Comprehensive Assessment of a Project Based Learning Application in a Project Management Course[1]

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The focus of this study is to implement multiple assessment methods in order to comprehensively assess the impact of a Project Based Learning (PrBL) application in construction project management course. The assessment methods include various direct (objective) and indirect (subjective) evaluations methods. These methods included a pre and post questionnaire of student opinions, homework grades, in-class "clicker" quiz grades, overall project grades, embedded test question grades, a video lecture project, and short answer case study questions on exams from the Fall 2017 to Fall 2019 semesters. The data for this study was taken from the past six offerings of the same course, which was compared to a similar course in the same department. The analysis demonstrated that the students preferred both the use of an actual real-world project and the PrBL delivery method. The particular assessment methods that provided the most beneficial assessment were the embedded test questions and the case study section of the exam. The overall grade assessment method demonstrated an average of four percentage point increase in grades from previous offerings of the course and a similar course that does not include the PrBL pedagogy.

INTRODUCTION

This study reports on a multi-year Project Based Learning (PrBL) implementation in a project management course, which prepares students to work in technical positions in

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[1] This study was produced/improved from the data/text of conference paper published "ASEEs 123rd Annual Conference & Exposition New Orleans, LA June 25-29, 2016."

the concrete industry. This study provides a new state of the art through its seven-year evolution and development and improves on a preliminary implementation discussed in the work by Torres *et al.* (20016). This study also provides a unique, robust, multi-layered, assessment technique to ascertain the efficacy of the PrBL delivery method. Lastly, this study is an implementation and assessment of a higher-education project management course, which is currently lacking in the literature. The course, "Understanding the Concrete Construction System" is a junior level course that is required for all Concrete Industry Management (CIM) students. The CIM program is a four-year undergraduate degree that is offered at Texas State University. The past six offerings of this course included a PrBL method utilizing a real-world concrete construction project. A PrBL was an ideal fit for this course as the principles taught and learned are directly applicable to a course project. Therefore, the students can directly apply what they learn from the lectures to an existing real-world project, mimicking what they would interact with in their future careers. Incorporating a project in the course is a realistic method to learn the material, therefore, a PrBL pedagogy method aligns both in the content delivery method and the principles of the class. The first offering of the course (Fall 2013) served as a baseline (non-PrBL intervention). Following the first offering, the course became more developed and is now includes more PrBL pedagogical principles which focus on improving student learning. The original development of the PrBL method used in this study can be found in reference (Torres et al., 2017). The current study focuses on a comprehensive assessment of the efficacy of the initial PrBL pedagogy. This was done by developing and implementing a comprehensive set of assessment techniques. Table 1 shows a breakdown of how the project outlined in reference (Torres et al., 2017) was introduced into the CIM course and how the PrBL methodology was incorporated and assessed across the years.

Table 1

Project evolution by semester

Fall 2013	Fall 2014-Fall 2016	Fall 2017-Fall 2019
Project introduced and used as traditional project.	PrBL and milestone formatting incorporated into course.	Previous formatting and assessment methods incorporated into project and course.

Since the CIM course is a once a year course, occurring in the Fall semesters, the development of this study took seven years to complete. As seen in Table 1, the project was first initialized in the Fall 2013 semester. The project evolved and incorporated the milestone formatting as described in reference (Torres et al., 2017) in the Fall of 2014 and was continued through Fall 2016. The same project was used in the Fall of 2017 – 2019 semesters, however, the assessment methods described in this study were incorporated in those years. There was no change to the project and assessment methods between the Fall 2017 - 2019 semesters. This was done as positive results were received in Fall 2017 and the authors desired additional data on the newly developed assessment methods. The assessment methods explored, included both subjective (indirect) and objective (direct) evaluations. The indirect evaluations included a pre and post questionnaire (before and after project experience). Additionally, video lectures/documentaries of real-world construction projects were shown to the students followed by an assessment of the students. These assessments included a post-

questionnaire that incorporated an assessment of specific learning outcomes and objective based questions. The direct evaluations included homework grades, in-class "clicker" quiz grades, overall project grades, embedded test question grades, and short answer case study questions on exams. The test questions included multiple-choice questions, true/false questions, and a lifelike case study (short answer) section. For comparison purposes the assessment methods in the Fall 2017 - 2019 semesters were analyzed and remained applicable, compared to those in the past offerings of the course. Specific assessment methods were compared to assessments in a similar course, which did not incorporate the PrBL project. The instructor who teaches the CIM course also teaches a separate Project Management and Scheduling. The majority of the lectures and test questions were shared. Therefore, the embedded test questions that were used to assess the PrBL pedagogy were compared across courses.

Background on Assessment methods

PrBL is a type of learning that is student-centered, which is based on three principles: learning is context-specific, learners are involved actively in the learning process and they achieve their goals through social exchanges and the sharing of knowledge and understanding (Crossouard, 2012). It is also considered to be a type of inquiry-based learning where the context of learning is provided through authentic questions and problems within real-world problems (Al-Balushi & Al-Aamri, 2014), which lead to meaningful learning experiences (Wurdinger, Haar, Hugg & Bezon, 2007). Blumenfeld, Fishman, Krajcik, Marx and Soloway (2000), describe PrBL as, "A process in which students need opportunities to construct knowledge by solving real world problems through asking and refining questions, designing and conducting investigations, gathering, analyzing, and interpreting information and data, drawing conclusions, and reporting findings". PrBL is similar to Problem Based Learning (PBL), however, PrBL includes a lengthier project with multiple facets to encourage various degrees of deep-learning. These projects typically take years or individual semesters to complete and incorporate realistic, real world, problems (Kwon, Warderip & Gomez, 2014). Multiple investigators have shown the efficacy of PrBL through pre-school all the way through higher education (Kokatsaki, 2016). These investigators have used various techniques and methodology to implement their studies throughout many different disciplines. However, there is varying degree of success assessing their studies beyond a conventional pre and post questionnaire or commentary describing the outcome (Kokatsaki, 2016). Therefore, there is a demand to create and implement a robust assessment technique that can be applied in the classroom, and especially higher education project management courses. The literature provides insight into how to develop and introduce assessment methods for pedagogical methods such as PrBL.

When designing assessment methods for evaluating PrBL it is necessary to contemplate the skills, abilities and knowledge that instructors need to convey to future technical professionals. Savage et al (Savag et al., 2007) state that, "For an engineer in industry, a project is a sequence of tasks required to reach an objective. Typically, the objective is to design a device or process that has value to a customer (user). The project begins by defining a performance problem associated with an application and ends with a design solution. The problem drives the learning required to complete the project. Managing

the project requires the engineer to demonstrate effective teamwork, clear communication and the ability to balance the social, economic and environmental impacts of the project." This explanation demonstrates the attributes of a project or students' performance that needs to be assessed. It is important to considerer that in any PrBL based course, instructors are mostly trying to assess learning in a practice-based or professional application context. This is in contrast to traditional modes of testing in academia that utilizes exams, quizzes, and homework that tend to focus on the retention of specific technical principles, theories, or other factual information (Macdonald and Savin-Baden, 2004). Thus, a demand exists to align learning outcomes, teaching and learning activities and assessments. Particularly this is needed because pedagogies such as PrBL have been adopted to encourage deep level learning, rather than surface level learning (Biggs, 2003).

The literature on assessing active learning techniques is very heavily weighted toward PBL not PrBL. However, since problem, enquiry and PrBL all share many similar characteristics such as being student centered, focused on deep learning, instruction being driven by a central problem and the instructor primarily facilitating the process of learning, traditional assessment methods used with PBL should prove beneficial in the case of PrBL as well. Macdonald (Macdonald, 2005) provides a comprehensive list of types of assessment that have been successfully used in this context, which move away from traditional assessment methods. Macdonald (Macdonald, 2005) and Caroll (Caroll, 2005) both describe that for project based activities to be truly effective, educators need to ensure that reflective learning is facilitated, so that students can truly learn from the process (Caroll, 2005). Thus, assessment is an integral part of the learning cycle and occurs both during and at the completion of the project (Solomon, 2003). Instructors should plan for both formative and summative assessment as part of the course. That is, they need to collect and act on information that will help students improve as they proceed, and they need to have measures that show what students learn overall. Evaluations should assess both individual and group work and represent multiple formats, such as written work (formal assignments and informal journal entries), observations (of group and individual activities), presentations, informal discussions and questions, and the final product (Solomon, 2003).

García-Berdonés *et al.* (2014) describe the evolution of PrBL designs which include different assessment techniques. In their study, the authors describe that both direct and indirect assessment techniques are necessary. These are techniques that are subjective, such as student opinions and objective such as student performance through their grades. The authors demonstrate that most PrBL assessment techniques are primarily subjective questionnaires from the student and/or the instructors perspective. Existing studies may also include the student's overall performance (course grade), however, as the authors suggest, two assessment methods may not be sufficient to comprehensively assess the intervention of a PrBL delivery method. Kokatka (2016) have suggested that for a comprehensive assessment to exist multiple assessment techniques need to be incorporated at various stages of the project.

Therefore, this study aims to fill this gap in the literature. This is accomplished by providing six years of overall data, comparisons to intervention and non-intervention classes, and developing various assessment techniques that include both subjective and objective test measurements, which assess multiple skill sets, based off of recommendations from the literature.

METHOD

The purpose of this research is to develop a comprehensive set of assessment methods to ascertain the effectiveness of a PrBL pedagogy used in a concrete industry geared project management course. The research questions that were explored are listed below:

1) Is the use of a PrBL pedagogy improving the students understanding of concrete project management?

2) Are the developed assessment methods providing a reliable assessment?

Demographics and Details Of Assessment Methods

Demographics

The participants of this study include the authors and the students enrolled in the Fall 2017, Fall 2018, and Fall 2019 semesters of the course. The Fall 2017 section of this course contained 14 male and two female students ranging in age of 19–22 years, with the average age being approximately 21 years old. The Fall 2018 section of the course contained 12 male students and one female student ranging in age of 21–23, with an average age of approximately 22 years old. The Fall 2019 section of the course contained 15 male students and one female student ranging in age from 21-22. Therefore, the investigated sections of the course contained majority of male students, which shows no major demographical difference between each semester. The average grade point average from the two semesters was 3.14/4.00. The students have had all of the same CIM courses prior to being allowed in to "Understanding the Concrete Construction System". All students enrolled in all sections of the course were full time students taking a minimum of 12 credit hours at the university. The demographics of the Fall 2013 – 2016 semesters are reported in reference (Torres et al., 2017).

Pre and Post Questionnaires

Pre and post questionnaires are a conventional assessment method used to investigate the impact of new teaching methods. Although they provide sufficient feedback to the instructor, the subjective nature of the questionnaires can be restrictive, as not all students will respond at the same level of openness. If questionnaires are used, it is best to make the questions as specific to the individual learning outcome as possible. In the initial implementation of the PrBL pedagogy (Fall 2014) pre and post questionnaires were used, as described in Reference (Torres et al., 2017). The same questions were used in this study, however, the questionnaire has had some minor changes and have been categorized into four categories: A. Communication, B. Teamwork, C. Ethics and Professionalism, and D. Leadership. These four new categories were selected as each category represents a desirable and employable work attribute. The questionnaire used a 5-point Likert scale in which 5 was 'Strongly Agree' and 1 was 'Strongly Disagree. The questions and results can be seen in Table 2 and Figure 1, respectively.

Documentary/Instructional Videos with Post Questionnaire

A video documentary related to construction practices, particular to concrete pavement was incorporated into the class. The video, which is entitled, "A Span in Time" (Brown, 2006) is 45min in duration and describes the construction and replacement of the Oakland Bay Bridge. The information in the video strengthens material that was taught in the class, which include specific topics such as construction personnel, equipment, and practices, and other desirable soft attributes such as strong communication between partners, teamwork, ethics and professionalism, and leadership. The video was shown on the first day of class and was accompanied by commentary from the professor before, during, and after the video was shown. During the video a pre-questionnaire that included both subjective and objective questions was provided to the students. For comparison purposes, the same video and the same questionnaire, now referred to as a post-questionnaire, was provided to the students near the end of the semester after all of the pertinent topics were discussed in the course. A five point Likert scale was used to gauge the subjective based questions, in which 5 was 'Strongly Agree, and 1 was 'Strongly Disagree'. The post documentary/instructional video questions can be seen in Table 3, which includes the results.

Homework Grades, Overall Project Grades, and "Clicker" Quiz Grades

Three different direct assessment methods were used in this study. The first was the homework grades. As described in great detail in reference (Torres et al., 2017), the project used for this class was sectionized into 5 milestone deliverables. The course utilized a unique format in implementing the PrBL pedagogy, such that the project was sectionized into deliverable milestones and each milestone was due shortly after students received formal instruction on the topic during lecture sessions, as well as delivering one final packet (which include all milestones) at the end of the semester. This method allowed each student team to get two attempts in accomplishing each milestone, which encourages reflective learning (Kokatka, 2016). Due to the complex nature of the real-world project and the students' lack of experience with preparing a real-world proposal to an owner, the students often are not entirely sure what is expected for the project. Allowing the students to submit the individual milestones after the topic is covered in class, not only illustrates the practical application of the topic, but also allows the students to learn from their mistakes upon the first submission of the milestone deliverable. The students' first attempt of each milestone deliverable is recorded as a homework grade, whereas the entire project packet is recorded as a separate project grade. However, when the final project packet is graded each milestone is graded individually and the average of the total becomes the final grade. This was done such that an assessment of the first attempt and the second attempt can be recorded and compared. In certain cases, the students were allowed three attempts at a specific topic, due to the importance of the topic. The students had the project milestone grades, plus an additional homework assignment on the topic. It should be noted that course time constraints also factored into this decision. The specific milestone topics that had an additional individual homework assignment were the risk assessment topic and the scheduling topic. Being able to identify any type of risk in construction management is

extremely important, therefore the students were provided a real-world Request for Proposal (RFP) for a commercial health clinic to be constructed in the local area. After the lectures on identifying risks, the students were asked to read through the proposal and, as a general contractor, identify the possible risks involved with bidding this project. Then the students were asked to provide a synopsis on how to mitigate the identified risks.

The scheduling topic is a very important topic in construction management, therefore extra time was spent on learning how to produce and analyze a schedule. An individual assignment was provided to the students, in which they had to solve a network-based schedule for a small warehouse, using the Critical Path Method (CPM). Subsequently, the students had to quantify the three types of float on each node. The grade comparison for assessing the impact is categorized as a first, second, and third attempt of the individual milestone (if applicable) and reported in two comparative sets, one set being that of the 2014-2016 semesters (averaged) compared to the 2017-2019 semesters (averaged). This was done as it compares the initial assessment of the PrBL strategy to that of the PrBL strategy incorporating the additional assessment strategies described in this study. This comparison of the milestone homework versus the overall project grade can be seen in Figure 2 along with additional discussion. In addition to the homework and overall project grades, the students were asked in-class "clicker" questions related to each individual topic. To those not familiar with a "clicker", this is a portable electronic device that each student purchases and brings to class. The clickers are electronically synchronized to a USB receiver, which is connected to the presentation computer alongside acquisition software. The students, beforehand, register their clicker such that their individual answer to each question can be tracked, recorded, and graded. The software allows the professor to prepare questions before hand, with multiple-choice options, true or false options, or short answer case study options. Therefore, "clicker" based quiz questions were incorporated into each lecture in order to assess the students' understanding of each major topic.

The questions were objective, featuring either multiple choice or true/false questions. A set of 2-5 questions were presented at the beginning of the lecture, before any content was presented, and the same questions were presented subsequently, either interspersed within the lecture or at the end of the presentation. This permits a before and after comparison of results. The justification for asking the same questions interspersed within the lecture is to promote an active learning environment and thereby keep the students engaged until the end of the lecture. This method also provided opportunities to discuss the results of the questions during the lecture as opposed to towards the end when time may be limited. The clicker quiz results can be seen in Table 4.

Embedded Test Questions

An additional direct assessment method used in this study was embedded, multiple choice and true/false, test questions. Each offering of the course incorporated three exams and a comprehensive final exam. These exams included multiple questions that directly related to the five milestone objectives of the project. The questions relating to each topic (which averaged to 10 questions each) were grouped together and averaged

per semester of each course offering (2017, 2018, and 2019). As previously discussed, a separate construction management course, in which the PrBL method was not implemented, however, similar topics are taught and the same embedded test questions are used. Therefore, a comparison has also been made to the Spring 2017. Spring 2018, and Spring 2019 Construction Science and Management (CSM) version of the course.

Short Answer Case Study Test Questions

The remaining assessment method used in this study was a short answer, case study style, test question, included in each exam. As with the embedded test questions mentioned above, not all milestone objectives were made into a short answer case study, due to applicability and time constraints of the examination. Therefore, only the Soil Characteristic, the Work Breakdown Structure (WBS), and the Scheduling milestones were assessed via the short answer case study assessment method. The case study questions were similar to the project, with different issues and variables. The students were required to describe and/or produce their answer in their own words. The results of this method can be seen in Table 5.

FINDINGS

Pre and Post Questionnaires

As previously described, a pre and post questionnaire was provided to the students at the beginning and end of the course respectively. The results from the Fall 2017, 2018, and 2019 have been combined and averaged. The questions can be seen in Table 2 and their individual results can be found in Figure 1.

Table 2
Pre and post questionnaire questions.

| |
|---|
| A. Communication |
| 1. I expect that my studies in this course will increase my ability to design and deliver effective presentations for a variety of audiences. |
| 2. I expect that my studies in this course will increase my ability to write in a clear, coherent, and professional manner. |
| B. Teamwork |
| 3. I expect the instructor and the experience of working on a team in this course to provide new insights or develop skills that will increase my ability to work effectively in a team environment. |
| 4. I expect to be able to work effectively in a team environment. |
| C. Ethics and Professionalism |
| 5. I understand the kinds of ethical concerns that I might come across in the context of the concrete industry. |
| 6. I feel well informed and empowered to act ethically and in a professional manner in the context of the concrete industry. |
| D. Leadership |
| 7. I understand the leadership function in the concrete industry professional organization. |
| 8. I feel well informed and capable of serving effectively in a professional leadership capacity. |
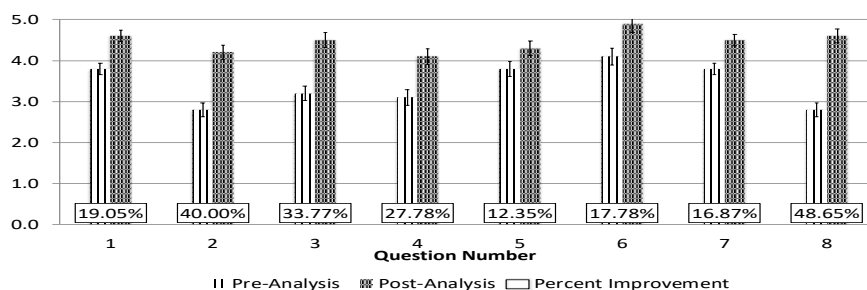
Figure 1
Pre and post questionnaire analysis result comparison.

As shown in Table 2 and Figure 1, there are improvements in every category, which is appropriate for a pre and post questionnaire assessment, as the students are learning construction management practices. To determine if there is a statistical difference between the pre and post questions a sample t-test was performed. The data was analyzed at a statistical significance of 0.05. This analysis revealed that all results in Table 2 and Figure 1 are statistically significant between each other. Assessing the data, it shows that both pre-questions 2 and 8 had the lowest score of 2.8 ("Disagree"), which also had the highest improvement in the post-questions, up to 4.2 and 4.6 respectively ("Agree"). Question 2 assessed the students' communication, with a specific emphasis on written communication. The lower score on the pre-questionnaire is understood to be due to a common misconception that writing is not a requirement of the class. However, written communication is a substantial requirement for all technical managers and is extensively covered in the course, which is why a high increase is observed in the questionnaire assessment. The highest performing question from the pre-questionnaire was question 6. Question 6 assessed the students' understanding of being able to act ethically and professionally in the construction industry. The pre-questionnaire results of question 6 displayed a result of 4.1 ("Agree"), which is an expected result as ethics is covered in many other earlier courses within the discipline (TECH 3364 Quality Assurance and TECH 4380 Industrial Safety). There was an increase of only 17.78% on question six, corresponding to a post analysis score of 4.9, which is almost a "Strongly Agree". This is a significant learning gain as ethics is very important for construction managers. In order to ascertain the validity and reliability of this method a Confirmatory Factor Analysis (CFA) was completed on the pre and post questionnaire data. The results demonstrated that the questionnaire had a good fit to the data. The alpha coefficients also demonstrated acceptable levels. Additionally, the work by Dolmans *et al.* (2005) and Patria (2015) further substantiates the reliability of Likert-scale based questionnaires as an assessment tool for PrBL pedagogy. This assessment method ultimately demonstrates the students' perceptions to understanding these topics or gaining the respective abilities. Although these results are all favorable, and demonstrates students' feelings towards the PrBL pedagogy having a positive effect on their education, the assessment is not enough to draw conclusions on its own (Carrol, 2005). Therefore, additional assessment is needed and is provided.

Documentary/Instructional Video with Post Questionnaire

The documentary/instructional video was a new assessment method added to bolster the assessment methods of this study, which contains a pre and post questionnaire. The questionnaire included both subjective and objective questions related to the video. The questions and results for both Fall 2017, Fall 2018, and Fall 2019 are found in Table 3.

Table 3
Documentary questionnaire questions and results.

Question	Pre-Result	Post-Result	% Improvement
D1. I understand the role of a General Contractor (GC).	4.3	5	15.05%
D2. I know what a Joint Venture is.	2.8	5	56.41%
D3. I know the role of a Project Manager.	3.9	4.8	20.69%
D4. I understand the importance of effective communication on the job site.	4	4.3	7.23%
D5. I know the importance of a thorough soils analysis before construction begins.	3.2	4.4	31.58%
Question	% Correct	% Correct	% Improvement
D6. What was the name of the GC?	73%	95%	26.19%
D7. The superintendent was in charge of all the subcontractors? (T/F)	89%	100%	11.64%
D8. Who was the client/owner of the project?	82%	100%	19.78%
D9. What does USCS stand for?	55%	90%	48.28%
D10. What type of schedule was used?	75%	100%	28.57%

As shown in Table 3, it can be seen that 10 questions were asked, such that the students were not overwhelmed with questions while watching the video. The designation "D" has been used to distinguish between other questionnaires used in this study. In this case, "D", refers to documentary. Between the 10 documentary questions, half of the questions were opinion based; gauging the students' understanding of certain topics outlined in the video, whereas the other half were objective questions, based on the video. Similar to the overall questionnaire discussed in the previous section, there were improvements between the pre and post questions. Questions D1 and D2 increased to 100% understanding of the topic. The lowest improved topic was question D4, in which the students' demonstrated an understanding of effective communication on the job site. There was also improvement in all objective questions, with three questions scoring a 100% in the late semester showing of the video. This is likely due to the fact that these topics were covered extensively throughout the semester. The question that scored the lowest was question D9, which was the definition of the USCS acronym. The lower than expected result was due to strict grading adopted by the professor. All four words had to be identified, spelled correctly, and in the correct tense. If a student defined the first "S" as Soils, then the answer was incorrect as the first "S" is not plural (i.e., Soil). After the questionnaire was graded and returned to the students, the justification for the strict grading was explained, as it is important to be exact when communicating in the construction industry. A sample t-test was performed to determine if there is a statistical difference between the pre and post questions. The data was analyzed at a statistical significance of 0.05. This analysis revealed that all results in Table 3 are statistically

significant. The validity and reliability was also confirmed via a CFA statistical assessment.

Homework Grades, Overall Project Grades, and Clicker Quiz Grades

The main assessment methods used in this study was to compare the grades of the individual milestones from the Fall 2014-2016 semesters to that of the Fall 2017-2019 semesters. As previously mentioned each milestone allowed for at least two attempts; two of the milestones allowed for three attempts. The average grades for this assessment method can be seen in Figure 2.
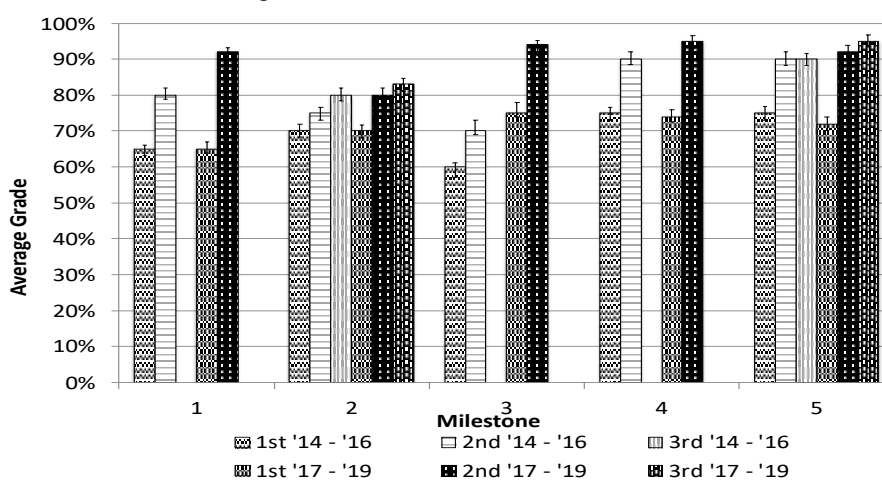

Figure 2
Grade comparison between first, second, and third attempt between Fall 2014 – 2016, and Fall 2017 – 2019.

As pictured in Figure 3, it is evident that the milestone (i.e., multiple attempt) deliverable method is a successful teaching tool. For a complicated project such as the one included in this study, it is beneficial to allow the students to have multiple attempts at each milestone, with a lecture explaining the correct method and/or answers in between each milestone. This allows the student to instantly reflect on their work and improve on their mistakes. It is also observed that the Risk Assessment and the Schedule milestones that offered three attempts either increased or remained the same. When comparing from semester to semester, it is observed that the Fall 2017- 2019 semesters out-performed the combined Fall 2014 – 2016 semester, with the Fall 2017-2019 semesters having vary similar results. This improvement is thought to be due to the extra learning activities and assessment methods included in the in the Fall 2017-2019 semesters. This improvement had an influence on the students learning and comprehension of the major topics, such as the instructional/documentary video and the short answer case study questions. A student t-test was also performed on these results, which demonstrated statistical significance between all first and second attempts. Milestones 2 and 3 each had three attempts, which also showed statistical significance

between attempts one and attempts two, but no statistical significance between attempts two and three. Although attempts three were mostly higher grades in these milestones, they were not statistically significant.

An additional assessment method that was presented in the Fall 2017-2019 semesters, that may have had an impact on the increase in students' grades was the clicker quizzes. As previously discussed, the students were given a clicker quiz before each milestone topic, then the lecture was provided, followed by the same clicker quiz. Often times the questions were given during the lecture, immediately following the specific topic, to promote an active learning environment. The results of each question have been averaged and categorized within the milestone deliverable topics and are shown in Table 4.

Table 4
Results of the Clicker quiz assessment method

| | Pre-Lecture | Post-Lecture |
Milestone	Average Grade	Average Grade
1. Soil Characteristics	30%	95%
2. Risk Assessment	85%	100%
3. WBS	75%	95%
4. Estimate	75%	100%
5. Schedule	70%	95%

As observed in Table 4, there is a progress in each milestone topic, with the highest improvement occurring in milestone topic 1, Soil Characteristics. Throughout the CIM curriculum, there is no other course that teaches the students the importance of soils, therefore the students are not familiar with the topic of soils before the specific lecture. It is observed that the lowest average grade for the post-lecture was 95%. This quantity of improvement is expected for this type of assessment method as the topics are fresh in the students' memory and some of the questions take place closely following a similar example delivered by the professor. The results can also be attributed to the notion that the definition was previously given within minutes of asking the questions. Overall, this assessment method provides sufficient feedback on the individual millstone topics immediately after they are taught. A student t-test was also performed on this data, which confirms statistical significance between the pre and post lecture grades.

Embedded Test Questions

A further quantitative assessment method utilized was the use of embedded test questions on three exams, in both the CIM course in which the PrBL method was implemented, and a CSM course in which the PrBL method was not implemented. Two sets of data are reported for the CIM course (average Fall 2014 – 2016, Fall 2017-2019) and one set is reported for the CSM course (Spring 2017-2019). The results can be seen in Figure 4.
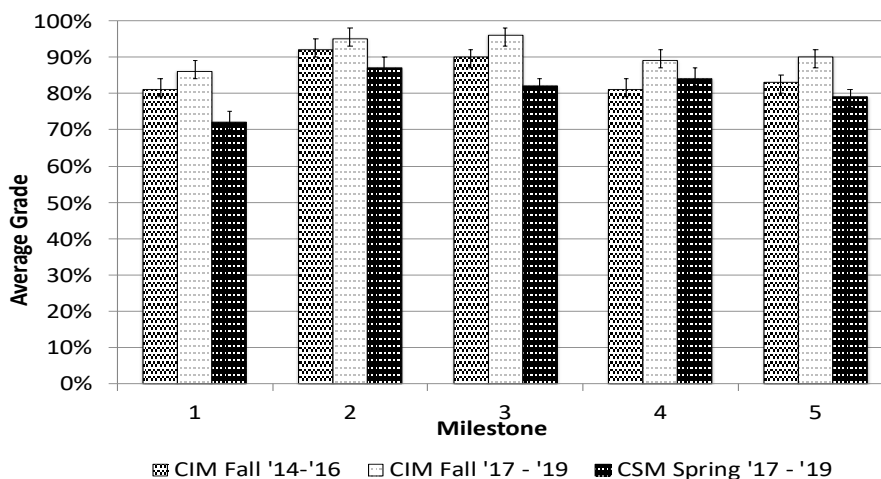
Figure 3
Embedded test question assessment comparison from two similar courses across multiple years.

The results of this technique show the most beneficial information, as this assessment method allows comparison between two different courses, one with the PrBL pedagogy and one without. Although the CSM course did not use the PrBL pedagogy, the embedded exam questions are still categorized into the relevant milestones for ease of comparison. Overall, it can be seen in Figure 3 that the CIM course that implements the PrBL pedagogy scored higher on the same embedded test questions. Taking an average of all embedded test questions from the CIM course scores produced an overall average of 89% as compared to an overall average of 82% for the CSM course. The only milestone category that the CSM course scored better in was the Estimating topic (milestone 4). The CSM majors have a full semester course dedicated to Construction Estimating, whereas the CIM majors learn Estimating in the course in which this study took place, therefore, it is expected that the CSM majors would outperform the CIM class in this milestone. An additional benefit of this assessment method is that a semester-to-semester comparison can be made. For the CIM class the Fall 2014 – 2016 combined semesters were also included. It is noticed that all of the average grades are higher in the Fall 2017-2019 semesters. These results demonstrate that improvements are being made each semester. Averaging the groups reveals a grade of 85% in Fall 2014 – 2016 to an increase of 91% in Fall 2017-2019 for the CIM course, whereas the CSM displays an average of 84% in Spring 2017-2019. As with the homework and overall grade assessment method, it is understood that the additional assessment methods, such as the clicker quizzes and short answer case study questions, had an impact on these results. A statistical analysis (student t-test) was performed on the average values to determine statistical significance, and the results shows statistical significance between the two courses.

Short Answer Case Study Test Questions

The final assessment method used in this study was the use of short answer, case study, test questions added to the end of the exams. As previously stated, this assessment method does not have a straight comparison to a different semester or a pre or post offering of the method as it was the first time this method was introduced in the course. The impact of this assessment method can only be inferred through a comparison with the other semester in which it was used, which all show that the Fall 2019 scores are slightly higher than the other two offerings. It is important to reiterate, that only three milestones were investigated in this particular assessment. The results from the short answer case study test questions can be seen in Table 5.

Table 5
Short answer case study test question assessment results.

	Average Grades		
Milestone	Fall 2017	Fall 2018	Fall 2019
1. Soil Characteristics	95%	92%	96%
3. WBS	80%	84%	89%
5. Schedule	94%	95%	95%

The outcomes of this assessment method were encouraging and yielded good insight into the comprehension of student learning. The results of the short answer case study test questions were lower than anticipated for the WBS topic for the Fall 2017 semester, which was due to three students not understanding the question and inadvertently producing a network-based schedule. These students received partial credit as their network schedules were very thorough and included most of the required elements (activities) that would be included in a WBS, however, their grades still affected the average of that particular topic. However, there was improvement in the Fall 2018 semester for the WBS milestone. The latest offering of the course yielded the highest overall performance, between the three semesters, but not by a significant margin. The WBS milestone had the highest improvement, which is believed to be due to added clarification on the exam, such that the students do not accidentally produce a schedule versus a WBS. Overall, all semesters showed favorable results on the three topics investigated, which provides additional objective assessment of the PrBL pedagogy.

CONCLUSIONS

The results of this study demonstrated the development and implementation of multiple assessment methods in multiple classroom years. This was done in order to more comprehensively evaluate the effectiveness of a PrBL pedagogy used in a Construction Project Management course. Five different assessment methods were developed and incorporated, which all provided quality insight into the efficacy of the PrBL method. Each assessment provided a unique insight, such that some were student-based opinions and others were objective based assessments, all of which strengthened the PrBL course implementations. One unique assessment method stood out amongst the others, which was the embedded test questions and the case study section of the exam. Due to the fact that the students had to work with an individual lifelike case study in the exam, the

individual student's effort, understanding, and ability to solve technical problems from the PrBL pedagogy was quantified through the exam. In summary, these results ultimately answer the research questions proposed for this study. The implemented PrBL has improved student understanding of concrete industry project management. Secondly, the newly developed assessment methods have proved to be a reliable method to assess the efficacy of the PrBL methodology. A summary of the effectiveness of each assessment method is discussed below.

• The Pre and Post Questionnaire analysis revealed that the students' perception of understanding the concepts of the class have improved.

• The Documentary Questionnaire analysis revealed that the student's understanding of specific project management concepts was enhanced.

• The Homework Grades and Overall Project Grades analysis revealed that students' grades have improved after the intervention of the PrBL pedagogy. Additionally, the results revealed that the milestone formatting of the PrBL had a positive on student comprehension. The Clicker Quiz analysis reveals improvements in all categories investigated.

• Embedded Test Question analysis revealed an average of four percentage point increase in grades from past offerings of the course. An increase in student grades was also observed when comparing with a similar course that did not include the PrBL pedagogy.

• The Short Answer and Case Study analysis revealed high student comprehension across all four milestones investigated.

These results demonstrate that the PrBL pedagogy, with the use of milestone (deliverable) formatting, is an effective pedagogical approach that can promote a deeper comprehension of topics, while also promoting an active learning environment.

DISCUSSION AND SUGGESTIONS

This study demonstrated a comprehensive and effective assessment of a PrBL pedagogical technique. As articulated by García-Berdonés et al. (2014) a robust and comprehensive PrBL must require multiple objective and subjective techniques. The techniques also need to be implemented throughout the course to encourage reflective learning. Contrary to simply assessing the technique just at the end of the semester. The effort completed in this study followed these guidelines and have implemented a comprehensive PrBL assessment. Six different techniques were implemented, which included both types of assessment. The results were favorable, and demonstrated that the active PrBL intervention has improved students' comprehension. The first questionnaire focused on four key attributes: Communication, Teamwork, Ethics and Professionalism, and Leadership. Although the questions in this method contain specific language to the concrete construction industry, the attributes focus on developing the student for virtually any profession, as the attributes themselves are not specific. The students graduating from the CIM program obtain various roles in the industry from laboratory testing, sales, laborer, materials, and general construction, which all require very

different skills, but the same four key attributes, which align with the questionnaire. Based off of the results from the questionnaire, the students are better prepared for these future roles. The video questionnaire, which also showed improvements after the PrBL intervention, also helped prepare students for their role(s) in the industry. The video questionnaire was specific to the concrete construction industry, but the questions were generalized, but important enough that no matter the future role of the student, they will have to understand these concepts. The concepts asked about roles in the industry, acronyms, and other specific procedures. Although, the video questionnaire was more specific, the information learned was still general enough to transfer to any position. Therefore, both questionnaires provided meaningful insight to the preparedness of the students for their future positions within the industry. The objective assessment measurements are also generalized to the entire industry; however, some questions do contain more specific information, which is an overall objective of the class. As the topics become more specific to the overall course learning objectives, it appears that more meaningful assessment measurements are obtained. As seen with all objective assessment techniques of each type, there is constant improvement with the intervention of the PrBL pedagogy outlined in this study. The overall nature of the PrBL is to ultimately enable a deeper comprehension of the topics over a traditionally taught class. Therefore, by design, the pedagogy is putting stronger emphasis on the transfer of knowledge and deeper retention for improved student performance. By creating a classroom that drives the learning and comprehension of the topics through hands on learning and provides multiple attempts for improvement, higher student performance is expected. It is inherent nature to improve over time with practice, however, ensuring all course content is taught within the time limitation is the balance, and the PrBL pedagogy demonstrated in this study accomplishes just that. Specifically, the milestone delivery format, which was the mechanism that allowed the multiple attempts in this study, was most beneficial to the students, which is apparent by the questionnaires and the students' grades. The next step in the evolution of this study would further assess the students' retention of these topics into their next level of courses (senior year) and into their careers. The CIM courses in the senior year require knowledge gained from all previous classes, however, specific information could easily be forgotten, and a future assessment could ascertain the long-term effectiveness of the PrBL intervention. This could be done via questionnaires and embedding questions within future classes assignments; however, it may be difficult as it may interfere with the course objectives of the higher courses. Objective measurements may also be difficult to implement after graduation, as such a questionnaire may be the only method available. Future recommendations for work in this area would be to implement the PrBL in different types of courses. This could be course that teach similar disciplines or completely different disciplines.

It is understood that it may be difficult to replicate this case study exactly at a reader's own institution due to the specific project used. However, the essential pedagogical approach and assessment methods can be implemented across similar courses. The assessment techniques used are not exclusive to the authors' organization and can be to a similar project management course. To implement a PrBL methodology similar to this study, one would first need to identify a real-world project that covers all course

objectives, but is also within the degree of difficulty of the course. Then divide the course into multiple parts to create the milestone deliverables. This study used five milestones, which worked well, but a recommended range of 4-10 could also work for a 16-week course. Specifically, and as previously described, the initial questionnaire is geared towards general attributes for any position. Therefore, this questionnaire can be applied to virtually any course. The documentary video assessment technique and corresponding questionnaire is specific to the concrete construction trade, however, other disciplines can simply incorporate any video that they find suitable to their course topic and create corresponding questions. Regarding the objective assessment measurements, all questions whether they are embedded into exams, quizzes, or individual homework assignments are all specific to the concrete construction industry. However, to implement this PrBL pedagogical technique in other courses, one would simply have to ensure that that all of the objective measurements align with the milestones, and are taught, delivered, and graded (to provide feedback) before the next milestone is taught and delivered. There will likely be some overlap in grading and feedback discussion between one milestone to the other, but it is important to provide feedback as soon as possible when the information is fresh in the students' memory. If one follows these suggestions, a very similar milestone based PrBL delivery method and assessment techniques can be incorporated in virtually any course.

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