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Introducing Real Life Applications of Mathematics through Projects in Lower-Division Mathematics Classes

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Abstract: This paper investigates the effects of project-based teaching on students' learning. The aim of this study is to examine if incorporating mini projects in mathematics teaching can enhance students' understanding of mathematics and stimulate students' interest in mathematics. To achieve the research purpose, three pairs (or six sets) of data were collected from two different courses, each pair (or two sets) of data consists of two groups of students where one group received project-based instruction and the other group did not. For each pair (or two sets) of data, an independent unpaired t-test was conducted using SPSS (Statistical Package for the Social Sciences) to obtain the findings. A significant difference was found. The results show that project-based teaching with appropriate technology stimulated students' interest in mathematics, enhanced students' desire to discover and solve mathematics problems, increased students' confidence in mathematics, and enhance students' soft skills, including communication, teamwork, and problem solving. Thus, the project-based teaching approach is highly recommended for educational use by students and should be encouraged in universities.

Keywords: Project-based teaching, Technology, Mathematics learning

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Introduction

Few students start college with a clear idea of what they can do with mathematics, especially first-generation, minority, and those from underrepresented populations. There are multiple reasons why students do not seriously enjoy learning mathematics, including: (a) not connecting mathematics with their daily lives, (b) little public recognition and peer encouragement for activities and achievements related to applications of mathematics, and (c) uncertainty of how mathematics could be useful unless they want to become mathematics teachers. As a result, mathematics programs across the United States have been experiencing decreasing

enrollments; however, available data from the U.S. Bureau of Labor Statistics (BLS) indicates that the job market demand for mathematicians is on the rise (growth of 23% from 2012-2022).

Mathematics is one of the oldest disciplines in the world and is useful in solving many practical real-life problems in agriculture, construction, industry, accounting, taxation, and other social and bureaucratic areas. Humanity's progress would not be possible without the development and application of mathematics. Using real-life applications in teaching mathematics provides the opportunity for students to enjoy mathematics learning and develop skills that are needed in life. There is a long list of benefits, for instance, increasing students' engagement; enhancing students' comprehension of the key concepts; enabling students to apply their knowledge to their lives, helping students connect mathematics to other disciplines – not only in the area of science, technology, and engineering, but also in the area of arts, crafts, designs; and growing students desires to discover mathematics in the world around them. A study by Lee (2012) reveals that project-based teaching is a critical component of mathematics to real-life. Premadasa and Bhatia (2013) show that students in lower-division classes significantly prefer problems which have a certain level of intrigue and are easily related to their life. Furthermore, a host of research Carducci (1996), Jaiswal, Lyon, Zhang, & Magana (2021), Klymchuk & Spooner (2020), Spooner, Nomani & Cook (2023) finds that through the real-life applications and mathematical modelling lessons, students develop a new-found interest in mathematics, and gain a greater understanding.

Technology is a valuable asset in the learning process. Modern technological progress has advanced to the level where the results of complicated problems can be computed with explicit algorithms in moments; abstract concepts can be easily visualized by computer-generated graphics; interactive models, lessons, and projects can be created and exhibited on screens. With the proper use of technology, students could shift their focus from long, boring, and tedious computations to the interesting outcomes induced by the changes on the numerical conditions. This will lead them to a better understanding of the cause and effect, as well as logical and mathematical reasonings lurking behind the computations. In addition, technology has a significant impact on how to teach, having enabled us to simultaneously and asynchronously work on the same document in the same virtual space regardless of geographical location. For example, classrooms are now equipped with various technologies for local and distance learning; self-grading for homework assignments, quizzes, and tests are incorporated in the computer software systems; and group discussions can be initiated in virtual classrooms. Thus, the technological part of project designs should be simple, user friendly, and provide flexibility and freedom for students, especially those students with limited technical skills. The technology should help the students to understand and execute the projects independent of time and location. The goal of modelling real-life problems is for students to discover the cause-and-effect relationships between inputs and outputs; hence, the technology used should be able to display patterns of the input-output relationships. The aim of the use of technology is to make the learning process engaging and intriguing, and to provide greater understanding and motivation, where motivation is the most important facilitator of learning (Ralph, 2016).

Our project-based teaching utilizes real-life applications in our mathematics classes. The aims of introducing real-life applications of mathematics through group projects in lower-division mathematics classes are twofold:

to introduce mathematics and the career paths to freshmen; and to motivate freshmen to become promoters and ambassadors of mathematics among their peers. We intend to stimulate students' interest in mathematics through hands-on activities and expose them to a variety of means for exploring mathematics career options. Also, we intend through these pilot projects to build students' mathematics curiosity and drive to discover mathematics in their daily life, foster a positive attitude and confidence regarding mathematics, and encourage students to become promoters and ambassadors for mathematics among their peers. The ultimate goal of our projects is to related directly to Southeast Missouri State University's mission to "Educate students to succeed and make positive impacts in their communities." Specifically, our projects are designed according to Southeast's Strategic Action Plan to: (a) "improve academic programs continuously" by integrating "career exploration, career readiness, and experiential learning opportunities into academic programs"; and (b) "support a range of opportunities for engagement, skill development and persistence for all students" by expanding "academic, community, and alumni partnerships that provide valuable experiential learning opportunities" to promote "engaging and healthy student life experiences."

This study analyzes student performance data in lower division mathematics courses. To achieve the research purpose, three pairs (or six sets) of data are collected from two different courses, each pair (or two sets) of data consists of two groups of students where one group without project-based teaching and the other group with project-based teaching. The final exam grades of the three pairs were compared and an independent unpaired t-test was then conducted. By conventional criteria, the difference is considered extremely statistically significant. The results show that the project-based teaching with appropriate technologies stimulated students' interest in mathematics, enhanced students' desire to discover and solve mathematics problems, increased students' confidence regarding mathematics, and prepared students' professional competencies. Thus, the project-based teaching approach is highly recommended for educational use by students and should be encouraged in universities.

Method

MA140 Calculus I

Striving to accommodate students' needs and improve their interests and performance in mathematics learning, a real-life application component was introduced into MA140 Calculus I, a hybrid format mathematics course for undergraduate students in fall 2022. This component consisted of five projects where the learning objects connect mathematics with their daily life. In addition, the students were encouraged to present their learning outcome in the format of text, audio, video, and animation to enhance their digital media literacy skills in their discipline and profession. The same faculty taught the course without implementing these projects in fall 2021.

Five mathematics projects were incorporated in the course: (1) the photo project: the students were required to take a photo by themselves, give a short explanation of the photo, ask a mathematics question related to the photo, and provide an answer to the question; (2) the logo design project: the students were required to design a

logo with computer software, and explain how the design is related to mathematics; (3) the craft project: the students were required to make a craft with shapes, give a short description of the craft, and explain how the choice of the shapes impacted the craft; (4) the surface graphing project: the students were required to generate a graph of a surface using a computer software package such as Mathematica, Maple, or MATLAB, and explain where such a surface occurs in daily life; (5) the poster project: the students were required to create a poster presentation on integration, and exhibit the key content they learned that is closely related to daily life or other disciplines.

This study collected and analyzed student performance data in this hybrid course. Specifically, the final course grades of the students enrolled in the MA140 without a real-life application component were compared with the final course grades of the students enrolled in the MA140 with the real-life application component. The final exam grades of these two groups were compared and an independent unpaired t-test was then conducted.

MA123 Mathematical Reasoning and Modeling

The Mathematical Reasoning and Modeling Course is designed for students not majoring math. Many students who take this course have been avoiding mathematics as much as possible. They consider mathematics to be abstract, dry, and irrelevant. Many of them often remark that they are not good in mathematics, they don't like fractions or symbols, they feel frustrated with mathematics, and they have never used and most likely never will use mathematics in their lives. There are various reasons for this mindset, which may have developed since early childhood. It is extremely challenging to make any drastic change toward their mathematics background. The goal is to improve their attitude, perceptions, and expectations toward mathematics by connecting mathematics to their daily life through relevant and interesting mathematics projects.

In the course, we utilize Microsoft Excel (MS Excel) and Desmos Graphing Calculator (desmos.com). Both tools are easy to use and have great computational and visualization functionalities. MS Excel is widely used in many companies and organizations, and is useful in creating dashboards, tables, charts, and graphs, which make projects more alive and interesting. Most students are familiar with the program and can use it without any problem. Incorporating these technologies is meant to promote collaboration and conversations among students, increase the communication between instructor and students, and build students' mathematics confidence.

The following projects are completed during the course: (1) Application of Bayes' theorem - introduction of characteristics of diagnostics tests such as specificity, sensitivity, positive/negative predicted value. This project guides students in creating confusion matrix and allows them to evaluate the performance of the diagnostic tests based on Bayes' theorem. The aim of the project is to help promote a deeper understanding of Byes' theorem, and to demonstrate that some complex problems can be solved by a simple set of skills and tools. (2) Application of Expected Value – most suitable choice of two health insurance plans based on the individual circumstances in the decision-making process using MS Excel. The goal of the project is to show students how to apply the expected value formula to estimate the average cost of each medical insurance plan, and reflect on

advantages and disadvantages of each case, and justify the risk level associated with their choice when making the final decision. (3) Regression Models - create linear and exponential regression models in MS Excel using real-life data. Students are required to exam different models and select the best fit models to make predictions. (4) Finance Project - using a dashboard, an interactive and dynamic tool that is created in MS Excel that allows users to observe the effects of changing input parameters on outcomes, to select the most effective payment option to a credit card loan, to learn low and high risk level loans and to analyze the difference in the total payment amount between those cases.

Results

MA140 Calculus I

For MA140 Calculus I, a comparison of the descriptive statistics for the two groups revealed that the mean, median, and mode were all higher for the group with the real-life application component, where Group 1 is the class without the real-life application component, and Group 2 is the class with the real-life application of mathematics project component. First, the range of scores was smaller for Group 1 (See table 1). For the final exam scores of Group 1, the range was 31.13%, the median was 77.53%, and the mode was B. For the final scores of Group 2, the range was 33%, the median was 87.98%, and the mode was A (90%-100%=A, 80%-89.9%=B, 70-79.9%=C, 60%-69.9%=D, 0-59.9%=F). There was a big difference between Group 1 and Group 2 in terms of median, mode, and range. Group 1 consists of 16 students, among which 9 students obtained a final exam score between 80.16% and 88.13%; whereas Group 2 consists of 28 students, among which 15 students received a final exam score between 90.5% and 98%. Table 1 reveals that Group 2 performed better in the final exam than Group 1. An independent unpaired t-test was then conducted using SPSS (Statistical Package for the Social Sciences) to determine if there was a significant difference in final exam scores between the two groups of students participating in this study. The two-tailed P-values equal 0.0003. By conventional criteria, this difference is considered extremely statistically significant. The mean of Group 1 minus Group 2 equals 10.4503, and 95% confidence interval of this difference is from -15.8470 to -5.0535. Intermediate values used in calculations are: t=3.9078, df=42, and standard error of difference equals 2.674. The data shows that Group 1: Mean=77.5319, SD=8.7253, SEM=2.1813, N=16; Group 2: Mean=87.9821, SD=8.4245, SEM=1.5921, N=28.

Table 1. Medians, Modes and Ranges of the Final Exam Scores for the Two Groups

	Median	Mode	Range
Group 1	77.53%	B	57%-88.13%
Group 2	87.98%	A	65%-98%

MA123 Mathematical Reasoning and Modeling

Implementation of projects went through many stages. Originally, this course incorporated only one major project in fall 2021 and spring 2022; then in fall 2022, three major projects were implemented, and it grew to

four projects in the spring 2023. There have been significant positive effects on students' learning and students' attitude toward the course. Students were usually excited to see how mathematics are used when comparing 15-year and 30-year long mortgages, or the payment schedules for house/car loans. They found that these project problems provide them with practical knowledge and skills that can be used and appreciated throughout their lifetime. Furthermore, the projects brought fascinating discussions and collaborations among students. Students often commented that it was amazing to see how mathematics interacts with other disciplines and areas of life, especially he use of technology in projects, which helped them visualize the big picture and enhanced their understanding. The fact that students can learn how to use technology, applications, and software to solve serious real-life problems gives them a new level of confidence and a great feeling of accomplishment. Quite a few times, students expressed that mathematics made sense for the first time in their life.

In general, students enrolled in the spring semester are the students who withdraw from the fall semester and are repeating the course. Therefore, two separate comparisons are performed, where table 2 compares the performances of the two groups of students from fall 2021 and fall 2022, whereas table 3 compares the performances of the two groups of students from spring 2022 and spring 2023. Two separate and independent unpaired t-tests are conducted using SPSS to determine if there was a significant difference in final exam scores between two groups of students from fall 2021 and fall 2022 semesters and spring 2022 and spring 2023 semesters, respectively.

For MA123 Mathematical Reasoning and Modeling, a comparison of the descriptive statistics for two fall semesters listed in Table 2 revealed that the mean, median, and mode were all higher in fall 2022 than fall 2021. Note that in fall 2022, one final test score of 6.8% is an outlier and is not included in table 2. The two-tailed P-value equals 0.0193. By conventional criteria, this difference is statistically significant. The mean of fall 2021 minus fall 2022 equals -12.514, and 95% confidence interval of this difference is from -22.869 to -2.159. Intermediate values used in calculations are: t = 2.4534, df = 35, and standard error of difference = 5.101. The data shows that fall 2021 class: Mean=70.877, SD=14.979, SEM=2.938, N=26; and fall 2022 class: Mean=83.391, SD=11.957, SEM=3.605, N=11.

Table 2. Medians, Modes and Ranges of the Final Exam Scores for Fall 2021 and Fall 2022 Semesters

Semester	Median	Mode	Range
Fall 2021	72.4%	B	44%-99.2%
Fall 2022	86.6%	A	63.6%-97.7%

Table 3. Medians, Modes and Ranges of the Final Exam Scores for Spring 2022 and Spring 2023 Semesters

Semester	Median	Mode	Range
Spring 2022	78.3%	C	42.6%-92.2%
Spring 2023	73.8%	A	41%-100%

Similarly, for MA123 Mathematical Reasoning and Modeling, a comparison of the descriptive statistics for two spring semesters listed in Table 3 reveals that the mean, median, and mode were all higher in spring 2023 than spring 2023. The two-tailed P-value equals 0.5318. By conventional criteria, this difference is not statistically significant. The mean of spring 2023 minus spring 2022 equals 3.766, and 95% confidence interval of this difference is from -8.379 to 15.910. Intermediate values used in calculations are t = 0.6324, df = 31, and standard error of difference = 5.955. The data shows that spring 2022 class: Mean=78.960, SD=12.895, SEM=3.329, N=15; and spring 2023 class: Mean=75.194, SD=19.801, SEM=4.687, N=18.

The difference shown in the data in Table 3 is not statistically significant. We credit this to several changes made in spring 2023 – the addition of the fourth project, the change of the weights of the projects in the grading system, and the loss of three class periods due to weather related university closing. However, there are obvious improvements observed in the spring 2023 class comparing against these in spring 2022 class – the mode of letter grade is improved from "C" to "A," and the upper bound in the range of final exam grades is increased from 92.2% to 100%. It is obvious that the loss of three class periods generated a significant amount of anxiety regarding the learning process. However, it is difficult to determine the contribution of the additional fourth project and the change of grading policy to the P-values. The instructor suggests that a further study should be conducted.

Discussion

Based on the collected student projects in MA140 Calculus I, it shows that through photographs, arts and crafts, and design projects, students reduce their mathematics anxieties, gradually build mathematics confidence, learn to discover mathematics in their daily life, and develop a desire for applying mathematics in other disciplines. Students who did not really know where mathematics are used in the real-life at the beginning of the semester had better understandings through the assigned projects and realized that mathematics occur anywhere and everywhere and are extremely useful. The experience through these projects increases the students' mathematical appreciation which may have an impact on their future. In addition, these projects provide opportunities and motivate students to learn to use mathematical software which is crucial to their mathematical skills. By using interactive mathematics software, students create graphics, animations, and posters. Using technology not only fosters a deeper conceptual and meaningful understanding of mathematics, but also advances students' abstract thinking skills. Furthermore, these technology skills are highly desired in a variety of professions. Providing students an early exposure to useful and practical technology skills prepares students' professional competencies, improves their career marketability, and strengthens their eligibility in career choices.

Based on the instructor observation in MA123 Mathematical Reasoning and Modeling, projects sparked more discussions and collaborations among the students. This in turn brought the students together. They were less likely to hide behind the desks, and more willing to share their ideas and help one another. It is clearly shown

that the students gradually connected mathematics with other disciplines and their own life experience. In particular, the use of technology in these projects assisted the students in overcoming their weakness in arithmetic computations, eased their fear in numbers, and improved their understanding of the mathematical principles lurking behind the applications. There were a lot of "Aha!" moments for the students throughout the projects, and it was obvious that they finally clicked on the mathematics they have been using without realizing it. These moments of enlightenment are the foundations for the change of their attitudes toward mathematics and have a positive and motivational impact on their future learning in mathematics.

Another interesting aspect of involving projects in the teaching is that there are some unexpected positive outcomes in addition to those predictable outcomes. One of the surprising outcomes observed by the instructor of MA123 Mathematical Reasoning and Modeling is that the students are eager to share their experiences with technology. For instance, MA123 Mathematical Reasoning and Modeling was taught as a Zoom-based online distance learning class. In such a delivery mode, the instructor lectured in a classroom that was designated as a digital hub for multiple sections from several remote satellite campuses. To overcome the separation in the physical locations and engage all students, small in-class activities or mini real-life projects using technology were injected throughout the class period. The students in the satellite campus actively participated in class via Zoom by exchanging tech ideas or tips on the types of technology that worked the best for their projects, shortcuts that were useful, and how to approach specific parts of the projects with a particular technology. It is amazing to see how much they understood each other, made each other comfortable and confident, and learned from each other. It is undeniable that these conversations contributed to students' learning.

Conclusion

The real-life applications of mathematics through group projects were implemented in a few lower-division mathematics classes. The data analysis shows that an extremely statistically significant improement in students' performance in mathematics. In addition, these projects stimulated students' interest in mathematics, enhanced students' desire to discover and solve mathematics problems, increased students' confidence of mathematics, and prepared student' professional competencies. Furthermore, the discussions and collaborations among students demonstrate that the students are likely to apply the knowledge and skills learned through the projects to their daily lives and make more informed decisions.

Recommendations

This study provides unmistakable evidence that well-planed project-based teaching has a strong positive impact on students' mathematics learning, and significantly reduces the math anxiety among students. The students learn important social skills through discussions and collaborations and become socially and emotionally supportive of one another. This in turn promotes their mathematics learning and starts to build a small mathematics community. This research found that when students are exposed to real-life applications in their

education, a better understanding and an appreciation of mathematics are achieved, and these projects with appropriate technologies improved students' social and emotional support for one another. Thus, the project-based teaching approach is highly recommended for educational use and should be encouraged in universities.

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