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Learning Concrete in Construction Management Course through Bowling Ball Project

Prof. Pranshoo Solanki, Illinois State University

Dr. Pranshoo Solanki is a full professor in the Construction Management program of Department of Technology at Illinois State University. He received his doctorate in civil engineering from the University of Oklahoma in 2010. The overall theme of Dr. Solanki's research is innovative construction materials and methodologies which can be used for building a sustainable civil engineering infrastructure. Dr. Solanki mainly teach courses in the area of construction materials and design at Illinois State University.

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Abstract

Construction Management programs usually offer a Materials course which includes hands-on concrete technology laboratory involving series of experiments (e.g., compressive strength, flexural strength) to obtain strength of concrete specimens. However, Materials course lacks hands-on activity discussing concrete forming, and effect of mix design and ingredients on the fresh and hardened properties of concrete. In this study, a fiber-reinforced concrete bowling ball project was implemented in a Construction Material Technology course which is a core course for Construction Management students at Illinois State University. The objective of bowling ball project was to demonstrate the behavior of fiber reinforcement within concrete, to gain experience in forming and fabricating a fiber-reinforced concrete, and to encourage creativity in mix design predictions and analysis testing. The students received instruction and guidelines for this project early in the semester so that they can start thinking about different mix ingredients and how to prepare concrete bowling ball. However, this project was conducted in the last three weeks of the semester. Students worked together in groups to perform all the steps of the project from design to manufacturing and testing. Survey questionnaires were provided to the students at the end of the semester to acquire data regarding the learning of students using the implemented concrete bowling ball project. The results showed that the students favored using concrete bowling ball project as one of the laboratory activities in Construction Materials Technology course which improved their learning about concrete.

Introduction

Construction management programs usually offer a Materials course which includes hands-on concrete technology laboratory involving series of experiments (e.g., compressive strength, flexural strength) to obtain strength of concrete specimens. However, Materials course lacks hands-on activity discussing concrete forming, and effect of mix design and ingredients on the fresh and hardened properties of concrete including importance of finishing. In this study, a fiber-reinforced concrete bowling ball project was implemented in a Construction Materials Technology course which is a core course for Construction Management students at Illinois State University. The objective of bowling ball project was to demonstrate the behavior of fiber reinforcement within concrete, to gain experience in forming and fabricating a fiber-reinforced concrete, and to encourage creativity in mix design predictions and analysis testing. The students received instruction and guidelines for this project early in the semester so that they can start thinking about different mix ingredients and how to prepare concrete bowling ball. However, this project was conducted in the last three weeks of the semester. Students worked together in groups to perform all the steps of the project from design to manufacturing and testing. Survey questionnaires were provided to the students at the end of the semester to acquire data regarding the learning of students using the implemented concrete bowling ball project. The results showed that the students favored using concrete bowling ball project as one of the laboratory activities in Construction Materials Technology course which improved their learning about concrete.

Literature Review

Literature review shows importance of enhancing engineering education through student participation in competitions. Several student competitions are available for construction management and civil engineering students. For example, National Concrete Canoe Competition organized by American Society of Civil Engineers (ASCE), Steel Bridge Competition organized by American Institute of Steel Construction (AISC), Associated Schools of Construction (ASC) competition in several categories (e.g., Heavy Civil, Commercial, Design Build, etc.), and American Concrete Institute (ACI) student competition. Some of the student competitions such as Concrete Canoe and Steel Bridge competitions started more than 60 and 30 years ago, respectively. These competitions are designed to provide students with an opportunity to gain hands-on experience and leadership skills. Several studies were reported where instructor incorporated some type of experiential learning in the form of a competition in the course. Some of the relevant studies are summarized in subsequent paragraphs.

Sirianni et al. [1] carried out a survey of current civil engineering students and graduates of Rochester Institute of Technology for assessing the impact of the concrete canoe and steel bridge competitions on student learning and development. The study examined how participation affected the growth of technical and non-technical abilities, confidence, motivation, and academic success. Surveys, focus groups, and interviews were conducted for this study. According to the study's findings, taking part in these competitions helped students improve their confidence, motivation, and overall academic performance while also fostering the growth of their cooperation, communication, leadership, and problem-solving skills. Overall, the survey results indicated that the students who participated in competitions consistently rated themselves higher for all the different skills measured in the survey than non-participating students. Several ideas regarding enhancing the participation of students in the competition was also received.

Houston [2] incorporated concrete canoe and steel bridge planning into a construction management course. Students were divided into two competition teams, namely, Concrete Canoe and Steel Bridge, based on their area of interest. Then, two teams were asked to formulate a plan throughout 15-week term working project. It was reported that students who participated expressed appreciation. One of the challenges reported by author was technology transfer. Students were found reluctant in documenting their work until it is too late.

Sulzbach [3] illustrated the importance of concrete canoe competition in enhancing engineering education. The success of concrete canoe team was directly dependent on technical as well as oral and written communication skills. It was found that those students who participated in concrete canoe competition enhanced technical knowledge and built a project management structure and leadership skills.

Abramowitz [4] described an experiment in which students constructed and tested bridges out of the readily accessible material basswood. The study's objectives were to assess the viability of using basswood as a bridge-building material and to give students practical learning opportunities. The construction process for the bridges as well as the testing methods used to assess their durability, stiffness, and strength are described in the study. The experiment's findings show that basswood is a suitable material for making bridges and that students' practical skills in problem-solving, critical thinking, and communication were enhanced by the hands-on learning. The presentation finishes by emphasizing the possibility of utilizing affordable and easily obtainable materials in engineering education and the value of hands-on education in stimulating student engagement and learning.

Davis and Cline [5] discussed the importance of laboratory experiences in a construction management materials and methods course for educational value of students. This study also compared exam and course grades between students enrolled in a lecture-only version of the course and those enrolled in a version of the course that includes both lectures and laboratories. It was found that experiential learning provided through laboratory work promoted teamwork and increased students' learning and confidence.

Baharom et al. [6] implemented problem-based learning approach in concrete technology laboratory of Materials Technology course for deeper learning. Students were divided into groups and each group was given a task to design a concrete mix for a specific structural element in certain construction project. To achieve this, students determined the suitable grade of concrete, water cement ratio, slump and wet density of concrete and prepared their own mix. Then, students tested specimens to determine concrete grade. It was found that problem-based learning method enhanced students' understanding between lab works and the problem to be solved. Several challenges namely, increase in student workload, faculty timetable, facilities, and readiness of the technician were reported.

Hu et al. [7] implemented problem-based learning in addition to lectures in a concrete construction course. Specifically, *field hunting of concrete distresses* activity and *concrete distresses and repair case studies* term project were used to develop critical thinking and problem-based learning. For assessing students' learning and perceptions on the degree of accomplishment in the course, pre and post surveys were given to the students. The problem-based learning approaches were found to promote students' enthusiasm and learning. For future, authors recommended to prepare more case studies associated with homework and quizzes.

In a recent study, Torres et al. [8] and Torres and Sriraman [9] assessed project-based learning application in a construction project management course. Specifically, project-based learning was employed that utilized an actual concrete construction project from a local construction company. Students were randomly divided into groups of three and were assigned milestone deliverables as opposed to one project report at the end of the semester. The students' learning was assessed using various methods such as pre and post survey questionnaire and project grades. It was found that students learning enhanced through real-world field project delivered through project-based learning method, as opposed to a textbook project.

Course Structure

The Construction Materials course is typically one of the core courses that all construction management students take in the second or third year at Illinois State University (ISU). It consists of not more than 24 students. This course allows students to gain knowledge about fundamentals of different construction materials, strength of material and standardized testing procedure. This course is offered every fall and spring semester. The course meets twice per week for 110 minutes for 15 weeks. This is a combined lecture and laboratory-based course in which three-quarter of the semester consisted of five lab activities during which students learn about sample preparation and testing in compression, tension, flexure and shear modes. Entire class was divided into four groups consisting of five to six students. Specifically, topics covered in this course were material testing introduction, masonry, Portland cement concrete, asphalt materials, alternative concretes, steel and wood. The following is a tentative listing of lab activities: density, compression testing of concrete and wood, flexure testing of wood and concrete, and tensile testing of metals, wood and concrete. The laboratory experiences are designed to be completed within the allotted time in the class hours.

The required tasks in this course are quizzes, laboratory reports and final presentation. Quizzes were given frequently in this class in order to help measure comprehension of the lecture and reading material. Most of the quizzes required reading material or watch posted audiovisual and complete questions. Quizzes were taken online through Sakai learning management system (called as ReggieNet). Laboratory activities were assessed through reports related to laboratory activities. Additionally, out-of-lab activities were provided occasionally. The purpose of out-of-lab activity was to utilize time when students are not working in the lab and provide students with background information related to laboratory report questions. At the end of each lab activity, students prepared and submitted laboratory report. Each individual student was required to submit his/her own report via ReggieNet by due date.

Concrete Bowling Ball Project

This study's concrete bowling ball project is very similar to Fiber-Reinforced Concrete (FRC) Bowling Ball student competition offered by American Concrete Institute (ACI), except few changes. A brief explanation of the guidelines of this project is following:
(a) The whole class was divided into four groups and a maximum of 6 students were allowed in each group.
(b) Each group was asked to prepare two concrete bowling balls which should measure 200 ± 15 mm diameter, weigh no more than 5.5 kg and use at least one type of fiber.
(c) There was no limitation on curing for the bowling ball concrete mix.
(d) Following materials were provided by the instructor in the laboratory: foam cores (100 mm, 125 mm, 150 mm diameter), Portland cement, fly ash, blast furnace slag, sand, normal weight coarse aggregates, light weight coarse aggregates, plasticizer, air entrainer, six types of fibers. However, students were allowed to bring their own material and try something new which was not in the laboratory.
The concrete bowling ball project was divided into five weeks. In the first week, project guidelines were explained in the class along with a follow-up quiz. Then, students were asked to discuss among the group, how to prepare formwork and calculate required amount of ingredients for preparing concrete bowling ball. Instructor also provided guidance regarding formwork preparation (e.g., 3-D printing of the formwork, preparing formwork using wood) and mix calculations. In the second week, students started preparing formwork using 3-D printer and simultaneously started preparing first trial mix for concrete bowling ball using pre-made forms (bought from Amazon.com) provided by the instructor. In the third and fourth week, students refined mix designs and prepared additional concrete bowling balls based on their experience with previous trial mixes and better 3-D printed forms. In the fifth week, each group was asked

to pick two best bowling balls which were then tested in the presence of the instructor and each group was scored. Each group was scored (out of total 100 points) based on following five steps:
Step#1 Mass Test (10 points possible) – Each group was asked to take the mass of the bowling ball on a scale. If mass of concrete bowling ball was less than 5.5 kg, group received full points otherwise zero points.
Step#2 Diameter Test (10 points possible) – Each group was asked to measure diameter of bowling ball at three different location and report average diameter. Diameter within 200 ± 15 mm resulted in full points.
Step#3 Bowling Test (30 points possible) – Each group was given five chances to roll and knock 10 pins. Number of pins knocked down in each chance was recorded. A total of 30 points was given to a group for 50 pins knocked down.
Step#4 Toughness Test (30 points possible) – The concrete bowling ball was subjected to load under a Universal Testing Machine. Load was recorded for every 5 mm of crosshead displacement (i.e., at 5 mm, 10 mm, 15 mm, 20 mm, 25 mm) and the average of the five loads were computed and called as Toughness Load Test Score.
Step#5 Load Test (20 points possible) – Load was applied until crosshead displacement traveled 25 mm. This load at 25 mm was considered the final deformation load test score.
Students were also given the opportunity to improve their written and verbal communication skills by delivering a final report and class presentation, respectively, during the final evaluation week.

Student Assessment Data Collection

The population of this study comprised of undergraduate students enrolled in one fall and one spring semester. Based on the enrollments, each semester had 24 students and as per the class size, students were divided in four groups containing six students. The success of the Concrete Bowling Ball project was evaluated through two different aspects: student perspective on the project and student performance. Student perspective was evaluated through the course evaluation and survey questionnaire. The specific survey questions are as follows:
Q-1 Concrete Bowling Ball project helped you in understanding concrete mixes.
Q-2 Hands-on-activities through Concrete Bowling Ball project increased student participation and improved student learning in this course.
Q-3 In the future, this course should continue Concrete Bowling Ball project.
Q-4 Concrete Bowling Ball project lab presentation and report improved your learning in this course.
Q-5 I can accurately define what is meant by concrete mix design in construction projects.
Q-6 The lessons in this course provided me with an awareness of concrete mix design practices.
Q-7 I tried to relate material covered in lecture(s) to Concrete Bowling Ball project.
Q-8 I fairly contributed to the sample preparation part of the Concrete Bowling Ball project.
Q-9 I fairly contributed to the sample testing part of the Concrete Bowling Ball project.
Q-10 I fairly contributed to the report writing part of the Concrete Bowling Ball project.
Each question was rated on the scale of 1 to 5, 1 representing strong disagreement, 3 representing the neutral or not sure response and 5 representing the strong agreement. All the students were asked to complete the survey at the end of the course. The collected data was analyzed for evaluating perceptions of students about Concrete Bowling Ball project. The purpose of survey questionnaire was to know whether the students were able to take advantage of Concrete

Bowling Ball project and whether each group member contributed to the project in best possible way or not. Additionally, following three separate questions were given for getting written comments and feedback from students:
Q 1 Discuss the challenges you had to face or breakthrough during this project.
Q 2 Write how this project can be done differently in the future.
Q 3 Please provide any other comment or feedback.

Findings and Discussion

In the grade distribution 10% was assigned to Concrete Bowling Ball project activity and remaining 90% was assigned to other learning activities such as quizzes, exams and four lab reports. Out of 10%, 5% was assigned to scores received by testing Concrete Bowling Ball, 2.5% was assigned to Concrete Bowling Ball project report and remaining 2.5% was assigned to oral presentation. All groups showed satisfactory performance in both reports and presentations. Also, based on his teaching experience, instructor found that students were more engaged and enthusiastic during Concrete Bowling Ball project. Students were also found talking about this project outside class. Figure 1 shows photographic views of Concrete Bowling Ball preparing and testing.

As discussed earlier, at the end of Concrete Bowling Ball project students were given questionnaire. The responses of 48 subjects in questionnaire are presented in Table 1 and graphically presented in Figure 2. Based on responses to Question#1 and #5 presented in Table 1 and Figure 2, it is evident that more than 95% subjects gave a response of 4 or 5 (moderately or strongly agree) which indicates that Concrete Bowling Ball project helped students in understanding concrete mixes. The responses to Questions#2, #4, #6 and #7 indicated that more than 90% subjects agreed that hands-on-activities through Concrete Bowling Ball project work increased students' participation and improved learning in this course by relating lectures to lab project. Learning assessments such as presentation and report also enhanced learning and they became aware of concrete mix design practices. The response to Question#8, #9 and #10 indicated that more than 90% students participated fairly in the sample preparation, testing and report writing part of Concrete Bowling Ball project.

Figure 1: Students preparing and testing Concrete Bowling Ball

Table 1: A Summary of Students' Responses to Survey Questionnaire

Question#	**# of subjects with grading of 1 or 2 (Disagree)**	**# of subjects with grading of 3 (Neutral)**	**# of subjects with grading of 4 or 5 (Agree)**
1) Concrete Bowling Ball project helped you in understanding concrete mixes.	0	0	48
2) Hands-on-activities through Concrete Bowling Ball project increased student participation and improved student learning in this course.	0	0	48
3) In the future, this course should continue Concrete Bowling Ball project.	0	0	48
4) Concrete Bowling Ball project lab presentation and report improved your learning in this course.	0	4	44
5) I can accurately define what is meant by concrete mix design in construction projects.	0	2	46
6) The lessons in this course provided me with an awareness of concrete mix design practices.	0	0	48
7) I tried to relate material covered in lecture(s) to Concrete Bowling Ball project.	0	4	44
8) I fairly contributed to the sample preparation part of the Concrete Bowling Ball project.	0	0	48
9) I fairly contributed to the sample testing part of the Concrete Bowling Ball project.	0	2	46
10) I fairly contributed to the report writing part of the Concrete Bowling Ball project.	0	4	44
Total	0	16	464

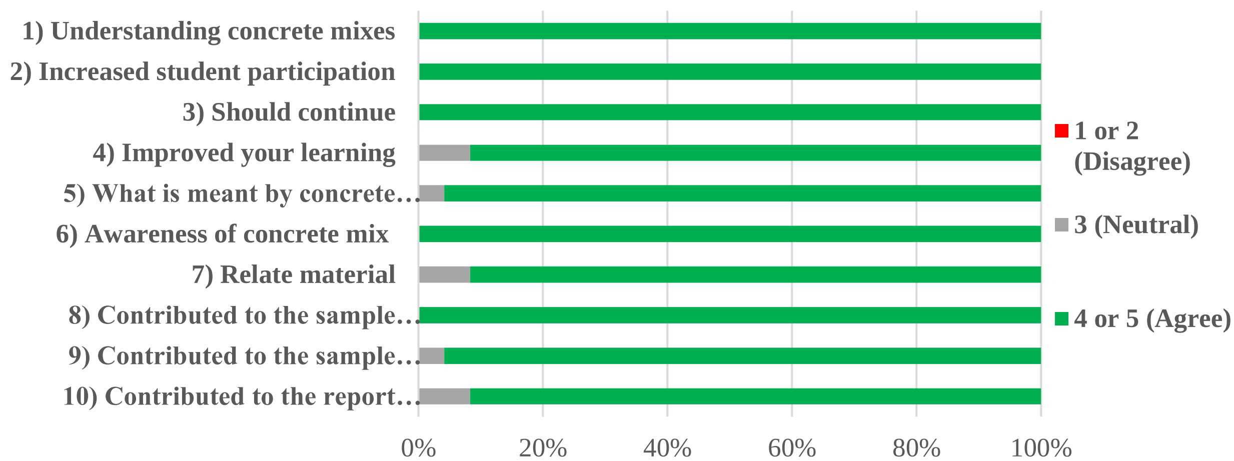

Figure 2: Student perception of Concrete Bowling Ball project

Course evaluation and feedback was also positive and some of the students expressed that they enjoyed hands-on-learning a lot. Some of the challenges pointed out by students were getting right finish and centering the foam core inside the concrete bowling ball, several students also mentioned limited time as one of the challenges and getting a stronger mix without going over the weight. Some of the comments provided by students in the survey questionnaire are provided below.

Q 1 Discuss the challenges you had to face or breakthrough during this project.

“The finish of the ball was the issue for our project. Due to a lot of fiber in the mix, it did not form together as smoothly as we were hoping, but it still held together good and produced satisfactory results.”

“My group ran into many challenges because this was our first time creating our own mix, so it is expected. Some problems we had to solve was adjusting our number of fines so we could get a cleaner finish on the final product ball after the curing. Another issue we ran into was what type of fiber we used. After switching up our fibers for the final 2 mixes we got a cleaner, smoother finish.”

“We had issues with the weight of our mixes.”

“A certain challenge that we went through is with the very first mix. Our group did not have a set idea of how to create our own concrete mix, so it was hard to figure out of what and how much material we needed.”

Q 2 Write how this project can be done differently in the future.

“One way we could do this project in the future would be to use all 3 of the foam cores to see how it effects the mass and load testing.”

“As well it would make the lab better if we were able to test a ball and then make another 3 designs to see what we would like to change while having a baseline to reflect on.”

“One thing that can be changed about this lab in the future is to use a different type of mold that is not 3D printed, it was easy to break/crack while releasing the dried bowling ball from the mold.”

Q 3 Please provide any other comment or feedback.

“The overall lab was interesting, the fact that we all had to collaborate and create our own mixes really helped us understand how important it is to mix concrete right. This lab was a good learning experience all around because it allowed us to use our own creativity and work more as a unit to produce ideas for each mix.”

“This project helped the students understand what variables are present when trying to develop a strong yet lightweight concrete mix. I learned that there are many ways to create a concrete mix depending on the intended purpose.”

“We learned a lot goes into making concrete and batching it ourselves. The smallest amount of change can make a huge difference within a mix.”

“What I learned about this lab the most was that fiber reinforcement is actually very beneficial. If we had not put any fibers into our mixes, I guarantee that our load and toughness tests would be way lower than what we tested.”

Concluding Remarks

As of now, the Concrete Bowling Ball project has completed two semesters. Students learnt about the importance of different ingredients in concrete mixes through Concrete Bowling Ball project. The learning of students about concrete mixes was found to enhance through this project and most importantly students were engaged and interested in this ‘learn while having fun’ project. Overall, hands-on-activities through Concrete Bowling Ball project work increased students’ participation and improved learning in this course by relating lectures to lab project. However, apart from talking about the success of Concrete Bowling Ball project, it is also important to mention challenges encountered by the instructor. One of the challenges encountered by instructor was time management to have a perfect balance of lectures as well as laboratory activities. Also, instructor had to manage availability of all materials in the laboratory.

Another challenge was 3-D printing of formwork which took 2-3 days. Some students already had experience with using 3-D printer but not all students had that experience and there was not enough time available to teach concrete formwork design for 3-D printing. To overcome this challenge, instructor took assistance from graduate assistants and Engineering Technology program student association who were already familiar with 3-D printing. Therefore, instructor got few 3-D printed formworks at the beginning of the semester to make sure that formwork is available for all groups, if needed. In future it is recommended to find better cost-effective as well as time-efficient ways for making Concrete Bowling Ball formwork.

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