

Post Implementation Report

2022 COURSE ENHANCEMENT MINI-GRANT
(STEM CENTER – SAM HOUSTON STATE UNIVERSITY)
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A copy of the original proposal

Title: Scholarship of Teaching and Learning: Discovery-based approach combined with active learning to improve student learning experiences for STEM students

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No current and pending funding related to this project

Budget: \$1500

STEM Courses involved in the proposal: Concrete/Masonry Construction - 20555 - ETCM 3368 – 01 –
Expected Enrollment: 24

Project narrative

Executive Summary

STEM students are expected to learn a large amount of information and concepts, but long-term retention of this information is a substantial challenge. Incorporating active learning strategies into class sessions can potentially improve long-term retention. For Construction Management students, learning the composition and production of concrete can be challenging because it is difficult to predict the properties of this composite material based on the jobsite condition (temperature, concrete volume, delivery method, etc). For this reason, rote memorization is frequently employed by STEM students studying Construction Management. Such methods are associated with poor long-term recall and poor performance on design questions and field activities. A combination of [discovery-based learning](#) (as a novel instructional approach) and [Pro-Con Grids](#) (as an active learning activity) would promote long-term retention of knowledge of concrete design and production. An active-learning approach will be used to teach selected sessions in a required Construction Management course. The students will be assigned to smaller groups (4-5 students per group) for a timeframe that lasts a few lectures or weeks and expected to review key concepts from the course Blackboard prior to the in-class sessions. During class, brief concept reviews will be followed by active-learning exercises, including a pro-con grids. Each group will be asked to come up with at least three points for each side. Once students complete the activity, the points on each side will be shared and discussed. Data will be collected through a student survey and the evaluation of students' grades.

Project Narrative

Rationale:

Active learning encompasses a wide range of pedagogical tools and strategies that help students make meaningful connections to course concepts; working in groups is among these pedagogical practices. Probably the main advantage is that students can apply concepts, solve problems, and, in general, engage cognitively with course content with the support of peers. ETCM 3368 is a lecture/lab course with 3-hour lectures and 1-hour lab per week. The labs rely on the use of structured groups that engage in specific concrete and masonry activities. The hands-on lab component of the selected class provides a unique opportunity to apply pedagogical strategies such as discovery-based and hands-on learning where students can be assigned specific roles that operate throughout the semester. I have taught this course twice in Spring 2020 and Fall 2021 and want to incorporate active learning pedagogies into my course for Spring 2022. Most of the students tended to memorize information based on repetition. Although they could quickly recall basic facts, it did not allow for a deeper understanding of subjects. I also noticed no connection between new and previous knowledge although students enjoyed the opportunity to do a hands-on project. I plan on using more learner-centered pedagogical practices to make the most of the limited time I have for

face-to-face classroom interaction. My hope is that cooperative learning would encourage students to think creatively when solving problems as well as increase their confidence when solving problems.

Materials and Methods

Discovery-based learning method provides structures for completing work or products by dividing work among group members. This cooperative instructional approach is chosen for the ETCM 3368 class because concrete projects can be tackled and completed by groups working collectively. For this study, students will be provided with a course lecture that discusses key characteristics of concrete in a powerpoint file and an instructional video prior to the active-learning in-class sessions. A short quiz will be used for each lecture to gain insight into students' understanding and to evaluate the effectiveness of the learning method. During the in-class session, a blank sheet of paper will be handed out to students for making a list of pros and cons/advantages and disadvantages for the concrete issues covered in the lecture. The students will be informed about the number of items expected to list and whether they should use words, phrases, or sentences in their list of pro and con arguments. Once the pro-con grid is complete, students will be directed to share their documents with the instructor. This will be followed by a summary of key concepts and then a review of the correct answers. Students will be encouraged to collaborate with their teammates to create a list of pros and cons.

Data will be collected for this study in two forms; through a student survey and grades. All students will be given a pre-survey at the beginning of the semester (when the study initially begins) that is also the same survey given at the end of the semester (conclusion of the study). The results of the surveys and the students' grades are statistically analyzed to see any statistically significant difference between pre-study and post-study results for the students in the experimental group. The survey will be administered via an individual online survey link using the Qualtrics platform. I am teaching a section of ETCM 3368 this semester and I plan to use the same survey by the end of the semester to gather the data for the control group. The students enrolled in this class are taught with the traditional lecture/lab method. The survey results can be used to measure the strength of the instructional approaches by comparing control (Fall 2021) and experimental (Spring 2022) groups.

Expected Results and Dissemination Plan (if any)

The foundation of this study is comprised by this research question: How discovery-based learning can improve my students' learning skill in concrete construction? This learning method combined with an active learning activity can help students in developing analytical and evaluative skills because it requires them to go beyond their initial position and come up with points of discussion for the other side of the issue. When the semester initially begins, students will be given a survey which will be the same survey given at the conclusion of the project/semester. The results will be analyzed and included in the Project Report. These results can be featured on the STEM Center website and included in STEM Center promotional materials.

Budget and Brief Budget Justification

I will assume responsibility for the overall project, revising course material, developing and conducting surveys, performing survey analysis, and writing reports. I will commit around 10% of my research appointment to this project; \$1,500 is requested as a faculty stipend. Without this budgetary line item, I won't be able to spend enough time for developing discovery-based learning components for my Spring 2022 class. The requested faculty stipend will be used toward the following objectives:

- Revise the course materials by developing discovery-based learning components through group activities in ETCM 3368 Concrete/Masonry Construction.

- Research and implement new teaching methods and pedagogical innovations to integrate active learning activities into the hands-on lab activities.
- Research and implement new assessment strategies to assess the effectiveness of the proposed discovery-based learning method.

A summary explaining which elements of the proposal were:

Completed according to plan

- The course material was revised to incorporate discovery-based learning components through group activities in ETCM 3368 Concrete/Masonry Construction.
- New teaching methods and pedagogical innovations were studied to incorporate inquiry-based learnings into the hands-on lab activities. It was concluded to use Pros and Cons grid in combination discovery-based learning to achieve this goal.
- Assessment strategies were studied to assess the effectiveness of the proposed learning technique.
- As a part of the revised instruction, a flipped classroom was used for the selected class. The students watched online lectures, while actively engaging concepts in the classroom, with a mentor's guidance. For this study, the students were provided with a course lecture that discusses key characteristics of concrete in a powerpoint file and an instructional video prior to the active-learning in-class sessions. A short quiz was used for each lecture to gain insight into students' understanding and to evaluate the effectiveness of the learning method. Each in-class activity would give students opportunities to communicate, collaborate, and think critically.

Modified from the original proposal

- During the in-class session, a blank sheet of paper was handed out to students for making a list of pros and cons/advantages and disadvantages for the concrete issues covered in the lecture. The questions are mostly focused on solving a problem (e.g., how to determine the water/cement ratio).
- The students were informed about the number of items expected to list and whether they should use words, phrases, or sentences in their list of pro and con arguments. Once the pro-con grid is complete, students were directed to share their documents with the instructor. This was followed by a summary of key concepts and then a review of the correct answers.
- The students were encouraged to collaborate with their teammates to create a list of pros and cons.

Materials for one (or more) student learning activities sponsored by the grant

Introduction

The National Academies of Sciences, Engineering, and Medicine (also known as NASEM or the National Academies) are private, nonprofit institutions in the United States that provide independently researched information on important matters in science and health policy. A recent National Academies report notes that more than 50 percent of students who complete a science, technology, engineering, and math (STEM) bachelor's degree switch to jobs or graduate programs outside of STEM (NASEM 2022). Such STEM students frequently decide to enroll in non-STEM majors after STEM introductory courses perhaps in response to the teaching methods and atmosphere they encountered in STEM classes. Many of them abandon their goal of earning a STEM degree due to the way that STEM is taught and the difficulty in attaining support. STEM students are expected to learn a large amount of information and concepts, but long-term retention of this information is a substantial challenge. For example, learning the composition and production of materials can be challenging for many construction management students because it is difficult to predict the properties of construction materials based on the jobsite condition (temperature, volume, delivery method, etc). For this reason, rote memorization is frequently employed by STEM students studying Construction Management. Such methods are associated with poor long-term recall and poor performance on design questions and field activities. A combination of discovery-based learning (as

a novel instructional approach) and Pro-Con Grids (as an active learning activity) would promote long-term retention of knowledge of concrete design and production.

Thibaut et al. (Thibaut et al. 2018) reviewed relevant studies describing learning and teaching in secondary education and found nine categories of instructional practices: integration of STEM content, focus on problems, inquiry, design, teamwork, student-centered, hands-on, assessment and 21st century skills. Discovery-based learning encompasses strategies that focus on most of these instructional practices; there is information exchange between student and other students when solving the problems (Anazifa and Djukri 2017); students are in control of their learning through hands-on exploration (Jambunathan et al. 2021), and discovery learning also provides students the opportunity to learn in groups, because group learning can develop cognitive and social interactions (Purmawanti et al. 2019). Incorporating active learning strategies into class sessions can potentially improve long-term retention. Active learning encompasses a wide range of pedagogical tools and strategies that help students make meaningful connections to course concepts; working in groups is among these pedagogical practices. Probably the main advantage is that students can apply concepts, solve problems, and, in general, engage cognitively with course content with the support of peers.

A review of discovery-based learning in STEM education (which is discussed in the next section) indicates numerous benefits that students notice while applying discovery learning, however the current literature contains few examples where an entire subject was taught through discovery learning. Despite these benefits, studies in the literature highlight few drawbacks associated with discovery-based learning, which include student confusion particularly with unguided learning, lack of measurable performance, and not sufficient scaffolding. Unlike in the real world, the students in higher education are first provided with an instruction then a problem. There is no doubt that direct instructions such as readings and lectures can prepare students for the real world. The problem occurs when students become accustomed to learning and working with a thorough instruction and relying on their teachers (Hurst 2015). The research question guiding this study is “how discovery-based learning can improve students’ problem-solving skill compared to conventional lecture/lab model. After a review of relevant literature in the following section, the experimental section provides details of the methods and experimental procedures used to answer this research question.

Instructor’s guide.

The class that is involved in this study is a required course for BSc students in Construction Management in the department of Engineering Technology at Sam Houston State University SHSU or Sam. The department of Engineering Technology has an enrollment of more than 550 students and the Construction Management program represent around half of the total enrollment of the department. The class selected for this study is Concrete/Masonry Construction containing 23 students with 2 females (9%) and 21 males (91%). The class is a lecture/lab course with 1-hour lecture and 3-hour lab per week. Figure 1 shows the concrete lab area that allows exposure to the machines and hands-on practices typically found in industry.



Fig. 1. The concrete lab facility for the selected class

The labs rely on the use of structured groups that engage in specific concrete and masonry activities. The hands-on lab component of the selected class provides a unique opportunity to apply pedagogical strategies such as discovery-based and hands-on learning where students can be assigned specific roles that operate throughout the semester. The author has taught this course twice in Spring 2020 and Fall 2021 and the active learning pedagogies were incorporated into the Spring 2022 class. Most of the students tended to memorize information based on repetition. Although they could quickly recall basic facts, it did not allow for a deeper understanding of subjects. It was also noticed no connection between new and previous knowledge although students enjoyed the opportunity to do a hands-on project. To solve this issue, more learner-centered pedagogical practices were used to make the most of the time the students had for face-to-face classroom interactions. The goal was to encourage students to think creatively when solving problems as well as increase their confidence when solving problems.

SHSU emphasizes hands-on learning in the classroom, allowing students to engage in real world activities that are similar to the activities that construction manager professionals engage in. The authors' effort has focused on applying active learning methods as an alternative to "cookbook" procedures. Traditionally, students in Concrete/Masonry Construction were supposed to perform the exact sequence of steps specified by the instructor or the textbook. From authors' observations, it could be seen that students did not learn when and how to apply these same procedures outside of the classroom. A deeper understanding of the concrete construction is needed. Most students were conditioned to wait for the instructor to give them the answer and did not take collaborative inquiry seriously. Based on the body of literature, we compiled a list of recommendations and strategies for improving the engagement and fulfilling the educational purposes.

Discovery-based learning method provides structures for completing work or products by dividing work among group members. This cooperative instructional approach was chosen for the Concrete/Masonry Construction class because concrete projects can be tackled and completed by groups working collectively. For this study, the students were provided with a course lecture that discusses key characteristics of concrete in a powerpoint file and an instructional video prior to the active-learning in-class sessions. A short quiz was used for each lecture to gain insight into students' understanding and to evaluate the effectiveness of the learning method. During the in-class session, a blank sheet of paper was handed out to students for making a list of pros and cons/advantages and disadvantages for the concrete issues covered in the lecture. The questions are mostly focused on solving a problem (e.g., how to determine the water/cement ratio). Second, each in-class activity would give students opportunities to communicate, collaborate, and think critically. The students were informed about the number of items expected to list and whether they should use words, phrases, or sentences in their list of pro and con arguments. Once the pro-con grid is complete, students were directed to share their documents with the instructor. This was followed by a summary of key concepts and then a review of the correct answers. The students were encouraged to collaborate with their teammates to create a list of pros and cons.

Data was collected for this study in two forms; through a student survey and grades. All students were given a pre-survey at the beginning of the semester (when the study initially begins) that is also the same survey given at the end of the semester (conclusion of the study). The results of the surveys and the students' grades are statistically analyzed to see any statistically significant difference between pre-study and post-study results for the students in the experimental group. The survey was administered via an individual online survey link using the Qualtrics platform. The students enrolled Spring 2020 and Fall 2021 were taught with the traditional lecture/lab method. The grades for these control groups were also utilized to measure the strength of the instructional approaches by comparing control (Fall 2021 and Spring 2020) and experimental (Spring 2022) groups. Figure 2 shows an example of the concrete project given to the student. For this example, the students were asked to make concrete pavers used in landscaping. They had one week

to search for five interlocking concrete pavers available in home improvement retail stores. In the first 5 minutes of the class session, the students were asked to share their findings with the instructor and then see what they discovered by themselves. Next, they were asked to consider the advantages and disadvantages of using flowing concrete to cast the pavers. It was notified that mistakes were inevitable, so timely feedback was provided to quickly correct the mistakes.

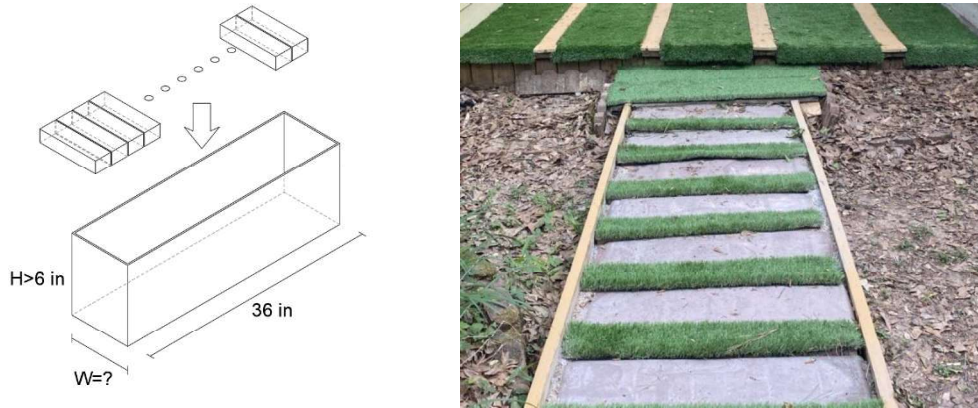


Fig. 2. An example of the concrete activity for making concrete pavers

Assessment Tools and Results

Table 1 shows the results for the pre- and post-study surveys for the experimental group. The first four questions focus on individual student's ability to solve problems. In questions 5-6, we wanted to see whether students' confidence increases while their dependence on instructors for problem solving decreases by having them discover ideas and solutions. The last five questions focus on group problem-solving and the effects of various communication behaviors on the group's problem solving.

Table 1: Survey results for the experimental group (use of discovery-based learning)

Question		Strongly Agree 5	Agree 4	Undecided 3	Disagree 2	Strongly Disagree 1
1- I feel confident finding the correct type of cement/mix of concrete on my own.	Pre-study	13%	38%	38%	6%	6%
	Post-study	17%	30%	35%	9%	9%
2- It is easy for me to find a solution to a concrete problem.	Pre-study	6%	38%	38%	13%	6%
	Post-study	17%	30%	26%	13%	13%
3- I memorize and repeat concepts instead of finding and use information.	Pre-study	6%	44%	31%	13%	5%
	Post-study	4%	26%	30%	17%	22%
4- I see myself as a problem solver rather than a hands-on person	Pre-study	6%	13%	38%	38%	6%
	Post-study	4%	4%	43%	43%	4%
5- Finding information about my work/project is an important part of learning	Pre-study	19%	69%	6%	0%	6%
	Post-study	26%	57%	4%	4%	9%
6- Problem solving is a subject that I am good at.	Pre-study	19%	69%	6%	0%	6%
	Post-study	35%	43%	4%	17%	0%
7- Working in groups helps me better understand concrete.	Pre-study	19%	69%	6%	0%	6%
	Post-study	22%	65%	4%	4%	4%

8- I feel like I can help my group plan for a concrete assignment.	Pre-study	44%	50%	0%	0%	6%
	Post-study	30%	57%	9%	4%	0%
9- If I am struggling with an assignment, it helps to have a classmate explain it to me.	Pre-study	13%	56%	25%	0%	6%
	Post-study	31%	38%	31%	0%	0%
10- I feel like my opinions and ideas are used in my group.	Pre-study	13%	75%	6%	0%	6%
	Post-study	17%	57%	9%	13%	4%
11- Creative thinking is necessary for solving/doing a concrete problem/project.	Pre-study	48%	35%	4%	8%	4%
	Post-study	43%	39%	17%	0%	0%

Figure 3 better demonstrates the difference between the pre- and post-study surveys. Only one data point is presented for each question. As can be seen in the questionnaire, we used a Likert scale to quantify the strength/intensity of students' attitude. Each of the five responses has a numerical value to measure the attitude under investigation. The values are used to create an aggregated (or average) score for each question to measure the attitude of the experimental group.

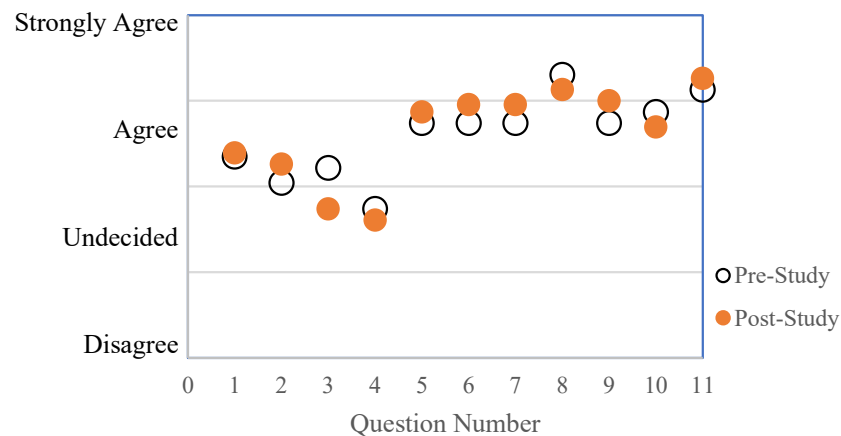


Fig. 3. Survey results for the experimental group (use of discovery-based learning)

The survey results before and after using PBL can be compared to find out whether there are different, and if so, how significant the difference is. The differences in the collected Likert scale data were considered statistically significant if the p value for a paired t-test statistic associated with the particular pair of means is smaller than 0.05. The t-test are conducted for all thirteen questions and the results are shown in Table 2.

Table 2: Paired t-test results for the pre- and post- survey results

Question	Mean		Std. deviation		t	Sig. (2-tailed)
	Pre-Study	Post-Study	Pre-Study	Post-Study		
1- I feel confident finding the correct type of cement/mix of concrete on my own.	3.35	3.39	1.11	1.16	-1.000	0.328
2- It is easy for me to find a solution to a concrete problem.	3.04	3.26	1.11	1.29	-2.472	0.022**
3- I memorize and repeat concepts instead of finding and use information.	3.21	2.74	1.04	1.21	-4.491	<0.001*
4- I see myself as a problem solver rather than a hands-on person	2.74	2.61	0.92	0.84	1.817	0.083**
5- Finding information about my work/project is an important part of learning	3.74	3.89	1.29	1.14	-1.367	0.186

6- Problem solving is a subject that I am good at.	3.74	3.96	1.29	1.06	-1.311	0.203
7- Working in groups helps me better understand concrete.	3.74	3.96	1.29	0.93	1.738	0.096**
8- I feel like I can help my group plan for a concrete assignment.	4.30	4.13	0.88	0.76	-1.699	0.103
9- If I am struggling with an assignment, it helps to have a classmate explain it to me.	3.74	4.00	0.86	0.95	-2.787	0.011*
10- I feel like my opinions and ideas are used in my group.	3.87	3.70	0.89	1.06	1.447	0.162
11- Creative thinking is necessary for solving/doing a concrete problem/project.	4.13	4.26	1.14	0.75	-1.141	0.266

* Significant at $P < 0.05$

** Significant at $P < 0.1$

The null hypothesis states “there is no difference in mean score of students’ opinion when discovery-based learning is used”. Based on the significance (2-tailed) value for the first four questions, we can conclude that there is less than 5% (or 10% for Q2 and Q4) probability that there is no difference in individual student’s ability to solve problems with and without using discovery-based learning. From the students’ perspective, there is a significant mean difference between their confidence level in solving concrete problems when they learned through discovery compared to the traditional teaching. Furthermore, the students found it easier to find a solution to a concrete problem when they work in groups (Q7) and when they have a classmate explain the problem to them (Q9).

Another important metric to measure the strength of discovery-based learning is the students’ grades before and after using this learning method and the comparison between the grades for the students in the control and experimental groups. The control groups were given similar quizzes. Although students’ grades are not necessarily an indicator of students’ problem-solving skill, they can reflect the knowledge possessed by the students and thus show the effectiveness of the proposed method. We use the paired t-test to compare the students’ grades before (from the beginning to the middle of the semester) and after using discovery-based learning (from the middle of the semester to the end of the semester) and the grades between the experimental group (Spring 2022) and the control groups (Fall 2021 and Spring 2020). To exclude and understand the changes in the grades for the second half of the semester, the paired t-test is also used for the control group and the results are shown in Table 3.

Table 3: Paired t-test results for the students grades in control and experimental groups

Group	Mean	Std. deviation	t	Sig. (2-tailed)
Control (Traditional Learning – Spring 2020)	7.73	1.34	-7.339	<0.001*
Experimental (Discover-based Learning – Spring 2022)	9.27	1.19		
Control (Traditional Learning – Fall 201)	8.16	1.28	-6.342	<0.001*
Experimental (Discover-based Learning – Spring 2022)	9.27	1.19		

* Significant at $P < 0.05$

The average difference in the students’ grades for the students learning through discovery-based learning and those with traditional learning is statistically significant ($p < 0.001$) and the students in the experimental group earned higher average grades than those in the control groups. There is unlikely that the use of discovery-based learning does not improve the students’ grades.

References

- Anazifa, R. D., and Djukri, D. (2017). "Project-based learning and problem-based learning: Are they effective to improve student's thinking skills?" *Jurnal Pendidikan IPA Indonesia*, 6(2), 346-355
- Hurst, C. (2015). "Thinking big about mathematics, science, and technology: Effective teaching STEMs from big ideas." *International Journal of Innovation in Science and Mathematics Education*, 23(3), 11-21
- Jambunathan, S., Jayaraman, J., Jayaraman, A., and Jayaraman, K. (2021). "Is peer-led discovery based learning effective in promoting leadership skills among middle school children? Evidence from India." *Education 3-13*, 49(4), 422-432
- NASEM (2022). *Imagining the Future of Undergraduate STEM Education: Proceedings of a Virtual Symposium*, The National Academies Press, Washington, DC.
- Purmawanti, D. E., Azizah, U., and Cahyaningrum, S. E. "The Effectiveness of Guided Discovery Based Learning Materials to Increase Students' Learning Outcomes." *Proc., National Seminar on Chemistry 2019 (SNK-19)*, Atlantis Press, 227-231
- Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., and De Cock, M. (2018). "Integrated STEM education: A systematic review of instructional practices in secondary education." *European Journal of STEM Education*, 3(1), 2