feet* by 12 *feet*. Carpet costs $10 per square *yard*. Note that 1 yard = 3 feet. How much does it cost to carpet the room?

(a) $720   (b) $2160   (c) $240   (d) $80   (e) $8

11. The fraction 13/38 is approximately

(a) 0.15   (b) 0.25   (c) 0.35   (d) 0.45   (e) 0.55

12. The square root of 100,000 is about

(a) 30   (b) 100   (c) 300   (d) 1,000   (e) 3,000

13. In a group of 900 voters, two-thirds said they would vote for the incumbent in the race for Governor. How <u>many</u> of the 900 voters said they would vote for the incumbent?

(a) 200   (b) 300   (c) 330   (d) 600   (e) 660

14. In 1997, a total of 3,000 students were enrolled at Moo University. In 1998, the corresponding figure was 3300. What is the percent increase in the number of students from 1997 to 1998?

(a) 1%   (b) 3%   (c) 10%   (d) 30%   (e) 33%

15. What is 80% of 60?

(a) 24   (b) 36   (c) 40   (d) 48   (e) 50

16. Order the numbers 0.08, 0.10, and 0.025 from *largest* to *smallest*:

(a) 0.10, 0.08, 0.025   (b) 0.025, 0.08, 0.10   (c) 0.08, 0.025, 0.10

(d) 0.10, 0.025, 0.08   (e) 0.025, 0.10, 0.08

17. Which of the following mathematics symbols, when inserted in the blank below, makes the statement true:

The Statement: 31____52

(a) >   (b) <   (c) =   (d) None of these

18. One "blip" is defined to be 4 feet. Below you are shown the location of two objects along a straight path measured in feet. What is the distance between the two objects in <u>units of blips</u>?
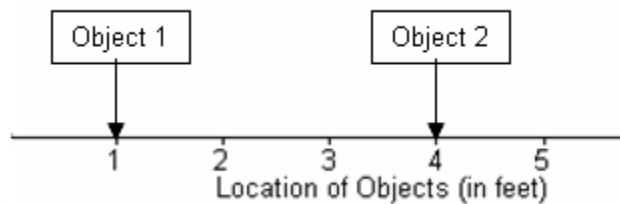
(a) 3 blips   (b) 0.5 blips   (c) 0.75 blips   (d) 1 blip   (e) None of these

19. Approximately 5.3% of Americans are color blind. Thus the ratio of the number of color blind Americans to the total number of Americans would result in the proportion:

(a) 5.3   (b) 0.53   (c) 0.053   (d) 0.0053 (e) None of these

20. Six hundred forty five adults out of 1000 randomly chosen adults said they "hate math." What percent of these 1000 adults hate math?

(a) 0.645%   (b) 6.45%   (c) 64.5%   (d) 645%   (e) None of these

Appendix B: Computer Output

Table 9. Binary Logistic Regression with Professors and Questions

	B	S.E.	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
					Lower	Upper
P2	-0.332	0.204	0.103	0.717	0.481	1.070
P3	0.908	0.302	0.003	2.479	1.371	4.483
P4	0.835	0.429	0.051	2.305	0.995	5.343
P5	-0.433	0.229	0.059	0.649	0.414	1.017
I1	0.721	0.447	0.107	2.056	0.856	4.940
I2	0.264	0.195	0.175	1.303	0.889	1.909
I3	0.116	0.698	0.868	1.123	0.286	4.415
I4	0.677	0.269	0.012	1.967	1.160	3.336
I5	-0.257	0.189	0.172	0.773	0.534	1.119
I6	0.426	0.172	0.013	1.531	1.094	2.143
I7	0.643	0.186	0.001	1.902	1.321	2.738
I8	-0.076	0.181	0.674	0.927	0.650	1.322
I9	0.200	0.184	0.275	1.222	0.853	1.751
I10	0.081	0.171	0.635	1.085	0.775	1.518
I11	0.001	0.175	0.995	1.001	0.710	1.411
I12	0.259	0.299	0.387	1.295	0.721	2.327
I13	0.507	0.249	0.041	1.661	1.020	2.704
I14	0.022	0.174	0.899	1.022	0.727	1.438
I15	0.186	0.192	0.333	1.204	0.827	1.753
Constant	-2.246	0.827	0.007	0.006		

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22