Should Calculus be a pre-requisite for Business Statistics? A longitudinal study

Carla Nietfeld,
Miami University

Hubert Setzler,
Francis Marion University

Hari K Rajagopalan
Francis Marion University

ABSTRACT

Business Statistics is a required course for undergraduate business majors and presents significant challenges for students with weak quantitative and critical thinking skills. This paper shows that changing the pre-requisite for the Business Statistics course from Business Calculus to Probability and Statistics makes a significant positive impact, despite the increase in course content, on student performance for business students at a comprehensive regional university in the southeast. It is recommended business schools that experience difficulties with students successfully completing business statistics to carefully consider curriculum changes, particularly the chosen pre-requisite courses.

Keywords: Business Statistics, Curriculum Change

INTRODUCTION

All undergraduate business majors are required to take Business Statistics as part of the business core. This course provides a foundation for students and is the pre-requisite for many upper-level classes such as Production and Operations Management, Finance, Marketing Research, Business Analytics and Management Science. Most business schools require their students take Calculus or Business Calculus as part of the general education requirement, and this course is the pre-requisite for Business Statistics. Islam et. al (2008) found that students who took Calculus performed better in Business Statistics than others. This also confirms the findings of Johnson and Kuennen (2006) that a priori mathematical skills measured are strong predictors of student performance. Math preparation and math skills are repeatedly strong predictors in student performance in Business Statistics(Dupuis et al., 2011; Lester, 2007; Li, Uvah, & Amin, 2012; Rochelle & Dotterweich, 2007; Wang, Tu, & Shieh, 2007). The basic recommendations that have come from this analysis is student performance in Business Statistics would improve by requiring them to take more math courses in calculus or imposing a minimum grade of C or above in Calculus.(Green, Stone, Zegeye, & Charles, 2007, 2009).

These solutions merely increase the bar thus creating more barriers to students who have a weak mathematical background. Rather than impose further restrictions on who can take Business Statistics, it is proposed that students be allowed to take an introductory course in probability and statistics as part of the general education requirement thus enhancing their ability to comprehend and understand the material in Business Statistics. This paper analyzes ten years of data collected while teaching the introductory business statistics course at a comprehensive regional university in the southeast and examine student performance variation due to changes in course content and the pre-requisite course. The next section contains a brief literature review, followed by the methodology for data collection and then the results section with the last section providing the conclusion and recommendation.

LITERATURE REVIEW

The literature on teaching business statistics starts in the 1970s arguing that teaching statistics should be innovative and exciting(Hogg, 1972). Brightman and Broida (1975) used statistics classes to develop critical thinking skills and later Brightman (1977) compared a traditional statistics course to a problem-solving orientation course with an emphasis on investigating real world problems. The conversation continued with a growing realization that statistics, particularly the introductory course, is viewed as difficult and unpleasant by many students and frustrating and unrewarding to teach by many instructors(Garfield, Hogg, Schau, & Whittinghill, 2002). This was confirmed by Harrington and Schibik (2004) who suggested alternatives to the lecture class format for the introductory business statistics course. While introductory business statistics continues to be unpopular among students and frustrating to teach for faculty, the course has become increasingly important in business curriculum due to the growth and popularity of data analytics.

The importance of statistical understanding was recognized in the early 1970s, but it was not until the 1990s that the importance of reforming the teaching of introductory statistics gained attention(Cobb, 1993). With an emphasis on promoting “statistical thinking”(Snee, 1990, 1999; Wild & Pfannkuch, 1999), there was increased emphasis on data analysis due to the pressure put on educational systems due to jobs requiring more analytical, quantitative, and computing skills(Moore, 1997).

There were many attempts to look at improving student performance by using (1) Multimedia (Cuban, 2003; Harrington & Schibik, 2004; Velleman & Moore, 1996) , (2) homework management systems (Chua-Chow, Chauncey, & McKessock, 2011; Palocsa & Stevens, 2008) and (3) focusing on the pre-requisites(Dupuis et al., 2011; Lester, 2007; Li et al., 2012; Rochelle & Dotterweich, 2007; Wang et al., 2007). Both use of multimedia and homework management systems have shown inconclusive results with some studies showing a positive impact and others arguing that it does not. However, the studies which focus on pre-requisites all show that math skills are the best predictor for student performance in Business Statistics. The recommendations from these studies however focus on increasing the Math pre-requisites for Business Statistics (Green et al., 2007, 2009) which essentially results in weeding students out of the program. There has been no research specifically requiring two probability and statistics courses rather than calculus for business students with the first one being a strong foundation on probability and the second course the regular business statistics course.

METHODOLOGY

Data was collected from a university whose mission is to serve the state and local area and is situated in an economically depressed area where public schools are not adequately funded(Black, 2017; Street, 2018). Much of student body is first generation students who are either working part time or full time while attending classes. In addition, many of the students struggle grasping the quantitative skills required for an undergraduate degree. Students often take introductory math before being placed into college level algebra and then calculus. Until Fall 2011, the required math course for business students following College Algebra II was Business Calculus, the pre-requisite for Business Statistics at that time.

In 2006, the School of Business received feedback from companies requiring students to have stronger analytical skills. The School of Business decided to increase the content and depth of the business statistics course which resulted in a deterioration of student performance. To improve student performance the pre-requisite course was changed from Calculus to Probability and Statistics. Total student enrollment is shown in Table 1 (Appendix).

During this period, the Business Statistics course was taught by two different professors, both from the same discipline. The two professors worked closely with one another to coordinate teaching styles, grading rubrics, and the type of exams given. All changes in the course were synchronized between the two professors with the exams being similar and consistent over a ten-year period. Thus, it is reasonable to assume that exam grades as well as overall course grades are comparable across classes and years.

In the first year of data, Fall 2006 – Summer 2007, the curriculum covered (1) Descriptive Statistics, (2) Introduction to Probability, (3) Discrete Distributions, (4) Continuous Distributions, (5) Sampling and Confidence Intervals and (6) One Sample Hypothesis Testing (Z scores only). By the Fall of 2007, based on feedback from stakeholders, the curriculum was expanded to include One Sample Hypothesis Testing (Z and t scores) and Two Sample Hypothesis Testing. After this content expansion, there was a perceptible drop in student performance. Despite efforts by the two faculty members attempting different methods to improve grades, student performance continued to deteriorate.

In 2010-2011, the School of Business dropped Calculus and introduced the Probability and Statistics course offered by the Mathematics Department as the new pre-requisite for Business Statistics. The Probability and Statistics course covered (1) Descriptive Statistics, (2) Introduction to Probability, (3) Discrete Distributions, (4) Continuous Distributions, and (5) Sampling and Confidence Intervals. This allowed the professors teaching Business Statistics to change their curriculum to (1) Discrete Distributions, (2) Continuous Distributions, (3) Sampling and Confidence Intervals, (4) One Sample Hypothesis Testing (Z and T scores), (5) Two Sample Hypothesis Testing (Z, Independent Sample t-tests and Matched Sample t-tests), (6) Chi Square and (7) Simple Regression. This ten-year period broken down into four different time periods. Period 1 is from 2006 – 2007 before additional material was added to Business Statistics and pre-requisite was Calculus. Period 2 is from 2007 – 2011 when an additional chapter was added, and calculus was the pre-requisite. Period 3 is from 2011 – 2013 when two more additional chapters were added, and the pre-requisite could have been Calculus or the probability and statistics class. Period 4 is from 2013 – 2016 where the pre-requisite for all students is the probability and statistics class.

RESULTS

Grades were assigned on a 4-point scale with 0 representing F and 4 representing A. Table 2 (Appendix) shows the performance of students in Business Statistics during the four time periods. The first part of Table 2 (Appendix) has the mean and standard deviation when students who withdrew from the course (Grade W) during the semester were assigned a grade of 0. The average GPA drops between Time Period 1 and Time Period 2, goes up slightly in Time Period 3, and goes up again in Time Period 4. The standard deviation drops from 1.51 to 1.34 as the rigor increased in Business Statistics. Time Period 3, contained a mixture of students with Business Calculus and Probability and Statistics as pre-requisites, does not show much variation compared to Time Period 2. The real increase in average performance happens in Time Period 4 when all students have Probability and Statistics as a pre-requisite.

Analyzing the students who completed the course (excluding students with a W from the sample), the sample size for Time Period 1 drops from 195 to 142 as 53 (27.18%) of the students dropped the course. There is a huge increase in students completing the course with the drop percentage going down from 27% in Time Period 1 to 18-19% in Time Period 2 and 3 to 10% in Time Period 4. As expected, the average GPA for all time periods is now higher (compared to average GPA in Table 2 (Appendix)) as we exclude a substantial number of students assigned a GPA value of "0". In addition, there is a substantial increase in average performance from Time Period 2 and 3 to Time Period 4, although the average performance at Time Period 4 (1.94) is still less than Time Period 1.

Since the residuals for GPA are non-normal, Kruskal-Wallis H test (1952) is used. There is a significant difference (p-value < 0.0001) in GPAs, regardless of whether the students who withdrew from the course were included. For pair-wise comparisons Steel-Dwass-Critchlow-Fligner method recommended by Hollander and Wolfe (1999) was used. Table 3 (Appendix) shows the pair wise comparison for student performance for different time periods with and without the students who withdrew from the course. In both cases Time period 4 is significantly different from 2 and 3 and not significantly different from 1. There is a significant drop in performance in time periods 2 and 3 which is then corrected by the change in pre-requisites in time period4.

To investigate how specific student grades were impacted during this time, GPA was grouped into three categories: (1) Above Average (A, B+ and B), (2) Average (C+, C, D+ and D) and (3) Below Average (F and W). Figure 1 (Appendix) shows student performance in these three categories. The percentage of students in the below average category initially increases due to the expanded course content, peaking in 2009 – 2010 at 55%. With the change in the pre-requisite course, this percentage begins to drop and reaches its minimum of about 27% in 2015 – 2016. Similarly, the percentage of students in the above average category drops to a low of 9.74% in 2009 – 2010 before reaching its maximum of 36.79% in 2015 – 2016. There is a clear negative trend in the percentage of students in the below average category and a positive trend in the percentage of students in the above average category, which indicate the positive impacts associated with the course changes, specifically the pre-requisite change. It is to be noted that course content of the Business Statistics course also increased in time period 4. Despite the increase in course content, students performed better than previous time periods due to a firm grounding in descriptive statistics and probability gained from the new pre-requisite course.

The aggregate course GPA for students across all years of data was examined for individual exam outcomes compared across two time periods. Table 4 (Appendix) shows five exams (labeled Exam A – E) given throughout the entire time frame under investigation and lists the content of each exam along with the time period in which each exam was given. Exams A – C were given in time periods 1 and 2 while Exam D was only partially given in time period 1 and fully given in time period 2. Exams B – E were given during time periods 3 and 4. During time periods 3 and 4, Exam A was not given as the material was previously covered in the new pre-requisite, Probability and Statistics.

Due to the overlap of exam material during time period 2 and time period 4, we focus our attention on comparing these two time periods. During time period 2, Exams A – D were given and a significant decline in student performance occurred compared to the previous time period. Similarly, during time period 4, Exams B – E were given and a significant improvement in student performance was observed. In support of the change in the pre-requisite course, it could be argued that student performance should significantly improve on Exams B, C, and D. An increase in scores on Exams B and C should be observed, because the exam material is also covered in the new pre-requisite, Probability and Statistics. In addition, any improvement on Exam D would indicate a better understanding of the new material due to a stronger foundation in probability and statistics.

Table 5 (Appendix) displays the comparison of student performance on each exam between time periods 2 and 4. The t-tests show that there is no significant improvement in student performance on Exam B but there is significant improvement in student performance on Exams C and D. This has important implications to business courses as the material covered on Exams C and D contain sampling, confidence intervals, one sample and two sample hypothesis testing. These are the foundations of statistics, and it is crucial that students understand these topics for upper-level business courses in marketing research, business analytics, operations, finance, and other areas. Furthermore, in time period 4, Exam E covers chi-square and simple regression. These are complex topics and students are unlikely to do well unless they have a firm understanding of hypothesis testing. An average score of 75% on Exam E shows that students have benefitted from the two-semester sequence of Probability and Statistics and Business Statistics

Each of the exams were designed so that the material of one build upon another and thus requires the student to have a good understanding of the previous exam material in order to improve on the next exam. Time period 2 shows an unencouraging pattern in student performance with average scores increasing on Exam B and then decreasing on Exam C. In contrast, in time period 4 there is consistent improvement in student performance from one exam to the next.

CONCLUSION AND RECOMMENDATIONS

This study analyzes ten years of data collected from 2006-2016 while teaching Business Statistics at a comprehensive regional university in the southeast. Student performance variation due to changes in course content and the pre-requisite course from Business Calculus to Probability and Statistics was examined. Changing the pre-requisite course was shown to increase student performance. Based on these results, the following recommendations are offered for institutions who want to improve business student outcomes in Business Statistics.

Business Schools would need to consider whether they need Calculus as a pre-requisite for Business Statistics and instead allow students to choose Probability and Statistics as the replacement course. This may be especially important to students who have a lower Math SAT/ACT score, as these students may lack the level of knowledge and skills required to successfully complete Business Statistics. Allowing students to take a course like Probability and Statistics as a pre-requisite may help students to develop the skills that are critical in Business Statistics, such as analyzing graphs and evaluating simple equations, whereas Business Calculus addresses entirely different material. As shown in the discussion, changing the pre-requisite course has increased overall student course GPA as well as individual exam scores, supporting the choice of the new pre-requisite option.

In addition, it is recommended that Business Schools and Mathematics Departments coordinate Business Statistics and its pre-requisite course to make sure the courses build upon one another in a way most appropriate for their university's student body. For the university under discussion, it is imperative that Business Statistics overlaps and fortifies some of the material introduced in Probability and Statistics to help students grasp an even better understanding of the concepts before moving to more complex material. Specifically, from the discussion regarding individual exams, the benefit of having a pre-requisite that directly relates to the course under investigation is apparent in student performance outcomes. This university's students performed better on all topics covered in Business Statistics after taking Probability and Statistics as a pre-requisite course.

It is important to note that this study has some inherent weaknesses. The professors did not collect data with the intention of conducting this study. Therefore, student demographic data is not present, neither are the actual pre-requisites students took, their performance in the two mathematics classes they took as part of their general education requirement, nor their original SAT/ACT scores. Having this data to include in the analyses would allow us to make much stronger arguments than what is presented here. However, the effect size of changing the pre-requisite course is large enough that it can be safely concluded that the pre-requisite course change has had a significant positive impact on student performance in Business Statistics.

REFERENCES

Black, D. (2017, 11 26). *Kids will suffer because court refused to do its duty*. Retrieved from The State: https://www.thestate.com/opinion/op-ed/article186489863.html

Brightman, H. (1977). An evaluation of two models of undergraduate statistics. *Decision Sciences, 8*, 287-299.

Brightman, H., & Broida, M. (1975). On problem solving, motivation and statistics. *The American Statistician, 29*, 164-166.

Chua-Chow, C., Chauncey, C. A., & McKessock, D. (2011). Enhancing the Study of Business Statistics with an e-Homework System. *Journal of Education and Vocational Research, 1*(3), 96-105.

Cobb, G. (1993). Reconsidering Statistics Education: A National Science Foundation Conference. *Journal of Statistics Education, 1*(1).

Cuban, L. (2003). *Oversold and Underused Computers in Classroom.* Harvard University Press.

Dupuis, D. N., Medhanie, A., Harwell, M., Lebeau, B., Monson, D., & Post, T. (2011). A Multi-Institutional Study of the Relationship Between High School Mathematics Achievement and Performance in Introductory College Statistics. *Statistics Education Research Journal, 11*(1), 4-20.

Garfield, J., Hogg, B., Schau, C., & Whittinghill, D. (2002). First Courses in Statistical Science: The Status of Educational Reform Efforts. *Journal of Statistics Education, 10*(2).

Green, J., Stone, C., Zegeye, A., & Charles, T. (2007). Changes in Math Prerequisites and Student Performance in Business Statistics: Do Math Prerequisites Really Matter? *Journal of Economics and Finance Education, 6*(2), 27-38.

Green, J., Stone, C., Zegeye, A., & Charles, T. (2009). How Much Math Do Students Need to Succeed in Business and Economics Statistics? An Ordered Probit Analysis. *Journal of Statistics Education, 17*(3). doi:10.1080/10691898.2009.11889532

Harrington, C. F., & Schibik, T. J. (2004). Methods for maximizing student engagement in the introductory business statistics course: A review. *Journal of American Academy of Business, 4*, 360-364.

Hogg, R. V. (1972). On statistical education. *The American Statistician, 26*(3), 8-11.

Hollander, M., & Wolfe, D. (1999). *Nonparametric Statistical Methods.* New York: John Wiley and Sons.

Islam, F., Khan, S., Wilson, I., & Gooch, R. (2008). The value of prerequisite courses for statistics. *The Journal of Business Inquiry, 7*(1), 61-67.

Johnson, M., & Kuennen, E. (2006). Basic Math Skills and Performance in an Introductory Statistics Course. *Journal of Statistics Education, 14*(2).

Kruskal, W. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association, 47*(260), 583-621. doi:10.10802F01621459.1952.10483441

Lester, D. (2007). Predicting Performance in a Psychological Statistics Course,". *Psychological Reports, 101*, 334.

Li, K., Uvah, J., & Amin, R. (2012). Predicting Students' Performance in Elements of Statistics. *US-China Education Review, 10*, 875-884. Retrieved from https://files.eric.ed.gov/fulltext/ED537981.pdf

Moore, D. S. (1997). New pedagogy and new content: the case of statistics. *International Statistical Review, 65*, 123-137.

Palocsa, S. W., & Stevens, S. P. (2008). A Study of the Effectiveness of Web-Based Homework in Teaching Undergraduate Business Statistics. *Decision Sciences Journal of Innovative Education, 6*(2), 213-232.

Rochelle, C., & Dotterweich, D. (2007). Student Success in Business Statistics. *Journal of Economics and Finance Education, 6*(1), 19-24.

Snee, R. (1990). Statistical thinking and its contribution to quality. *The American Statistician, 44*, 255-258.

Snee, R. (1999). Discussion: development and use of statistical thinking: a new era. *International Statistical Review, 67*, 255-258.

Street, L. (2018, 3 30). *NEWS: New budget keeps underfunding education by hundreds of millions*. Retrieved from Statehouse Report: https://www.statehousereport.com/2018/03/30/news-new-budget-keeps-underfunding-education-by-hundreds-of-millions/

Velleman, P. F., & Moore, D. S. (1996). Multimedia for teaching statistics: Promises and pitfalls,. *The American Statistician, 50*, 217-225.

Wang, J.-T., Tu, S.-Y., & Shieh, Y.-Y. (2007). A Study on Student Performance in the College Introductory Statistics Course. *AMATYC Review, 29*(1), 54-62.

Wild, C. J., & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry. *International Statistical Review, 50*, 221-248.

APPENDIX

	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Total	195	255	288	195	235	171	144	176	106	106

Table 1: Student enrollment in Business Statistics classes

	Time Period	1	2	3	4
	Sample	195	887	299	376
W and F combined	GPA Average	1.64	1.15	1.20	1.75
	Std Dev	1.51	1.34	1.34	1.49
	% Dropped	27.18%	18.49%	19.40%	10.11%
W dropped from the sample	Sample Size	142	723	241	338
	Average	2.25	1.41	1.49	1.94
	Std Dev	1.32	1.35	1.33	1.44

Table 2: Performance of Students in Business Statistics

Time period	W and F combined	W dropped from the sample
1 – 2	Sig (0.000)	Sig (<0.0001)
1 – 3	Sig (0.007)	Sig (< 0.0001)
1 – 4	Not Sig (0.844)	Not Sig. (0.158)
2 – 3	Not Sig (0.925)	Not Sig. (0.832)
2 – 4	Sig (< 0.0001)	Sig (< 0.0001)
3 - 4	Sig (< 0.0001)	Sig (0.001)

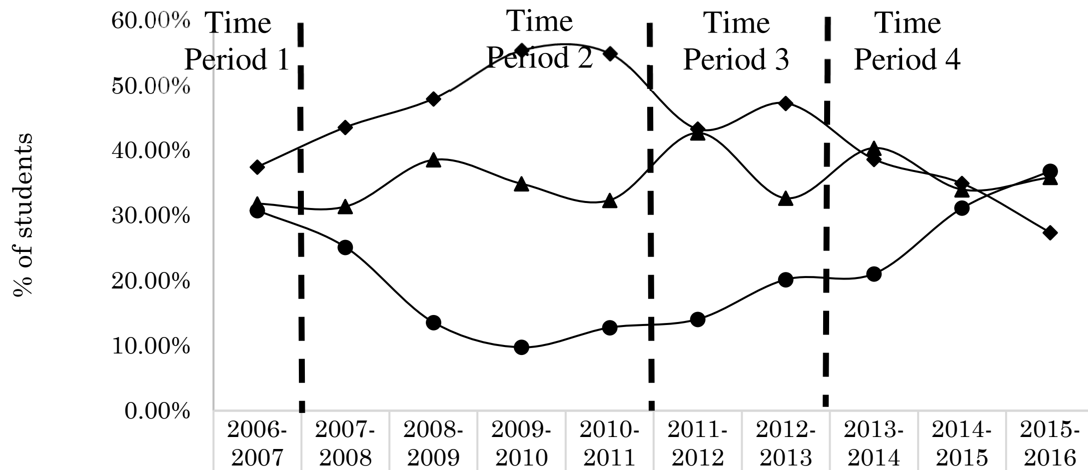
Table 3: Pair-wise comparison between student performance

Exam	Content	Time Period
A	Descriptive Statistics, Introduction to Probability	1, 2
B	Discrete Distributions, Continuous Distributions	1, 2, 3, 4
C	Sampling, Confidence Intervals	1, 2, 3, 4
D	One Sample Hypothesis Testing, Two Sample Hypothesis Testing	1 (partial), 2 3, 4
E	Chi Square, Simple Regression	3, 4

Table 4: Exams, Content, and Time Period Given

Time period		Exam A	Exam B	Exam C	Exam D	Exam E
2	Sample	660	651	640	627	
	Mean	57.93	62.31	59.53	63.91	
	Std Dev	23.39	23.49	25.94	27.1	
4	Sample		322	317	303	295
	Mean	N/A	63.06	67.09	67.53	75.57
	Std. Dev	N/A	23.89	26.23	23.46	20.01
t-test (2 – 4)			Not Sig. (0.32)	Sig (<0.0001)	Sig (0.023)	

Table 5: Student performance comparison between Time Periods 2 and 4



	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Above Avg	30.77%	25.10%	13.54%	9.74%	12.77%	14.04%	20.14%	21.02%	31.13%	36.79%
Avg	31.79%	31.37%	38.54%	34.87%	32.34%	42.69%	32.64%	40.34%	33.96%	35.85%
Below Avg.	37.44%	43.53%	47.92%	55.38%	54.89%	43.27%	47.22%	38.64%	34.91%	27.36%

Above Avg   Avg   Below Avg.

Figure 1: Student performance in Business Statistics 2006 – 2016