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Evaluation of Intertwined Project-Based Learning in Introductory Mathematics and Statistics Courses

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Abstract

High-impact practices include many options to help increase student learning, and project-based learning (PBL) is one such method. In this study, we look at the effect of PBL activities embedded in the content for introductory level mathematics and statistics courses across a semester. A pre-test and post-test are used to measure student learning, while student reflections and satisfaction is measured by using a survey. Additionally, these sections with intertwined PBL are compared with sections of the same course without PBL on final grades. Our results indicate that students perform better on the post-test after intertwined project-based learning throughout the semester, and most of the students are satisfied with their learning through the projects and making connections with the content. The comparison of final grades for courses with and without PBL shows similar achievement levels, and student performance is not affected by the reassignment of instructional time to group work in lieu of traditional lectures. With this study we recommend intertwined PBL with milestone projects throughout the semester to improve student learning gains and satisfaction with introductory level mathematics and statistics courses.

Introduction

Majority of the mathematics courses designated as satisfying general education requirements, are for non-STEM majors and the relevance of the content is not apparent to the students' academic pursuits nor aligned to the major courses. These introductory level mathematics and statistics courses are generally classified as gateway courses. They typically have high enrollment, high non-productive grades and more importantly provide students with the quantitative skills and reasoning necessary for their majors and life-long learning. Timely completion and level of success for the gateway courses have received a great deal of attention from educators and administrators alike.

Research shows students' performance in the gateway courses impacts their progression (Sonnert & Sadler, 2014) and success of their academic career (Kovacs, 2016). There is a correlation between the completion of the general education math requirement and student progress in all their majors (Moore & Shulock, 2009), factors including disparate mathematical preparation, attitude towards mathematics and math anxiety have been shown to have negative implications for mathematical development and engagement in mathematics-related activities (Nunez-

Pena et al.., 2013). It is not unusual for students in gateway mathematics courses to make comments and responses such as, “Why do I need math in my major?”, “Is this math course relevant to my major?”, “I am not a math person” and “Will this be in the exam?”. These are among many expressions of students' perceptions, anxiety and negative attitude that point at obstacles students experience in learning mathematics (Belbase, 2013). These attitudes and mindsets play a crucial role in the teaching and learning process of mathematics and affect students’ achievement (Harun et al., 2021). As such, combinations of interventions and practices that can boost achievement in gateway mathematics for a diverse student body needs to be investigated. Besides procedural and conceptual fluency, effective teaching and learning of mathematics rests on improving students in all aspects of skills development that focuses on students' experiences and providing mathematical sense making as an integrated whole.

One of the important challenges of our pedagogy is maintaining a balance of teaching and learning approaches that allow and help students develop and practice those skills in solving mathematical, nonmathematical and non-routine problems (Belbase, 2013). Providing opportunities for authentic learning experiences and presentation of mathematical concepts as a connected body has been fronted as a possibility of steering students from the habits of mimicking procedures, “plug and chug” approaches and symbolic manipulations that have in recent times been supported by computer algebra systems. Innovative models in teaching have been shown to contribute to greater efficiency of the teaching and learning process (Biljana & Dragana, 2017). Effective instruction has been predicated on the educators to choose from and use a variety of high-impact practices (Hattie, 2009; NCTM, 2014; Smith, & Baik, 2021). It is evident that no one such high impact practice can effectively help students achieve key learning outcomes and improve learning in isolation; and, therefore, developing intentional choices among those practices that have been shown to improve learning is critical. Blending learning models with best practices has been shown to activate student initial knowledge and improve student’s problem-solving skill (Gunawan et al., 2020).

This suggests a need to depart from the traditional lecture approach to one that applies a combination of high-impact instructional strategies that promote students’ participation, acquisition of problem-solving skills, growth mindset and collaborative learning. This includes intertwining projects with class activities and solving targeted conceptual content problems. This approach connects at least five of the key elements of High Impact Practices (HIPs), namely;

1. Significant investment of time and effort by students over an extended period of time
2. Interactions with faculty and peers about substantive matters
3. Frequent, timely, and constructive feedback
4. Periodic, structured opportunities to reflect and integrate learning
5. Opportunities to discover relevance of learning through real-world applications

(see https://www.aacu.org/trending-topics/high-impact)

Some of the quantitative outcomes of the gateway mathematics and statistics courses in the University System of Georgia includes 1) students effectively apply symbolic representations to model and solve problems and 2) students have the ability to model situations from a variety of settings in generalized mathematical forms (see

Learning Goal A2: Quantitative Outcomes in
https://www.usg.edu/academic_affairs_handbook/section2/handbook/2.4_core_curriculum/).

On these outcomes, work has been conducted for gateway mathematics courses that showed improved students' perception of course satisfaction and improved final grades using flipped classrooms (Shukla & McInnis, 2021). There is limited literature available on approaches to introductory mathematics and statistics courses, particularly combining strategies of intertwining projects and within the environment of elements of High Impact Practices. These outcomes further suggest focusing on teaching features that support conceptual understanding within a cycle that includes action, reflection, and application (Hiebert & Grouws, 2007; Wrenn & Wrenn, 2009).

There is growing emphasis on providing multiple and varied opportunities within the gateway courses to allow students to develop, apply and transfer their quantitative skills and reasoning in solving real-world problems. Additionally, embedding mathematics within a context that holds meaning for students (Polman et al., 2021) and supported by environments that makes students understand and relate the content (Verschaffel & Greer, 2013; Vargas-Hernandez & Vargas-Gonzalez, 2022). Adjustments in teaching methodology and innovative teaching of the subject content have been suggested to result in improved gains in mathematics and other areas of general education (Hagedorn et al., 2000).

This work is motivated by interweaving practices in project-based learning, advance organizer (pretest) and assessment-driven instruction based on the target conceptual problem in the pretest, to leverage student's achievement and satisfaction in introductory level mathematics and statistics courses. This is guided by activities derived from the five elements of High Impact Practices and components of engaging pedagogies including; 1) knowing the learner and the curriculum, 2) creating a positive and safe learning environment, 3) problem-solving, and 4) using various forms of low stakes assessment.

In this approach we combine pretests as advance organizers, multiple mini projects embedded in courses, and assessment-driven instruction based on pretest conceptual problems across two introductory level mathematics and statistics courses namely; MATH 1001 and STAT 1401 at Columbus State University. The instructors used the same structure in multiple and cross-listed sections of these courses with a total of 87 active students. The effect of the intertwined project-based approach was examined both quantitatively and qualitatively, based on posttest, final exam, and mini projects and surveys respectively.

While non-STEM majors require quantitative skills and reasoning that can be embedded in their areas of study, introductory mathematics and statistics pathways for non-STEM majors hardly effectively address this issue. This requires a different approach to traditional mathematics and statistics courses that ensures appreciation for skills addressing deficiencies, attitudes and mindset and within environments that reduce math anxiety (Elrod & Park, 2020). The motivation to intertwine diverse learning strategies is founded on the different learning styles of the learners and evidence that no one strategy works in isolation.

The purpose of this work is threefold. The first is to test to what extent the pretest used as an instructional tool

influences achievement, attitudes and mindsets towards gateway mathematics and statistics courses. The second is to examine the marginal improvement in student performance achieved by intertwining multiple mini projects with intervals of content review, problem-solving, and reflections. We predict gains in performance as well as satisfaction and change in attitudes as a result of using multiple mini projects instead of a semester-long project. The third purpose is to examine the extent to which the intertwined projects approach achieves select elements of high-impact practices and promotes student learning in gateway mathematics and statistics courses.

Pre-Test/Post-Test

Pre-post testing provides valuable information to the instructors because it provides baseline information when beginning instruction. It provides instructors with insight and current information on entry behavior, preparedness and functioning of the students. While pretesting is in no way going to determine the content, instructional methods, and the scope, it serves as a 'road map' for the topics (Berry, 2008). Also, the pre-tests serve as an advance organizer to communicate to some degree, the learning outcomes, expectations and the relevance of the content to the students before instruction begins. The pre-test is not viewed as a checklist of, to "check off" what needs to be covered nor a determination of students' prior knowledge without deeper questions about learning outcomes, quality of delivery and mindsets.

Pretesting has been suggested as a preinstructional strategy that significantly influences subsequent student learning (Richland et al., 2009). In addition to its evaluation role, the pretest serves as an advance organizer which accordingly prepares and strengthens students' cognitive structures (Joyce et al., 2003). Pretesting has been shown to be a more active method that optimizes learning (Shaffer et al., 2020). In this work, pretesting is presented as a learning strategy giving students a preview of what to expect and how to learn. Pretesting has been shown to be quite effective and teaches students to be attentive, alert and free of test anxiety (Weinstein & Underwood, 1985). Pretesting has been shown to affect learners' attention, intentional learning behaviors as well as improving future learning. Students' interaction with test questions as a class activity improves students' attitude towards mathematics (Vionita & Purboningsih, 2017) and which has been established as a factor influencing student achievement. Pretest also has the potential to significantly enhance retention and pretested information is learned better than non-pretested information (Shaffer et al., 2020).

Though the students are likely to fail the pretest, the questions not correctly answered provide opportunity and motivation for future learning after unsuccessful retrieval (Richland et al., 2009). Designed with the learning outcomes in mind, the pretest not only serves as an advance organizer; but also provides authentic problems that the student needs to accumulate the skills to solve. As noted in (Richland et al., 2009), pretests not only direct attention to critical information, but also trigger other processes that promote deeper processing of subsequent information. On the other hand, pretesting has been shown to influence the subsequent learning of information that is not itself pretested but that is related to the pretested information (Little & Bjotk, 2016).

To develop pretest as an instructional tool requires practices rooted in learning outcomes and assessments. The pre-testing procedure encourages instructors to critically evaluate course objectives and goals, and to assess the

quality of their teaching. Backward design promises the alignment of course outcomes with learning activities and assessment. Pretesting with the characteristics for assessment and for instruction will be enriched by a backward design. According to Hagedorn et al. (2000), testing should be viewed as a form of dialogue between the instructor and students and a formidable educational tool.

Long-term retention is said to be dramatically increased when tests are utilized as learning events and information is presented in a test format (Halamish & Bjork, 2011; Toppino & Cohen, 2009); additional exposure, transfer-appropriate processing, and motivation have been attributed to test enhanced-learning (Yang et al., 2021). These theories affirm this work's use of pretest questions as prompts in the learning of content material. Relating the pretest questions to the course objectives and student learning outcome goals, information gained from the approach provides a measure of success towards achieving the goals (Simkins & Allen, 2000). This work is geared towards realizing the promise of incorporating pretesting as a factor for positive outcomes in the teaching and learning process.

Project Based Learning

One of the elements of High Impact Practices (HIPs) is engaging students in activities that require significant investment of time and effort by students over an extended period of time (AAC&U). A project is considered useful if students find it meaningful and they undertake it for an educational purpose (Larmer & Mergendoller, 2012). Project-based learning (PBL) has been advocated for its promise; but evidence of its effectiveness in mathematics is limited, coupled with the difficulty of integrating PBL into instruction (Condliffe et al., 2017). The multiple mini-projects design allows students to incrementally acquire quantitative skills and knowledge while investigating meaningful content-related real-world problems over a period of time. Using a combination of project-based learning and performance assessment has been shown to encourage students to gain deeper understanding. Project based courses have been shown to increase student achievement, motivation and engagement in gateway courses (Julian, 2017). The problem-based courses have been shown to provide opportunity for students to utilize content while solving real world problems (Kumar & Refaei, 2013). The idea of multiple mini projects designed to be completed within the semester is gaining traction and accords the instructors more flexibility in their use. The Intertwined Project based approach is geared to enhance the student achievement gains, motivation and engagement in gateway mathematics and statistics courses; through a combination of learning strategies and elements of high-impact practices.

Assessment to Enhance Learning

Assessment has been shown to serve a formative function and that teaching which incorporates formative assessment promotes student achievement (OECD/CERI, 2008). Students' mathematical-related beliefs are positively influenced by formative-assessment practice which is recognized and appreciated as resources for their learning (Balan, 2012). Developments suggest that integrating assessment with instruction may have unprecedented power to increase student engagement and learning outcomes. A well designed, low stakes assessment supports learning by providing guidance about the next steps in instruction and in a way that

encourages the learner to direct energy towards growth (William, 2011). The low-stakes assessments in this context aligns with the need for frequent, timely and constructive feedback as highlighted in the elements of HIPs. In this work, the feedback from the targeted conceptual problems from the pretest creates a syllabus for teaching the concepts through the short videos, brief lectures and content review through class activities.

Formulating the pretest questions as elements of class activities presented feedback in a non-negative way, to deemphasize competition and promote personal improvement in acquisition of mathematics concepts and problem-solving ability. In deviating from the traditional lecture methods, we have designed a framework that allows students to participate in creating their problem-solving skills through interaction with the questions, content, instructor and peers. The students engage in problem-solving collaboratively for problems that are relevant to them given that they were in the pretests; as well as completion of related projects that reinforce the concepts. It is envisaged that the students perceive these interactions as substantive matter (AAC&U). This construction is anchored on the following premises;

- Learning in the mathematics classroom is social, not individual.
- Coming to know mathematics depends on active participation in the enterprises so valued in that community of mathematics practice that they are accepted within that community (Burton. 2002).

The scope of students' activities ranged from reading worked examples together, solving pretest problems, to solving non-routine problems as group projects. It has been shown for example, that group work, which is a foundational part of PBL, when done collaboratively and with respectful discussion would be supporting marginalized groups pedagogy (Schettino, 2016).

Method

Data Description

The data was collected over the Fall 2021 semester from two courses and three sections of MATH 1001: Quantitative Skills & Reasoning and one section of STAT 1401: Elementary Statistics. Each course used intertwined project-based approach, whereby each instructor embedded 3 projects in the course over the duration of the semester. These projects were designed to align with concepts in the content as well as meet the student learning outcomes. For example, the first project in STAT 1401 was on summary statistics. The students gathered data from an online source (Data and Story Library: https://dasl.datadescription.com/), imported the data into a statistical software package (SPSS), performed analysis on the data, and then summarized the results in a short 1-2 page report with graphs and tables.

In total, there were 87 students in both courses for which complete data was available. There were 52 students in MATH 1001, which was a 3-credit hour face-to-face class that met on Mondays, Wednesdays, and Fridays. There were 35 students in STAT 1401, which was a 3-credit hour online class that met asynchronously. The students worked in a pre-assigned group by the instructors.

STAT 1401: Elementary Statistics

Chapter 2 Project

Title: Describing Data with Numbers, Graphs, and Words

Purpose:

Data is available everywhere nowadays. Extracting data in order to use it in software is a valuable skill, as once the data is in a file that can be opened in statistical software, you have the power to create informative graphs, descriptive tables, and communicate those results (truthfully!) to others. The purpose of this activity is to help you become familiar with describing a data set in several ways.

An important part of statistics is being able to do the basics---gather data, clean it for analysis, use software to create graphs and tables, and then communicate the results. This requires an understanding of fundamentals of statistical skills and critical thinking, which will be helpful to your life and career, as there is great power in understanding the persuasiveness of numbers, especially used to mislead. Ideally, this task will be a practice in following through with scientific thinking and truthful communication of numbers.

Task:

To complete this activity, use the following sequence.

1. Go to: https://dasl.datadescription.com/
2. Under "Search by Statistical Method," choose "Boxplots." See picture below with circle.

Figure 1. First Page of Example Project from STAT 1401 on Descriptive Statistics

Project Name: Applications of set theory (100points)
Due date:

Note: Prepare your final group project paper on a separate piece of paper with neat handwriting or computer copy.

This is a group project so please write each student's contribution by name at the end of the paper.

Best group project will be given 3 points extra credit.

Objective: Apply the knowledge of set theory in real world life situations.

Purpose:

Set theory is foundational in many mathematical applications; this assignment is designed to help you practice the set theory so that you can see its role in a real-world context.

Understanding of set theory helps you to:

- See things in terms of systems
- Organize things in groups
- Begin to understand logic
- Apply it in decision-making in real life situations
- To compare the objects
- Judging/evaluating and selecting best solutions
- Creating/inventing a new interpretation, product

Mastering the set theory through this assignment prepares you for your majors in prenursing, political science etc.

Task:

Create a survey with 3 questions that are binary in their responses. In other words, each question on the survey has only 2 options to choose from. (This is easiest if you think of yes/no questions.) You may use the following questions or come up with some of your own. If you choose to make up questions on your own, remember that they must only have a choice of 2 responses.

1. Were you born in this state?
2. Have you ever traveled to another country?
3. Can you speak another language besides English?

Write your three questions if you choose not to use all of the ones above

1.
2.
3.

Figure 2. First Page of Example Project from MATH 1001 about Set Theory

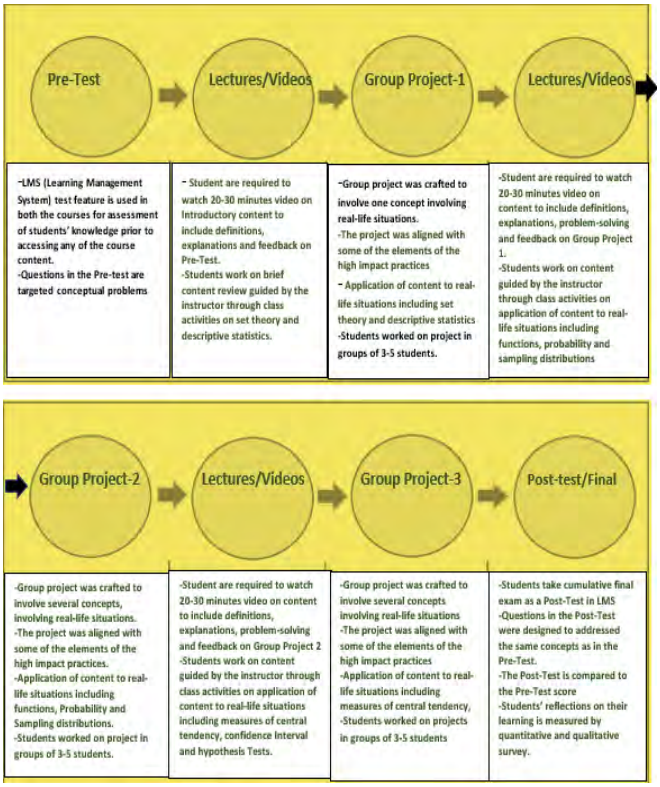

Figure 3. Intertwined Project-Based Learning Course Design

Data was collected over the semester for each student, which included scores on a pretest and a posttest. The pretest and posttest for MATH 1001 was the same-concept exam with 40 total points, with the pretest given during the first week of semester and the posttest given during the final week of the semester. Similarly, the pretest and posttest for STAT 1401 were administered with the exception that both were given online through WebAssign and assigned a total of 77 points. Students who did not take either the pretest, projects or posttest were excluded from the study. This data was normalized by considering the percentages.

Data Analysis

In order to compare the classes on a like-for-like scale, the points for both the pretest and the posttest were converted to a percentage of total points. Our question of interest is, "Did including project-based learning over the course of the semester improve student learning?" To measure this, we expect to compare the students' pretest and posttest scores as a percentage with a paired-sample t-test, and, in the event of obviously non-normal distributions in the pretest and posttest, we will perform the nonparametric Wilcoxon Signed Rank Test. Either result will indicate if the students' learning improved after the intertwined projects approach. All statistical analyses will be performed using SPSS.

Results

Summary Statistics

Summary statistics were obtained for the pretest and posttest for the scores as a percentage for the classes and are

shown below in Table 1. The percentage for the pretest averaged 16.80% with a standard deviation of 17.47%. The percentage for the posttest averaged 65.43% with a standard deviation of 25.87%. The percentages on the pretest were much lower, on average, than the percentages for the posttest; however, the variation on the posttest was almost 10% higher than the variation on the pretest (25.85% versus 17.47%, respectively).

Table 1. Summary Statistics for Pretest and Posttest as a Percentage

	N	Mean	Standard Deviation	Standard Error
Pretest %	87	16.80	17.47	1.87
Posttest %	87	65.43	25.87	2.77

Next, we investigate the distributions of the pretest and posttest using histograms. The distribution for the pretest as a percentage is presented in Figure 4, while the distribution for the posttest as a percentage is presented in Figure 5.

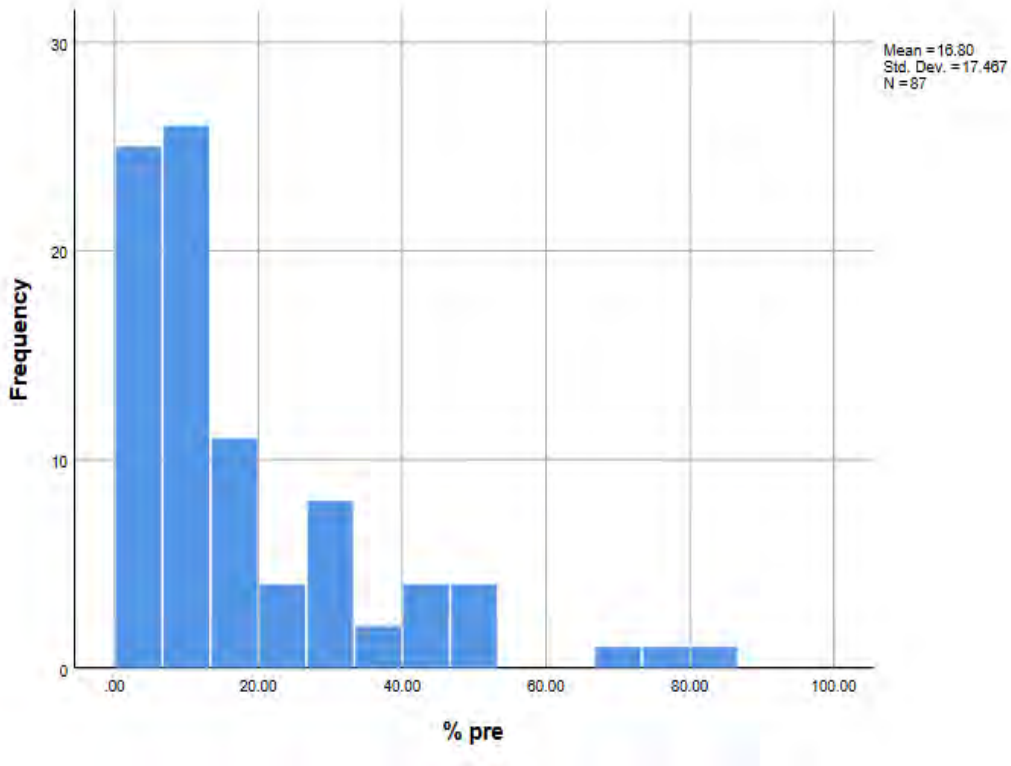

Figure 4. Histogram of the Pretest Scores as a Percentage

The pretest scores (see Figure 4) are very positively skewed, with most students scoring very low on the pretest. This is expected as the pretest was in part used as a tool to measure preparedness at the beginning of the semester. The distribution of the posttest scores (see Figure 5) shows a mirror image of the shape seen in the pretest scores histogram. These scores are negatively skewed, which means most students scored well or high on the posttest, compared to the pretest. It is expected that students answer more questions correctly as their knowledge and

understanding of the material progressively increases.

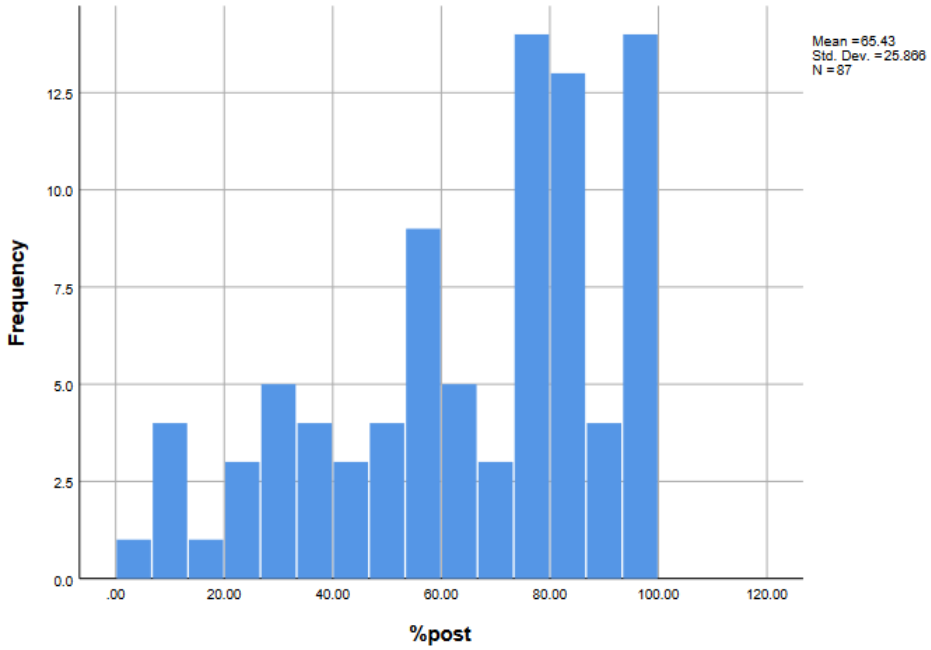

Figure 5. Histogram of the Posttest Scores as a Percentage

Although both distributions are skewed, we will plan to use the paired t-test to answer our research question of, "Did including intertwined project-based learning as a high-impact practice over the course of the semester improve student learning?" as our sample size is large enough.

Paired-Sample t-test

The Paired-Samples t-test is a parametric hypothesis test to be used for 2-sample paired data. This test is appropriate for our data because we have a paired sample with two data points, the pretest and the posttest percentages. The null hypothesis for our test is that the pretest percentage and the posttest percentage are not significantly different (H_0: $\mu_{post} = \mu_{pre}$), while the alternative hypothesis is that the posttest percentage is significantly higher than the pretest percentage (H_1: $\mu_{post} > \mu_{pre}$). The descriptive statistics of the Paired-Samples t-test are shown below in Table 2.

Table 2. Descriptive Statistics for Posttest % - Pretest %.

	Mean	Standard Deviation	Standard Error Mean	Lower 95% Confidence Interval of Difference	Upper 95% Confidence Interval of Difference
Posttest% - Pretest%	48.63	24.22	2.60	43.47	53.79

The average difference between the posttest and pretest percentage is 48.63%, indicating that a student's score

rose, on average, by about 50% from the pretest to the posttest after experiencing intertwined project-based learning. The standard deviation for the difference was 24.22%, while the standard error of the mean difference was 2.60. We are 95% confident that the mean difference between the posttest and the pretest is between 43.47% and 53.79%.

Table 3. Paired-Samples t-test Results for Posttest % - Pretest %

	t	df	P-value
Posttest % - Pretest %	18.73	86	0.000

The paired-samples t-test indicates that the posttest scores as a percentage are significantly higher than the pretest scores as a percentage (t=18.73, df=86, and p-value<0.001). In fact, we can see from the confidence interval in Table 2, that the students scored on average about 48.63% higher on the posttest than the pretest.

Control (No Project) versus Project-Based Learning Analysis

In addition to comparing the pretest to the posttest, an analysis will also be performed to compare final course grades from previous sections of the same courses from Spring 2021 to the sections from Fall 2021. The spring 2021 courses included no multiple-part projects embedded in the course while in fall 2021 courses included the multiple-part projects embedded in the course. Counts for each course by semester are presented in Table 4.

Table 4. Count of Students by Course and Semester for the Control versus PBL Analysis

Semester / Course	MATH 1001	STAT 1401	Total
Spring 2021 (Control)	27	70	97
Fall 2021 (PBL)	24	38	62
Total	51	108	159

For Spring 2021, there were a total of 97 final course grades with students that completed all of the work, with 27of those in MATH 1001 and 70 students in STAT 1401. For Fall 2021, there were a total of 62 final course grades with students that completed all of the work, with 24 of those in MATH 1001 and 38 students in STAT 1401. This yielded an overall total of 159 final course grades for this analysis.

Descriptive statistics for each semester are shown in Table 5. The average final course grade for sections with no multiple-part projects embedded was 78.61% (or a high C average) with a standard deviation of 20.13% on a total sample size of 97. The average final course grade for sections with intertwined project-based approach was 80.18% (or a low B) average with a standard deviation of 16.85% with a total sample size of 62. Although these final class grades are very close, there is a slight edge on the courses with the intertwined project-based approach.

Table 5. Descriptive Statistics for Final Class Grade by Semester

Semester	Average Final Course Grade	Standard Deviation of Final Course Grade
Spring 2021 (Control)	78.61%	20.13%
Fall 2021 (PBL)	80.18%	16.85%

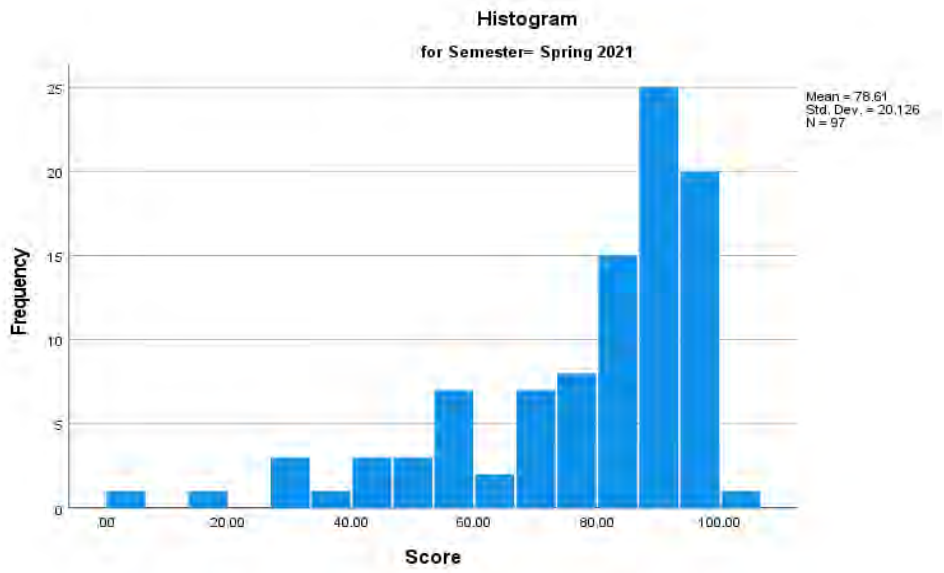

Figure 6. Histogram of Final Course Grades for Spring 2021 (Control)

The histogram of final course grades for Spring 2021 is above in Figure 6, and the histogram of final course grades for Fall 2021 is below in Figure 7. Both final course grade distributions are left skewed, with data indicating that most students scored between 70% - 90%, while fewer students scored below 70%. The mean final course grades are close for the two semesters.

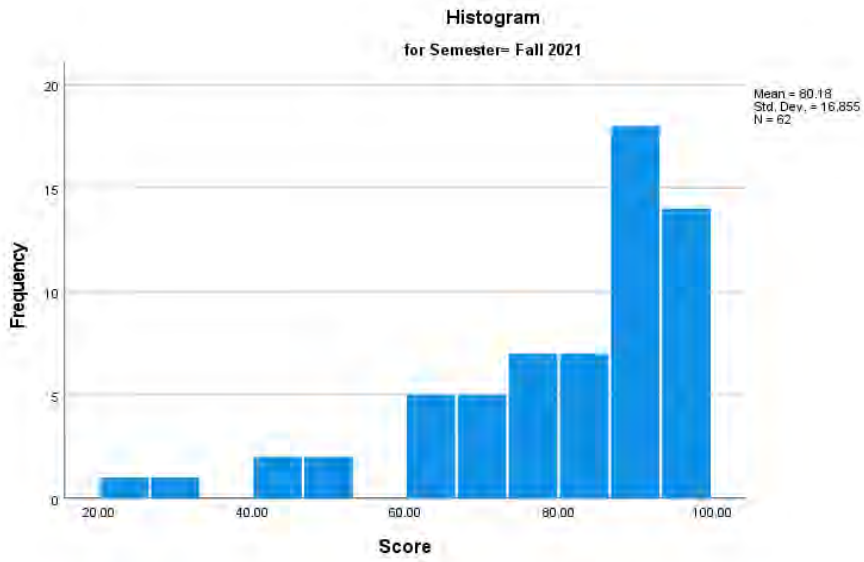

Figure 7. Histogram of Final Class Grades for Fall 2021 (PBL)

Table 6. Independent-samples t-test Results for comparing Spring 2021 (Control) to Fall 2021 (PBL)

	t	df	P-value (2-sided)	Mean Difference	Std. Error of Difference	95% CI for Difference
Final Class Grades	-0.509	157	0.612	-1.56	3.08	(-7.64, 4.51)

An independent-samples t-test is performed to compare the final class grades for Spring 2021, the control group with no multiple-part projects embedded in the course, to the final class grades for Fall 2021, the treatment group with intertwined project-based approach. The t-test results show that there is no significant difference between the final course grades for Spring 2021 and Fall 2021 (t=-0.509, df=157, p-value=0.612). Levene's test for equality of variances indicates that the variances are not different for the two groups (F=1.67, p-value=0.199). This is not a statistically significant result. These results suggest that using intertwined project-based approach throughout the semester does not change student performance on the final exam. Due to instructional time reassigned to introducing projects or using group work during class time, when compared to a traditional class, this is considered a gain on having applied the elements of High Impact Practices. This further suggests the need for qualitative analysis to highlight to what extent the intertwined project-based approach as an engaging pedagogy supports the five elements of HIPs presented above.

Survey Results

An 11-question survey was deployed to all active students at the end of the fall 2021 semester. Some extra credit points were offered as an incentive to students to complete the survey. A copy of the survey can be found in the appendix. The results of the survey will be summarized in this section. In total, 73 students responded to the survey, as shown in Figure 8 below. A total of 53 students (72.6%) from MATH 1001, and a total of 20 students (27.4%) are from STAT 1401.

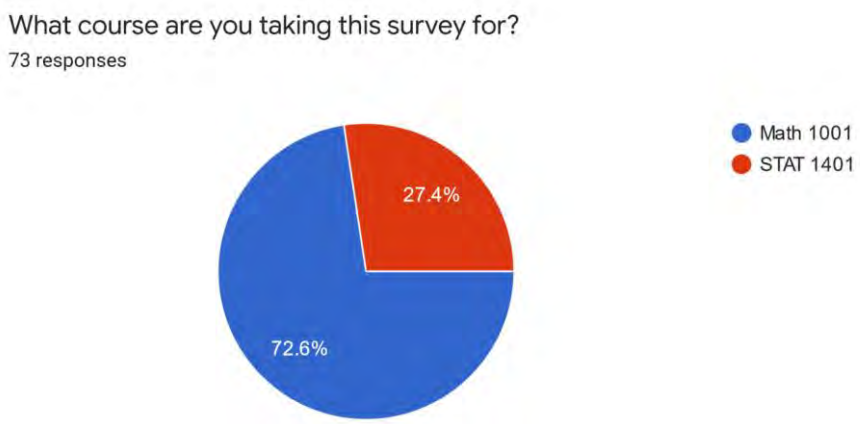

Figure 8. Pie Chart of Responses by Course

The next question of the survey asked students to rate the usefulness of the multiple-part projects in mastering the content of their respective courses. The results can be found in Figure 9. A majority of students (69.9%) rated the usefulness of the projects as a 4 or 5.

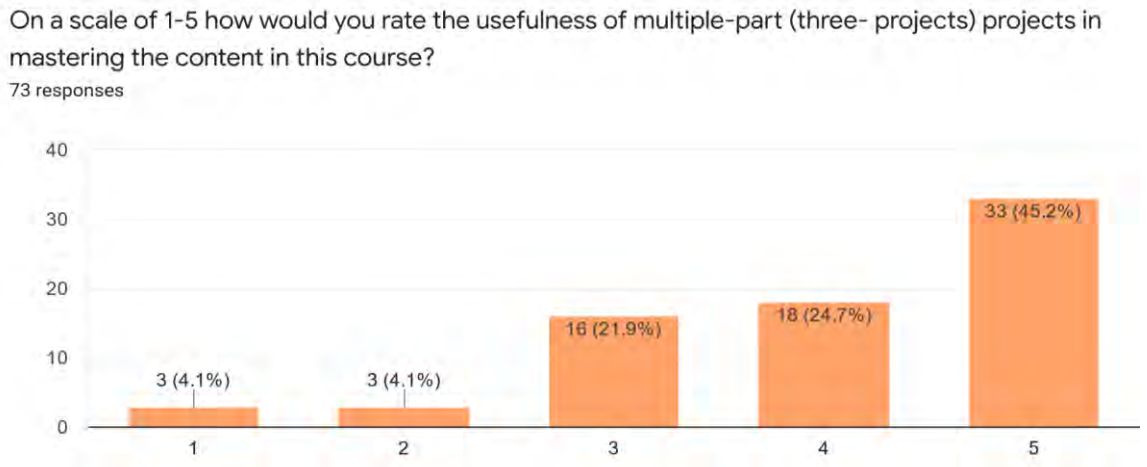

Figure 9. Bar Chart of Usefulness Rating of Projects

The third question asked students to rate the frequency of instructor feedback on the projects or exams throughout the course. The students had answer options: *Never, Sometimes*, or *Always*. The results are shown in Figure 10. below. Of those surveyed, 76.7% of the students responded *Always*, 20.5% of the students responded *Sometimes* while 2.7% responded *Never*.

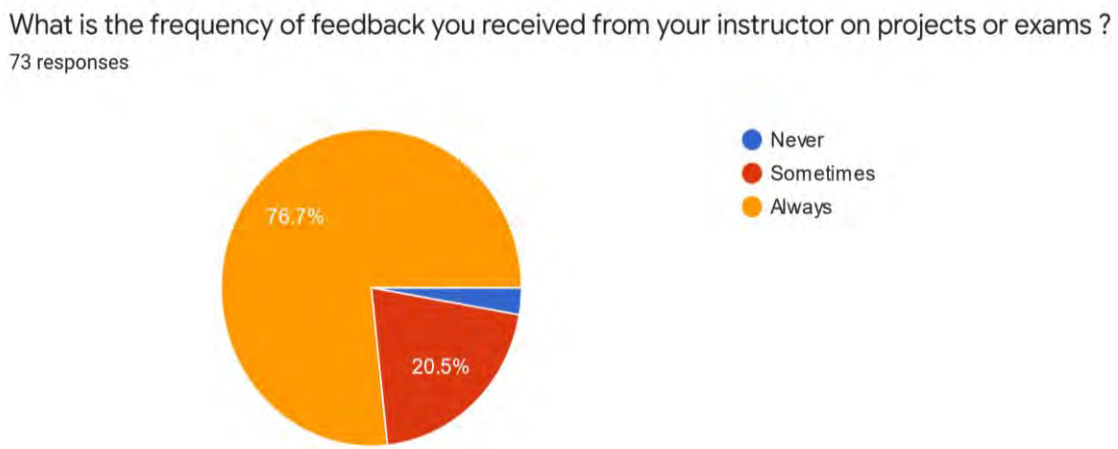

Figure 10. Pie Chart of Responses on Frequency of Feedback from Instructor

The fourth question asked about the effectiveness of the feedback that was received from the instructor. To rate the effectiveness, students had answer options: *Highly, Significant* or *Poor*. The results are shown in Figure 11. below. Of those surveyed, 61.6% of the students rated the feedback *Highly*, 37% of the students rated the feedback as *Significant*, while about 1.4% of the students rated the feedback as *Poor*.

The fifth question asked about how helpful the project was in making connections from the course material to the real-world problems. The students used a scale of 1-5 with 5 highest and 1 the least, to rate the helpfulness of the project in making connections from the course material to the real-world problems. These results can be found in Figure 12. The majority of the students (65.7%) rated the helpfulness as a 4 or 5, while 27.4% rated the helpfulness

as a 3. On the lower end, 5.5% rated the helpfulness as a 2 while 1.4% of the students rated the helpfulness as a 1.

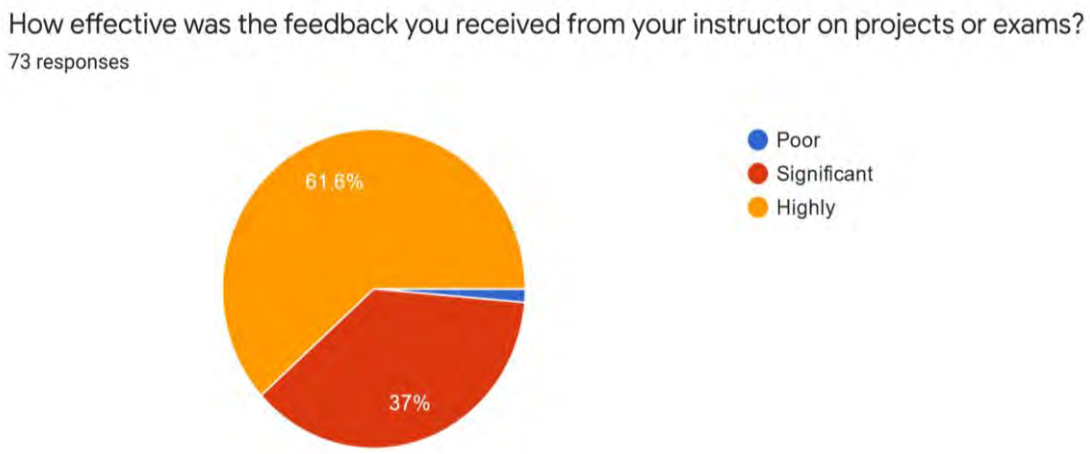

Figure 11. Pie Chart of Responses on Effectiveness of Feedback from Instructor

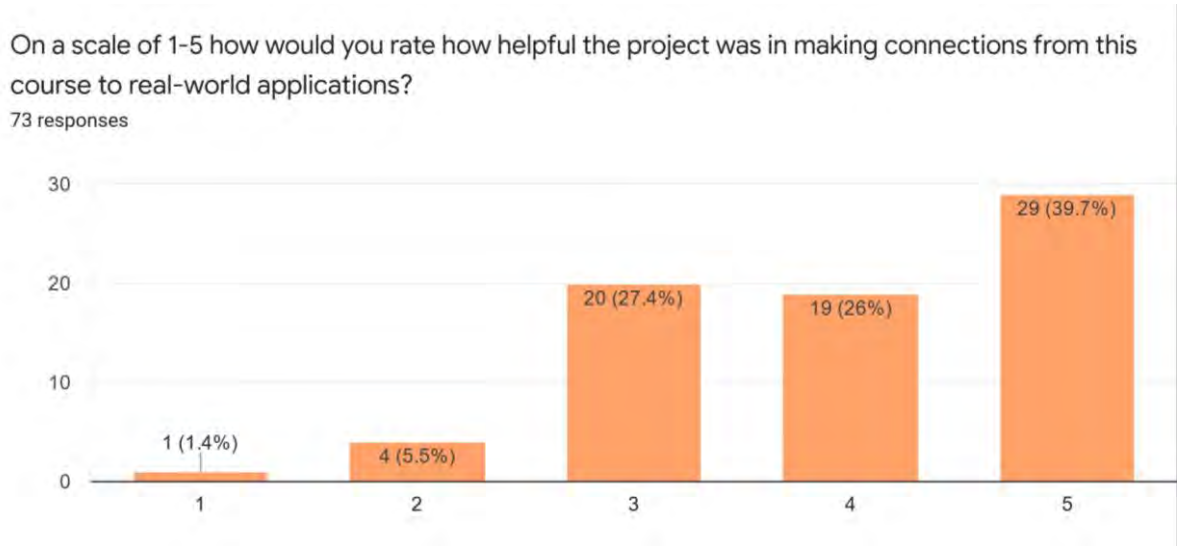

Figure 12. Bar Chart of Making Connections from Course to Real World

The sixth question asked the students to rate how frequently they participated online or in person to work on the group projects. To rate the frequency the students had answer options: *Frequently*, *Rarely* or *Never*. The results can be seen in Figure 13. A large majority (89%) of the students indicated that they frequently participated in group work, 11% indicated that they participated rarely, while no students responded as to never participating.

The seventh question asked students how they would rate the usefulness of the group work in the course. The students used a scale of 1-5 with 5 highest and 1 the least, to rate the usefulness of the group work in the course. The results can be seen in Figure 14. A majority (67.1%) of students rated the usefulness as 4 or 5 while 19.2% of the students rated the usefulness as a 3. On the lower end, 8.2% of the students rated the usefulness as a 2, while 5.5% of the students rated the usefulness as a 1.

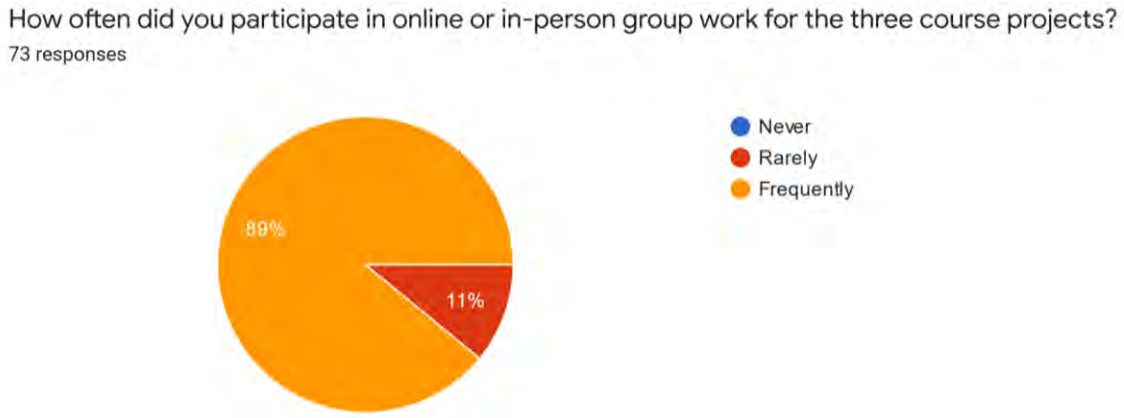

Figure 13. Pie Chart of Frequency of Participation

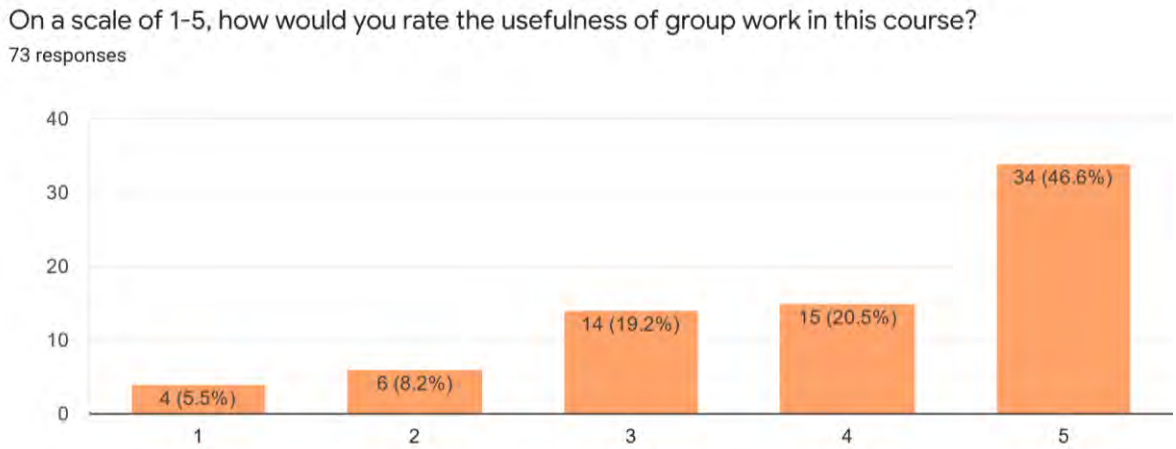

Figure 14. Bar Chart of Usefulness of Group Work in Course

The eighth question asked the students about their confidence in using the math skills developed in the course. To rate their confidence in using the math skills developed in the course, students had answer options: *Very confident*, *Confident* or *Need help*. The results can be found in Figure 15. A majority (57.5%) of the students were confident, while 30.1% were very confident. The rest 12.3% of the students indicated they were less confident and would need help with their math skills.

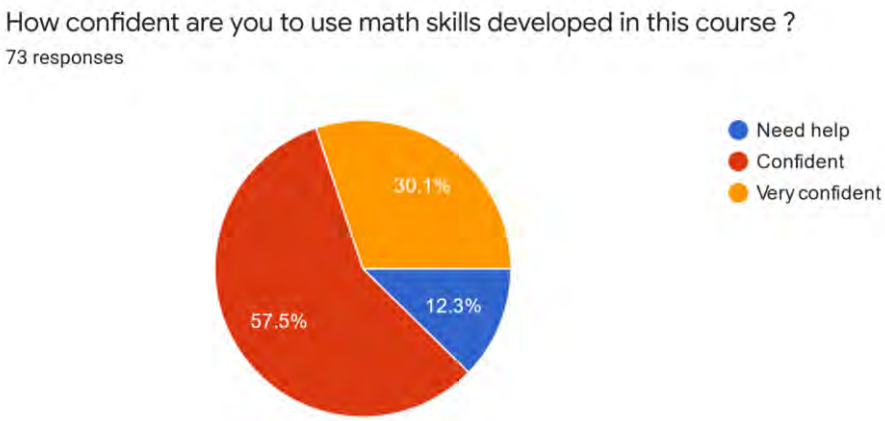

Figure 15. Pie Chart of Confidence in Math Skills

The ninth question asked students if there was anything they would change, improve, or keep the same from the project templates. The results can be found in Figure 16. A vast majority of the students (83.6%) indicated they would keep the projects the same. 8.2% of the students responded they would change the projects, while another 8.2% indicated they would like to see improvement in the projects.

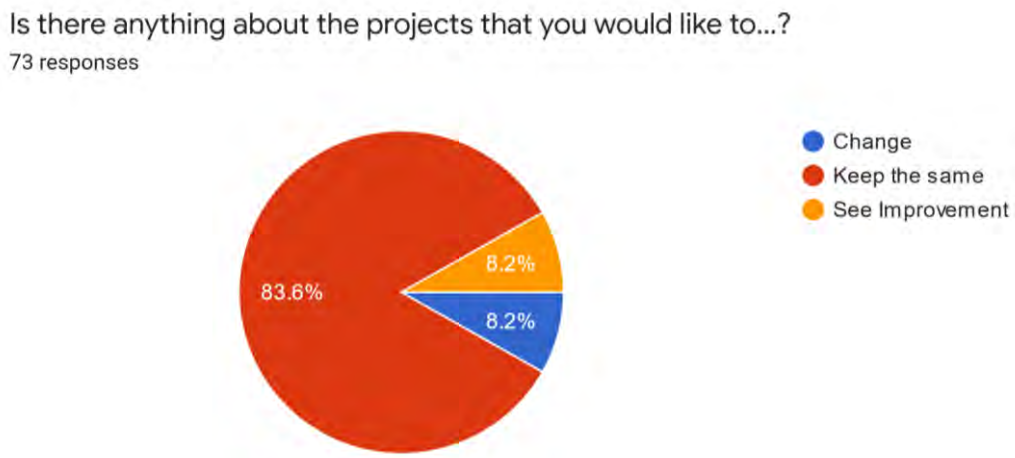

Figure 16. Pie Chart of Change or Improvement in Course

The last two questions on the survey were optional. Both of these questions were open-ended and had qualitative responses. The first open-ended question asked students, "If you chose improvements in the previous question, please explain what improvements you would like to see." There were 10 responses, and the most common response included students asking to be able to pick their own groups (50%).

The second open-ended question was about "What are the major challenges you faced in the group work and/or the collaborative tools to complete the project?". There were 66 total responses. A majority (66.67%) of the students mentioned communication (or lack thereof) with group members or participation (or lack thereof) of group members being a challenge during each project. This was not surprising as the students may need to develop the skills of working collaboratively and self-select into working groups. A few students mentioned that they had no challenges or problems with the group work and project, while a few others mentioned time management issues, regarding the scheduling of the projects conflicting with exams or projects in other classes. For example, here is a sampling of comments with a count of equivalent comments in parentheses after the comment:

- "Sometimes not all group members communicated well to get the project done, but the ones that did made it easy to get the jobs done." (45)
- "No challenges, everything was easy to use!" (10)
- "Time management was a challenge because some people in the group would say they would do their part on a certain day but never do it. I have to manage my time and do their part of the project." (4)

Discussion

This work is aimed at exploring a number of relevant outcomes for introductory mathematics and statistics courses

in light of the differences in course structure and subject matter sequencing. The investigations following the exposure to intertwined mini-projects showed knowledge gain across four sections of introductory Mathematics and Statistics courses. The initial analysis shows that posttest scores were statistically higher than the pretest scores for the project-based courses.

A follow-up analysis comparing courses with no projects with courses with projects for both MATH 1001 and STAT 1401 over two semesters found that there was no significant difference quantitatively in final course grades in the no-project courses and the intertwined project-based courses. However, qualitatively, learning gains and student satisfaction are evidenced through the survey results. These results are in line with Dureh (2021), findings on projected-based learning benefits. The observed performance differences coupled with the students' satisfaction attest to student learning, added value of combining instructional strategies guided by the targeted elements of high-impact practices. The advantages of this method resonate with the findings of Kovacs et al. (2021) mixture of modern teaching methods including project-based learning.

The analysis of the qualitative responses suggests that reassignment of instructional time for introductions, group work, related multiple projects, feedback and reflections does not harm student learning over the course of the semester, and further that intertwined project-based learning does make a positive impact on student engagement and satisfaction, and yielding equivalent student outcomes. The investment of devoting extended instructional time has advantages to the development of successful projects as emphasized in Shaffer (2014). These educational outcomes analyzed in this study are consistent with relative and absolute gains reported in Paľová and Vejačka, (2022).

In our classes, we implemented 2-3 mini projects throughout the semester, rather than one large project due at the end of the semester. In doing so, we included four elements of high-impact projects: (1) significant investment of time and effort by students over an extended period of time (as they had to complete 2-3 projects over the semester, and were given approximately 2-3 weeks to complete each project and receive feedback), (2) experiences with diversity (as the university's student population is very diverse). This includes the varying depth of mathematical knowledge in our introductory courses. According to Holmes & Hwang, Y. (2016) project-based learning decreases achievement gaps and is equally effective for students with differing levels of mathematics knowledge, which resonates with the demographics under consideration in this study. (3) frequent, timely and constructive feedback (feedback on intertwined-projects was given to students within one week after due date), improving knowledge acquisition and bridging gaps between their current and targeted performances, as noted in Dulfer & Akhlaghi (2021) and (4) opportunities to discover relevance of learning through real-world applications with meaningful interaction with student-student and student-instructor (each project was designed to relate back to a real-world situation where introductory math or statistics could be used to make sense or understand concepts).

Additionally, high-impact practices and project-based learning have been recommended to faculty as ways to increase student retention, progression, and graduation rate by the American Association of Colleges & Universities (AAC&U). In fact, our University System has set specific goals for institutions to increase student participation in experiential learning opportunities, like project-based learning. Our study provides an opportunity

to look further at how incorporating intertwined project-based learning and high-impact practices may be related in providing more equity-minded approaches to student success. This is in line with other studies that examine broader goals presented by Vesikivi et al. (2020), and those that demonstrated benefits beyond immediate student performance including course enrollments, subsequent course grades and benefits to diverse student populations studied by Nguyen et al. (2020).

Our research shows 2-3 mini projects work well for both students and the instructor, providing flexibility and frequent feedback. For the students, there is motivation, incremental progress, understanding of the content and developing 21st century problem-solving skills. For the instructors, the benefits include getting a sense of student capability, a timely adaptability for being able to adjust project objectives with students' needs and to require diverse strategies to increase student success. Additionally, structural benefits include less of a time investment when creating 2-3 mini projects either before or during the semester, smaller grading time investment, as opposed to one large project, which would need to be created and have instructions completed before the beginning of the semester. The sequence of mini projects provided for multiple levels of engagement, feedback and opportunities to discover relevance of learning through real-world applications, in line with high impact practices highlighted in this work.

Conclusion & Recommendations

In introductory mathematics and statistics courses at a regional university in the southeastern United States, we found that intertwined project-based learning had a positive impact on student success and satisfaction. Student learning was measured by a pre-test and a post-test, and students performed better on the post-test after experiencing multiple projects intertwined with active learning activities throughout the semester. These 2-3 mini projects covered concepts in both introductory mathematics including set theory, applications of functions, and central tendency, and introductory statistics including descriptive statistics, probability, sampling distributions, confidence intervals, and hypothesis tests.

In addition, these projects incorporated the five select elements of high-impact practices. We also found that when compared to a previous semester's sections of the same introductory courses that intertwined project-based sections performed similarly to the traditional lecture class. Both of these results imply that intertwined project-based learning has an overall positive effect on student success, and the survey results indicate that students have an overall high satisfaction with intertwined project-based learning in introductory mathematics and statistics courses. The apparent effectiveness of intertwined problem-based learning coupled with the students' satisfaction was strengthened by the pre-test procedure and use of multiple projects.

In future work, we would like to incorporate more elements of high-impact practices and scale the mini projects approach across more sections of introductory mathematics and statistics courses. In particular, we would like to add in-class and /or public presentations of student's findings, which would fulfill the "public demonstration of the competence" element and "incorporate feedback from peers", which would fulfill the "interactions with faculty and peers about substantive matters" element. We think a combination of these elements would provide

opportunities for students to further improve their mathematical and statistical skills and competence, in addition to communication skills which is an essential component of life-long learning. To develop another measure of student gain, we recommend considering specific questions in the pretest that will be assessed in post-test following related content activities.

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