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The Effects of a Project-based Course on Students' Attitudes Toward Mathematics And Students' Achievement at a Two-year College

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Abstract
This study was conducted to investigate the impact of Foundations of Quantitative Reasoning course on students' attitudes toward mathematics and students' achievement. The Foundations of Quantitative Reasoning is a project-based course containing several practical topics which students apply in daily life. It is offered at the University of Cincinnati as an alternative pathway for non-STEM majors to fulfill their mathematics requirements. Pre-survey-post-survey and pretest-posttest designs were used to test the effectiveness of the treatment regarding the attitudes toward mathematics and mathematics achievement respectively. The participants in this study were 21 students enrolled in a Foundations of Quantitative Reasoning course and 20 students enrolled in a College Algebra course offered at the University of Cincinnati Blue Ash College. Statistically significant results were observed for improvement in attitudes toward mathematics and mathematics achievement.

Keywords: project-based, attitudes, mathematics, achievement, anxiety, college

Introduction

Mathematics anxiety is a phenomenon that blocks students from learning mathematics. Mark Ashcraft defines math anxiety as "a feeling of tension, apprehension, or fear that interferes with math performance" (Ashcraft, 2002). Extended mathematics anxiety can contribute to the development of a negative attitude toward the subject. On the other hand, some researchers used mathematics anxiety as a part of their instrument to measure attitudes toward mathematics (Tapia, 1996). Thus, Mathematics anxiety and attitude toward mathematics can be interrelated, both having implications in teaching and learning mathematics. Anxious individuals will avoid subjects, courses, and careers that involve mathematics. Such avoidance can limit students' opportunities and career pathways. For this reason, Hoffer reported that attitudes change rapidly and must be studied more intensely (Hoffer, 1993). Moreover, many professional associations for mathematics have emphasized the need to improve students' attitudes toward mathematics.

Howson and Wilson suggested that mathematics courses must offer materials that are personally engaging and useful, or motivating in some ways (Howson & Wilson, 1986). Additionally, implementing real-life applications in class has been proven to be effective to improve students' attitudes toward mathematics (Wade, 2013). At the University of Cincinnati, Foundations of Quantitative Reasoning, a project-based course, was designed in 2012 to teach students to better understand the mathematics used in their daily lives and to use mathematics effectively to make better decisions every day. Contents are organized, with engaging coverage in sections like "Taking Control of Your Finances" and a full chapter about Mathematics and the Arts. After taking the course, students are expected to recognize that mathematics is important and relevant to their lives.

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This new course serves non-STEM majors to fulfill their mathematics requirements. While Foundations of Quantitative Reasoning contains a heavy load of applications, it has similar Student Learning Outcomes regarding mathematical concepts that are also covered in College Algebra. Both courses are college level; however, College Algebra falls in a slightly higher level because the prerequisite for College Algebra is a minimum score of 430 from the Math Placement Test while the prerequisite for Foundations of Quantitative Reasoning is a minimum score of 420 from the same test.

Related Literature

Students' attitudes toward mathematics have been studied for at least the last forty years (Neale, 1969; Aiken, 1976; Ma & Kishor, 1997; Alkhateeb & Mji, 2005; Hemmings & Kay, 2010). Several researchers reported a negative correlation between mathematics anxiety and low performance in mathematics, and negative attitudes towards mathematics (Fennema, 1977; Fennema & Shermon, 1977; Richardson & Suinn, 1972; Tobias & Weissbrod, 1980). Belbase discussed that perceptions of mathematics can have possible impacts on learning with the subsequent development of attitudes toward mathematics and associated mathematics anxiety (Belbase, 2013). In addition, negative attitudes toward mathematics often lead to poor engagement causing students to fail the course (Mayes, Chase, & Walker, 2008). There is also a correlation between attitudes toward mathematics and withdrawal rates from mathematics courses (Ma & Willms, 1999). There is some evidence showing that students' positive attitudes toward mathematics have positive impacts on students' achievement in college statistics and mathematics courses (House, 1995; Evans, 2007). The effect of the emporium teaching approach on students' attitudes toward mathematics and students' achievement is positive (Bishop, 2010). In particular, there is another study of the effectiveness of implementing real-life applications in class to improve students' attitudes toward mathematics in college mathematics courses (Hodges & Kim, 2013).

Objectives of the Study

The purpose of this study is to investigate the impact of the Foundations of Quantitative Reasoning course, a project-based course, on students' attitudes toward mathematics and students' achievement. The result of this research can be used to improve classroom pedagogy, to design or consider new college-level mathematics courses, and to contribute to the literature on students' attitudes toward mathematics.

Methodology

Study Design

The study was conducted by using a two-group, pretest-posttest and presurvey-postsurvey quasi-experimental design since the participants were not randomly assigned to treatment and control groups, but selected based on the way the students enrolled in the classes. The sample consisted of 41 students (control group 20 students and treatment group 21 students). The study was conducted during the Fall 2014 Semester at the University of Cincinnati Blue Ash College. The participants were enrolled in one of four classes. The control group consisted of two College Algebra classes taught by using traditional lecture instruction. The treatment group was comprised of two Foundations of Quantitative Reasoning classes taught by using project-based and lecture instructions with engaging real-life applications relevant to students. The control and treatment groups are significantly different from each other since College Algebra is in a higher level than Foundations of Quantitative Reasoning.

The participants in the control group hypothetically had higher level mathematical knowledge due to the higher prerequisite for College Algebra. Both courses share common Student

Learning Outcomes. The independent variable is the course and the skill levels of the students. There are two dependent variables: mathematics attitudes and achievement.

Mathematics achievement was measured by pre-test and post-test. The pre-test measured the knowledge prior the enrollment at the beginning of the semester. The post-test measured the achievement according to the common Student Learning Outcomes from both courses at the end of the semester. Students' attitudes toward mathematics were measured by pre-survey and post-survey using the Attitudes Toward Mathematics Inventory (ATMI) (Tapia, 1996; Tapia & Marsh, 2005). The attitude data were collected prior to any treatment and at the end of the study.

The goal of this research was to determine whether project-based instruction with engaging real-life applications relevant to students improves student achievement and attitudes toward mathematics. The following research questions were addressed:

1. What is the impact of Foundations of Quantitative Reasoning course on students' attitudes toward mathematics?
2. What is the impact of Foundations of Quantitative Reasoning course on students' achievement?
3. What is the relationship between attitudes and achievement for students in Foundations of Quantitative Reasoning and College Algebra courses?

Study Setting

This study was conducted in two sections of 3-credit-hour Foundations of Quantitative Reasoning course and two sections of 3-credit-hour College Algebra course at the University of Cincinnati Blue Ash College. All four classes met face-to-face, 2-3 times a week and used online homework assignments providing immediate feedback to students. The participants in the control group were enrolled in College Algebra where traditional lecture instruction was implemented. The participants in the treatment group were enrolled in the new course, Foundations of Quantitative Reasoning. In the past, students who needed to complete only one 3-credit-hour college-level mathematics course were typically enrolled in College Algebra since it was one of the lowest college level at the University of Cincinnati. As such, both STEM majors, such as engineering, science, and technology and non-STEM majors were enrolled together in the same classes. This appeared to make non-STEM majors feel even more uncomfortable with the subject and potentially provoked math anxiety in these students. Furthermore, the large majority of non-STEM students would not make use of formal mathematics in their careers or daily lives. In fact, typically 90% of non-STEM majors never take another college-level mathematics course after completing their core requirements. In the Fall 2012 Semester, the university began to offer a new college-level math course, Foundations of Quantitative Reasoning, to purposely serve non-STEM majors to fulfill the mathematics requirements for their degrees. This new course is a project-based course, emphasizing problem solving, model building, and basic data manipulation in real world contexts. The course presents the topics that are truly important to the future success of these students including problem-solving, statistical reasoning, linear and exponential modeling, and modeling with geometry. Despite the difference of teaching styles used in two groups, College Algebra and Foundations of Quantitative Reasoning share the following Student Learning Outcomes:

- Analyze and perform operations with functions including linear, exponential, and logarithmic.
- Use these functions appropriately to create and interpret basic mathematical models to solve a variety of real world problem applications.

Participants

The participants in this study were recruited from all students enrolled in either College Algebra or Foundations of Quantitative Reasoning courses described earlier. From a total enrollment of approximately 100 students, 41 students chose to participate. The control group contained 20 students from two sections of College Algebra, and the treatment group consisted of 21 students from two sections of Foundations of Quantitative Reasoning. The researcher taught participants in the treatment group. Two full-time instructors at the University of Cincinnati Blue Ash College taught participants in the control group.

Instrumentation

The instrument that was used to determine students' knowledge prior the enrollment in this study was a pre-test consisting of 14 algebraic problems developed according to prerequisites for both courses by two instructors who have taught both courses.

The instrument that was used to determine students' achievement in this study was a post-test consisting of six word problems developed by the same instructors according to the common Student Learning Outcomes of both courses listed above. The instrument used to measure students' attitudes was the Attitudes Toward Mathematics Inventory (ATMI) developed by Martha Tapia of Berry College (Tapia, 1996). The ATMI asks 40 items rated on a five-point Likert scale (Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree) divided on five subscales: Value of Mathematics, Enjoyment of Mathematics, Motivation in Mathematics, and Anxiety toward Mathematics. It had a reliability Cronbach alpha coefficient of 0.97. Tapia and Marsh showed that the ATMI is a reliable instrument for data collection and is appropriate for American college students (Tapia & Marsh, 2005). The sum of the subscales gives the total score of a student's attitudes towards mathematics. Maximum score on this inventory is 200 points. The higher the score on the ATMI, the more positive attitudes students showed towards mathematics.

Procedure

Participants for the research study were recruited in class during the first week of semester. The research instructions were read aloud by the researcher as students listened at the beginning of the period of their classes. Students choosing to participate in the study read a consent form and completed a short demographic questionnaire. The participants were informed about all research activities involved in the study. They were also assured that the data would be used for research purpose, that participation was voluntary, and that they could withdraw from the study at any time for any reason or no reason without penalty. Approval for this study was obtained from IRB (Institutional Review Board at the University of Cincinnati). The participants completed the pre-test and pre-survey at the beginning of the semester and post-test and post survey toward the end of the semester.

Data Analysis Strategy

The data were analyzed by Microsoft Excel for Mac 2011. The level of statistical significance was set at 5%, and the independent t-test was then carried out to determine the effectiveness of the project-based course on students' attitudes toward mathematics and students' achievement. The following interpretation of a p-value was used in this study:

- $p \leq 0.01$: very strong presumption against null hypothesis
- $0.01 < p \leq 0.05$: strong presumption against null hypothesis

- $p > 0.05$: no presumption against null hypothesis

The null hypothesis on math achievement includes
"No significant difference between Pre-test and Post-test scores in each group."
The null hypothesis on math attitudes includes
"No significant difference between Pre-survey and Post-survey scores in each group."

Spearman's rank correlation coefficient (ρ) was used in this study as a statistical measure of the strength of a monotonic relationship between paired data. We used the Spearman's rank correlation coefficient to measure the statistical dependence between Pre-test (Pre-survey) and Post-test (Post-survey) scores in each group and also the relationship between attitudes and achievement for students in each group. The closer (ρ) is to ± 1 the stronger the monotonic relationship. We described the strength of the correlation using the following guide for the absolute value of (ρ).

- .00-.19 very weak
- .20-.39 weak
- .40-.59 moderate
- .60-.79 strong
- .80-1.0 very strong

Results

The results showed that the Post-test average of the treatment group is higher than the Pre-test average of the same group and that these two sets are correlated with $\rho = 0.33$ and significantly different with $p \ll 0.001.$ However, the Post-test average of the control group is lower than the Pre-test average of the same group and that these two sets are correlated with $\rho = 0.41$ and significantly different with $p < 0.01.$ As shown in Table 1 the Post-survey average of the treatment group is higher than the Pre-survey average of the same group. Moreover, these two sets are correlated with $\rho = 0.62$ and significantly different with $p \ll 0.001.$ On the other hand, the Post-survey average of the control group is lower than the Pre-survey average of the same group. Also, Pre-survey and Post-survey scores of the control group are correlated with $\rho = 0.68$ and significantly different with $p \ll 0.001$.

Table 1: Achievement and ATMI scores

		Achievement Exam Score		**Math Attitudes ATMI Score**	
		Pre-test	Post-test	Pre-survey	Post-survey
Treatment Group n=21	M	42.75%	73.71%	63.17%	67.12%
	SD	22.62	20.18	16.94	19.67
	ρ	0.33**		0.62**	
Control Group n=20	M	64.30%	44.74%	63.20%	61.58%
	SD	18.24	23.02	16.78	18.23
	ρ	0.41*		0.68**	

Note: * $p < 0.01$ (one-tailed); ** $p \ll 0.001$ (one-tailed)

Table 2 showed that the treatment group's survey scores regarding all four subscales except the Value of Mathematics had increased after completing Foundations of QR course. However, the control group's survey scores regarding all four subscales except the Enjoyment of Mathematics had decreased after taking College Algebra course.

Table 2: Subscales

Subscales		Treatment Group		Control Group	
		Pre	Post	Pre	Post
Value	M	71.90%	71.81%	73.60%	69.50%
	ρ	0.34*		0.38*	
Enjoyment	M	58.38%	65.14%	60.30%	60.40%
	ρ	0.63**		0.67**	
Motivation	M	54.10%	58.67%	55.40%	52.20%
	ρ	0.83**		0.77**	
Self-confidence	M	63.56%	68.13%	60.80%	60.20%
	ρ	0.74**		0.68**	

Note: * $p < 0.01$ (one-tailed); ** $p \ll 0.001$ (one-tailed)

Table 3 shows that there is a positive moderate correlation between attitudes and achievement for students in the control group. The Pre-test and Pre-survey have a stronger correlation with $\rho = 0.51$ than the Post-test and Post-survey.

Table 3: Spearman coefficient in control group

		Math Attitudes ATMI	
		Pre	Post
Achievement Exam	Pre	0.51	
	Post		0.22

Table 4: Spearman coefficient in treatment group

		Math Attitudes ATMI	
		Pre	Post
Achievement Exam	Pre	0.26	
	Post		0.60

Table 4 also shows that there is a positive weak correlation between attitudes and achievement for students in the treatment group. The Post-test and Post-survey have the strongest correlation with $\rho = 0.60$ among other pairs.

Discussion

The present analyses suggest that the attitudes toward mathematics of the students in the treatment group improved over a semester, but the attitudes toward mathematics of the students in the control group became more negative over the same semester. Additionally, the enjoyment of mathematics and motivation in mathematics of the students in the treatment group increased, and anxiety toward mathematics of the students in the same group was reduced after taking the new course. These changes in student achievement and perceptions indicate that students' attitudes can be changed.

There are a number of factors that could have influenced students' attitudes toward mathematics. For instance, the instructors' attitudes and behavior might have contributed to changes in attitudes toward mathematics (Domino, 2009). The instructors' physical appearances or personalities could have influenced students as early as the first week of semester. The instructor who taught the students in the treatment group might have developed positive relationships with students more effectively than those who taught the students in the control group. Surprisingly, the students in the treatment group were tested in a higher average Post-test score than those in the control group on their mathematics achievement, even though their mathematics background was lower than the students' in the control group. This shows that students obtained the common Student Learning Outcomes more effectively in the project-based learning environment than the traditional teaching style. There are several explanations as to why this may be. For example, there was more engagement in learning among students and between students and the instructor in the treatment group (Southam, Liu, & Lewis, 2013; Barthlow & Watson, 2014). Also, the students in the treatment group had an opportunity to utilize the content while solving real world problems in each session (Kumar & Refaei, 2013). Moreover, student's attitudes could have had effects on their mathematics achievement as the results showed that the Post-test and Post-survey in the treatment group have the strongest correlation among other pairs. Once more the instructor might have had an impact on students' learning as well. It is possible that the instructor who taught the students in the treatment group could have been a more effective teacher than others. Lastly, at the end of the semester the students might be exhausted, and they did not use their full potential to complete the post-test since the test was not counted into their grades. Nevertheless, the students' performance on the achievement and attitude assessments encourage this project-based approach in teaching undergraduates, particularly non-STEM majors.

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