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Non-STEM graduate programs and the influence of an undergraduate statistics course on graduate statistics course success

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Abstract: *As the desire to attend graduate school grows, educators need to ensure students are well prepared for the rigors of a graduate program. To help ensure student readiness, academic institutions impose prerequisites to help foster academic success. However, requiring an excessive number of prerequisites could lead to unnecessary prolongation of time and money needed to graduate. In non-STEM programs, it's not uncommon for a graduate statistics course to have a mix of students who have and have not completed an undergraduate statistics course. This variability in students' previous coursework can make teaching and learning difficult.The purpose of the present study was to investigate the influence of an undergraduate statistics course on graduate course success in a sample of non-STEM graduate students. Fifty-three graduate students from a public university in the southeastern United States participated in the study. Participants were categorized into one of two groups; completed an undergraduate statistics course, or did not complete an undergraduate statistics course. Participants completed a statistics task on the first day and last day of class. To investigate the influence of an undergraduate statistics course on graduate statistics performance, an Analysis of Covariance was conducted. A large effect was revealed between participants who completed an undergraduate statistics course and those who did not complete an undergraduate statistics course. Theoretical and practical implications are discussed.*

Keywords: Mathematics curriculum; non-STEM mathematics curriculum; Academic performance, undergraduate statistics, graduate statistics

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I. Introduction

In Fall 2015, for the second time since 1986, graduate applications surpassed two million (Okahana, Feaster, & Allum, 2016). As the desire to attend graduate school grows, educators need to ensure students are well prepared for the rigors of a graduate program. Academic institutions generally impose prerequisites to help foster and appropriate curriculum. Requiring an excessive number of prerequisites could lead to unnecessary prolongation of time needed to graduate, while insufficient prerequisites can lead to inadequate readiness for more advanced material (Abou-Sayf, 2008).

As educators explore the need for prerequisites, graduate program developers should also explore the trends in graduate education. For example, there is an increasing focus in graduate programs on research methodology, which generally includes at least one statistics course (Onwuebuzie& Wilson, 2003). This focus may be due in-part to the increased competition between higher education institutions. Researchers find that research productivity has been associated with an institutions favorable reputation (Dundar & Lewis, 1998). Institutions of higher education may be placing an added emphasis on the research component in graduate programs as a way of training future academic researchers, as well as generating increased research productivity within the institution. However, this focus on graduate student research may be a challenge for students in non-STEM programs. For example, it is known that within non-STEM programs, statistics courses are often viewed by the students as among the most dreadedof courses (Chew & Dillon, 2014). The dislike of statistics courses could be a cause of students avoiding statistics courses during undergraduate studies (Ashcraft, 2002). As a result, it's not uncommon in non-STEM programs,for a graduate statistics course to have a mix of students who have and have not completed an undergraduate statistics course. This variability in previous coursework can make teaching and student learning difficult.

The prerequisite. Evidence is mixed when exploring the value of prerequisite courses. Arismendi-Pardi (1997) found based on Grade Point Average (GPA),that an algebra course prerequisite improved student performance in a subsequent calculus course. Specifically, students who had taken analgebra prerequisite received a mean grade of 3.014, while those who did not complete the prerequisite course had a mean grade of

2.541. Gwazdauskas and McGilliard (2014) explored the influence of previous coursework on pretest and posttest performance in a graduate physiology course. In the sample of 309 students, previous coursework had a significant impact on pretest and posttest performance. Hoyt (1998) posits that above average performance in prerequisite courses is necessary for future course success. For example, in astudy of 1,684 undergraduate students, researchers found that taking more math courses had significant positive impact on student performance in business and economics statistics courses (Green, Stone, Zegeye, et al., 2009).

However, a mathematicsprerequisite did not show a benefit to eventual success in a chemistry course (Wilson, 1994). Abou-Sayf (2008), also found negligible differences in course GPA when prerequisites were required vs. recommended. In another study, Wright, Cotner, and Winkel (2009) found only modest differences in grades between those who did or did not complete a prerequisite course. Specifically, 88.5% of the students without the prerequisite course earned a grade of C- or better, while 90.6% of the students who completed the prerequisite earned a grade of C- or better.

The overarching question of the present study is, how important is an undergraduate statistics course (as a prerequisite) to graduate statistics course success?To explore this question, the present study investigated the relationship between previous statistics course completion, and success in a graduate statistics course.This is an important question as graduate programsfurther emphasize the field of research, knowledge of statistics becomes a critical component to student success.

Generally, there are two designs used to study the influence of prerequisite courses (Abou-Sayf, 2008). First, researchers may compare performance of two different groups during two separate academic terms. In this design, one group includes students who complete a course before a prerequisite is required. The second group of students complete a course after the prerequisite is required. While there are benefits to this design, a risk is in the variability of different courses being taught during different terms. The second design compares the performance of a group of students who are attending the same course at the same time. The students are differentiated based on those who completed a prerequisite and those who did not complete a prerequisite course. This specific design is well suited for courses such as statistics in non-STEM graduate programs as there is often a mix of students who have or have not completed an undergraduate statistics course

*Present Study.*The purpose of the present study was to investigate the influence of an undergraduate statistics course on success in a graduate statistics course. The study included participants who completed a graduate statistics course. Participants were categorized into one of two groups; participants who completed an undergraduate statistics course, and participants who did not complete an undergraduate statistics course. All participants completed a statistics task on the first day of class (Time 1) and the last day of class (Time 2). The following research question was explored: *Does the completion of an undergraduate statistics course influence performance in a graduate statistics course?*

II. Method

*Participants.*A total of fifty-three (N=53) graduate students from a large public university in the southeastern United States participated in the study. All participants were either 1st or 2nd year students working towards their non-STEM Master’s degree. The course has the required text, Discovering Statistics Using SPSS, 3rdedition (Field, 2009). There are no specific prerequisites for the course beyond a bachelor’s degree. A total of 27 participants had not completed a statistics course, while 26 had completed an undergraduate statistics course.The sample included 36 females and 17 males. One participant identified themselves as American Indian / Alaska Native, two as Asian / Pacific Islander, 19 as Black, eight as Hispanic, and 23 as White.

*Materials.*All materials were created in Qualtrics survey software and completed on desktop computers in a standard classroom. The statistics knowledge task is a 50 item,four response multiple choice task. The items were generated from a test bank of the book, Statistics for Psychology, 6th edition (Aron, Coups, & Aron, 2012). Test items were generated from this book due to the general nature of the books content. The topics in the task include; probability, central tendency, variability, standard scores, error, confidence intervals, statistical power, effect size, statistical significance, correlation, regression, t-tests, and analysis of variance (ANOVA). The task includes items that capture understanding of equations, computations, and data interpretation. All questions were populated on the screen to allow participants to scroll the entire task to answer questions in the order they desired.Performance on the task was based on number of items correct out of 50. To document previous statistics course experience, one item asked the following, “Icompleted an undergraduate statistics course with a grade of C or better.” The response options were yes or no.

*Procedure.*The research protocol was approved by the university Institutional Review Board (IRB). The statistics knowledge task and questionnaire were completed in a standard classroom where all participants had access to desktop computers. On the first day of class, participants were instructed to logon to Blackboard and access a series of web links to the task and questionnaire. The participants were instructed to complete the task and questionnaire to the best of their ability and that they had as much time as they needed to complete the tasks. On the last day of class, the participants completed the same statistics knowledge task, but items were randomized. It was emphasized to the participants to answer all the questions on the test.

Analysis. To investigate the influence of an undergraduate statistics course on graduate statistics performance, an Analysis of Covariance (ANCOVA) was conducted. The independent variable was completion of an undergraduate statistics course (Yes, No), while the dependent variable was performance on a statistics test at the end of the graduate statistics course (Time 2). The covariate variable was performance on a statistics test on the first day of the graduate statistics course (Time 1). Prior to conducting the analysis several assumptions were validated.

III. Results

All data was exported from Qualtrics into SPSS. The average time to complete the statistics knowledge task was 38.38 minutes (SD = 12.08, Range = 16 – 85 minutes). There was no difference in completion time between Time 1 and Time 2 tests. Additionally, there was no difference in completion time between participants who completed an undergraduate statistics course, and those who did not complete an undergraduate statistics course.

Does the completion of an undergraduate statistics course influence performance in a graduate statistics course? To determine the unique contribution of an undergraduate statistics course on performance in a graduate statistics course, An Analysis of Covariance (ANCOVA) was conducted. The independent variable was completion of an undergraduate statistics course (Yes, No): while the dependent variable was performance on a statistics test at the end of the graduate statistics course (Time 2). The covariate variable was performance on a statistics test on the first day of the graduate statistics course (Time 1). Prior to conducting the analysis several assumptions were validated. The four methodological assumptions included, dependent variable being continuous, the independent variable being categorical, the covariate variable being continuous, and independence of observations were valid. Additional assumptions were explored by various analyses. There was a linear relationship between Time 1 and Time 2 statistics tests for each level of the independent variable, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant$F(1, 53) = 3.060$, $p = .087$. Standardized residuals for each level of the independent variable were normally distributed as assessed by Shapiro-Wilk's test ($p > .05$). There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. There was homogeneity of variances as assessed by Levene's test of homogeneity of variance ($p = .129$). Finally, there were no outliers as assessed by no cases with standardized residuals greater than +/- 3 standard deviations.

Descriptive statistics were reviewed to explore the overall impression of the data. As illustrated in Table I, participants who completed an undergraduate statistics class outperformed participants who did not complete an undergraduate statistics class.

Table I. Performance on Statistics test, based on completing an undergraduate statistics course

	Undergrad Statistics	**Mean**	**SD**	**N**
Time 1	No	14.81	4.105	27
	Yes	23.42	5.693	26
	Total	19.04	6.549	53
Time 2	No	26.81	5.350	27
	Yes	39.23	3.570	26
	Total	32.91	7.729	53

After adjusting for the Time 1 statistics test, there was a statistically significant difference at Time 2 between the individuals who had completed an undergraduate statistics class and those who did not complete an undergraduate statistics class, $F(1, 52) = 33.661$, $p< .005$. Further, as reported by Cohen (1988): results revealed a large effect, $\eta^2 = .402$.

IV. Discussion

With the increase in graduate school attendance, educators need to continually explore activities that will help ensure students are well prepared for graduate school. The present study provides evidence to the value of previous coursework on the successful completion of a graduate statistics course.

The fifty-three students had an average score of 19.04 (SD = 6.549) or 38% on the first test (Time 1). At the end of the course (Time 2): the students had an average score of 32.91 (SD = 7.729) or 66%. Interesting results can be found between the students who completed an undergraduate statistics course and those who did not complete an undergraduate statistics course. At Time 1, the students who completed an undergraduate statistics course had an average score of 23.42 (SD = 5.69) or 47%, while the students who did not complete an undergraduate statistics course had an average score of 14.81 (SD = 4.105) or 30%. At Time 2, the students who completed an undergraduate statistics course had an average score of 39.23 (SD = 3.570) or 78%, while the students who did not complete an undergraduate statistics course had an average score of 26.81 (SD = 5.350) or 54%. Unfortunately, while the students who completed a previous statistics course demonstrated good knowledge of the material at Time 2, the students with no undergraduate statistics course experience clearly struggled to gain an acceptable knowledge of the material.This is an important finding which provides evidence to the value of an undergraduate statistics course to graduate statistics course success.

Further evidence to the value of undergraduate statistics can be found in the field of medical education. Wu et al. (2015) conducted a cross-sectional survey of perceived learning of statistics among graduate and undergraduate medical school students. Interestingly, 62.58% of the graduate students felt it was very hard to learn statistics while only 27.2% of the undergraduate students felt it was very hard to learn statistics. This suggests students may be more willing to learn statistics at the undergraduate level than the graduate level. In another study of 121 first year graduate entry medical students, researchers found a strong relationship between the completion and perception of performance in previous mathematics courses, and attitude towards statistics (Hannigan, Avril, & McGarth, 2014). Here the study suggests a value of undergraduate coursework to graduate statistics success. Finally, Baldi and Utts, (2015) have recommended that doctors should have knowledge that can be obtained from an undergraduate statistics course.

Some strengths and limitations should be noted. A strength of the research is its generality to the broader ethnic population which lies in the diversity of the present sample which consisted of 36% Black, 15% Hispanic, 43% White, and 5% American Indian / Alaska Native, or Asian / Pacific Islander. However, there were a limited number of male participants (28%) in the study. In addition, only graduate students from a public, Southern university were included in the present research.

*Conclusion.*In general, graduate programs are an extension of an undergraduate program. Students in graduate programs expect to take more advanced courses than they experienced in their undergraduate studies. It's a progression of coursework; taking an introductory college math course, then an undergraduate statistics course or courses, and for those attending graduate school, advanced courses in statistics. This progression allows for the steady learning of more complex topics. Unfortunately, students taking a graduate statistics course may not have followed a typical progression of courses. For example, non-STEM undergraduate programs such as Education, typically do not include a statistics course as a required program component. However, students in graduate programs in Education, will often be required to complete a graduate statistics course. The present study provides evidence that students entering masters and doctoral level programs who did not complete an undergraduate statistics course, may be at a disadvantage when it comes to the graduate statistics requirement. In this instance, the student may not have the knowledge to successfully comprehend the content of the graduate statistics course. This could have a serious negative impact on the students ability to complete a thesis or dissertation, both of which require knowledge of more advanced statistics.

The present study has practical and theoretical implications. Practically, graduate program developers should consider including an undergraduate statistics course as a prerequisite for acceptance into graduate programs, particularly the programs that include a statistics course. Theoretically, researchers could explore various aspects of undergraduate statistics courses. It is possible that specific content, student performance, and amount of time between the undergraduate and graduate statistics courses may influence graduate statistics success.

In summary, as educators, our priority should be the development of curriculums that maximize the students' potential for success. Adetailed evaluation of the students past experiences, particularly in statistics, should play a prominent role in graduate curriculum development.

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