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ENGINEERING TEACHING IS STUCK IN THE PAST: HOW TO MOVE FORWARD FROM THE TRADITIONAL AND OBSOLETE APPROACH?

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Abstract

Engineers are required to be self-directed learners during their entire professional life. Therefore, as students, they should learn problem-solving skills and deal with real-world problems. Unfortunately, teaching has been reduced to the transmission of information. The amount of information received by students in a class, very often, is overwhelming. It becomes difficult, for any human being, to recall all the information in the long term. Therefore, innovative ways to teach the new digital generation of students are needed in the classroom. Active learning is an approach that can be considered when designing the class syllabus. This instructional method engages students in the learning process by incorporating meaningful activities. The main goal is to provide students scenarios that allow them to analyze and to apply class concepts/content to real-world situations. The aim of this paper is to present active learning applications in a Construction Management course. This course is part of the Civil and Environmental Engineering Program at Virginia Tech. To this end, the concepts of critical thinking, engaged pedagogy, and networked learning were applied. All engineering disciplines are different by nature, which makes each student learning experience diverse. Incorporating a process of analysis and synthesis, providing a safe space for questions and discussions, and acknowledging that the potential of diversity in the classroom leads to a better learning process.

Keywords: active learning; critical thinking; networked learning

Resumen

Los ingenieros deben ser autodidactas durante su vida profesional. Por esta razón, como estudiantes deben aprender habilidades de resolución de problemas y a su vez desarrollar

problemas del mundo real. Desafortunadamente, la enseñanza se ha reducido a la transmisión de información. La cantidad de información recibida por los estudiantes en una clase, frecuentemente, es abrumadora. Por lo tanto, existe la necesidad de incorporar enfoques alternativos de enseñanza en los cursos de ingeniería. La enseñanza orientada a la acción es una metodología de instrucción que incentiva la participación de los estudiantes en clase a través de escenarios que les permiten analizar y aplicar conceptos vistos en clase a situaciones del mundo real. El objetivo de este artículo es presentar la aplicación de este enfoque al curso de Gestión de la Construcción que hace parte del programa de Ingeniería Civil y Ambiental de la universidad Virginia Tech. Para este fin, se aplicaron los conceptos de pensamiento crítico y aprendizaje en red. Las disciplinas de ingeniería son diferentes por naturaleza, lo que hace que la experiencia de aprendizaje de cada estudiante sea diversa. Incorporar un proceso de análisis y síntesis, proporcionar un espacio seguro para preguntas y debates, y reconocer el potencial de la diversidad en el aula, conducen a un mejor proceso de aprendizaje.

Palabras clave: *aprendizaje en red; enseñanza orientada a la acción; pensamiento crítico*

1. Introduction

Over the years, teaching has focused on what professors teach instead of how they teach (Langer, 2000). This traditional approach tends to promote mindlessness because different perspectives of learning are neglected in the classroom. At present, the engineering industry demands professionals and leaders that make substantial contributions to the research and practice fields. Engineers are required to be self-directed learners during their entire professional life. Therefore, as students, they should deal with real-world problems and learn problem-solving skills.

Unfortunately, students are not being prepared for the real world. Lectures are becoming an old-fashion and ineffective approach to teach. According to Carnes (2011), "students quit and fail not because they lack funds, but because they lack motivation and interest". Teaching has been reduced to the transmission of information. The amount of information received by students in a class, usually, is overwhelming. Students retain about 70% of what they hear in the first ten minutes of class and just 20% during the last ten minutes (Meyers and Jones, 1993). Therefore, it becomes difficult, for any human being, to recall all the information in the long-term.

To overcome the challenge of keeping students' attention and retention, active learning becomes an indispensable tool in the classroom. This instructional approach engages students in the learning process by incorporating meaningful activities. The main goal is to provide students scenarios that allow them to analyze and to apply class concepts/content to real-world situations. According to Freeman et, al (2010), active learning improves the performance of STEM students. In their study, Freeman et, al (2010) found that undergraduate students taking traditional classes are 1.5 times more likely to fail than students taking active learning-based classes.

The aim of this paper is to present active learning applications in a Construction Management course. This course is part of the Civil and Environmental Engineering Program at Virginia Tech (United States).

2. Background

Engineering courses require a lot of problem-solving skills and some learning methods do not fit properly in their content. Therefore, several learning approaches should be explored and then should be considered when designing the course syllabus. This section briefly describes some of the teaching strategies that were applied in the Construction Management course at Virginia Tech.

2.1 Engaged Pedagogy

Engaged pedagogy is an approach that requires active participation between the student and the teacher (Hooks, 2010). To this end, both should get to know each other to guarantee a free and comfortable exchange of ideas in the classroom (Hooks, 2010). Engaged Pedagogy recognizes students as contributors to the learning process and builds a sense of community in the classroom where the teacher and students learn from each other (Hooks, 2010).

2.2 Critical Thinking

Critical Thinking demands that students not only to receive information but also that they reflect on it and analyze it. That is, finding answers to the questions and then using that knowledge to determine what is significant (Hooks, 2010). In this process, both sides of an issue should be considered (Hooks, 2010). Thus, teachers must keep an open mind to consider different perspectives and must not be attached to a single viewpoint. The way how children learn is a good example of how to incorporate critical thinking into the classroom (Thomas & Brown, 2017); (Hooks, 2010). Children are not afraid of asking “why” all the time. In a similar way, asking questions is a practice that should be encouraged in the classroom.

2.3 Active Learning

Active learning is a teaching methodology that engages students in learning by doing meaningful activities (Bonwell, 1991). Under this method, students are not only watching, listening, and taking notes as usually happens in a traditional lecture. Instead, students are doing activities that promote their critical thinking. During these activities, students apply and reinforce the concepts learned in class, and develop additional skills when working in groups.

Problem-based Learning (PBL) and Networked Learning are considered active learning approaches. PBL is an active learning strategy that promotes critical thinking and problem-solving skills (White, 1996). In PBL, students learn about a subject through real-world problems. Instead of teaching students the concepts, students must work in groups to identify what they know and what they need to learn in order to solve a problem (White, 1996). Otherwise, Networked Learning is an approach where students build their knowledge through technology tools (Campbell, 2016). By connecting students with learning resources, Networked Learning forces them to think, reflect, and form their own opinion by exchanging ideas, promoting discussions, and receiving feedback.

3. Active Learning -Based Approach

The actual learning environment in engineering courses should change and adapt to today's generation. In this new digital era, teachers face the challenge of taking advantage of the unlimited resources that the internet provides and combine them with an environment that allows students to build and experiment the topics, concepts, ideas, or examples in an innovative way (Thomas & Brown, 2017). For that reason, the Construction Management course, which is part of the Civil and Environmental Engineering Program at Virginia Tech, was re-designed to be taught under a more active learning approach.

3.1 Classroom, Class Size, and Class Length

The course had a size limit of 40 students and a 75-minute session that met two times per week. The classroom could be reconfigured as the instructional needs dictated because the majority of the rooms of one of the newest buildings at Virginia Tech were configured as SCALE-UP classrooms. SCALE-UP is a design that facilitates team-based and active learning. The classroom has state-of-the-art technology, moveable furniture, and several whiteboards to support different concurrent pedagogy practices. The classroom where the construction management class was held is shown in Figure 1.



Figure 1. The Layout of the Classroom.

3.2 In-Class Active Learning-Based Activities

This section describes some of the activities that were performed in the Construction Management class to explain concepts such as the Work Breakdown Structure (WBS), Scheduling, Project Delivery Methods, Estimating and Bidding Process, and Negotiation Theory. These concepts are not explained in this paper since the main purpose is to highlight the teaching and learning approaches applied in the class.

Work Breakdown Structure (WBS) with Sticky Notes: Each team had to identify the tasks needed to build a specific project (one by sticky note) and then, to post them anywhere on the whiteboards. Students grouped the notes that could be good together and then found a name for the related activities. This activity helped students to understand that a WBS organizes the activities into a group of related tasks. Having multiple whiteboards in the classroom allowed students to move around the sticky notes until they came up with the best WBS. An example of a WBS developed for one of the teams is shown in Figure 2 (left).

Scheduling with Sticky Notes: Each group built the schedule of a house using sticky notes. Students determined the logical sequence of the project from a list of activities. Based on their knowledge and experience, students estimated the duration of each activity. Then, the sticky notes, which represented the activities, were posted on the whiteboard and connected using markers. This activity helped students to understand how to estimate the final duration of a project and how to identify the critical path in a schedule. An example of a schedule developed for one of the teams is shown in Figure 2 (right).



Figure. WBS and Scheduling Activities using Sticky Notes.

Class thought exercises/activities should be incorporated into the class to ask students “what would happen if” (Kincheloe, 2008). This practice promotes a critical thinking environment in the class. Following that approach, based on each team’s schedule, students analyzed hypothetical scenarios. For example, what would happen if a specific activity is delayed and how the critical path would change.

Scheduling Introductory Exercise: Each team received the same amount of sticks of spaghetti and marshmallows to build the tallest freestanding spaghetti tower in five minutes. After the time was over, students were asked questions related to the common aspects usually considered when developing a schedule. For example: Did you identify the activities needed to build the tower? Did you identify the order in which activities should be performed? Did you assign responsibilities? In addition, the concepts of over-budget, under-budget, behind and ahead of schedule were explained thanks to the fact that all the teams received the same amount of materials and had the same time to build the tower. Some of the teams finished earlier and others used more material than that required.

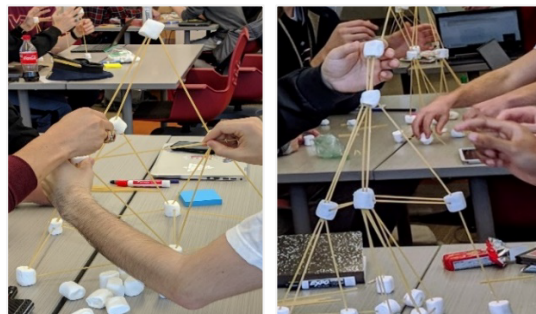


Figure 3. Teams building the Spaghetti Tower.

Project Delivery Methods: Two different activities were designed to reinforce the concepts of project delivery methods and to gauge the students' understanding of this subject. Due to time constraints, only the second exercise was performed. By doing these activities, students can understand the differences between each method and become familiar with the types of projects being delivered by each delivery method.

1. Each team should explore the websites of top construction companies and observe the reasons why these companies are the leaders in their respective delivery method. Then, each team should create their own company and develop an argument for the class explaining how their company would become one of the leaders in a specific project delivery method.
2. Each group received information about a completed project such as scope, financial and schedule requirements, and delivery requirements by the owner. Each team assessed these requirements and identified the delivery method that best met the project needs. Afterward, the actual delivery method used to perform each of the projects and the reason of that selection were discussed in class.

Estimating and Bidding Process: Two different activities were designed to develop students' cost estimating skills and to simulate a real bid process. Due to time constraints, only the second exercise was performed.

1. Each team has to determine the cost to install a flagpole (Mattila, 2009). Information about materials, labor, and equipment costs should be provided to the students as well as the specifications and drawings of the flagpole. Each team should fill out a bid form including the cost of the flagpole installment in a sealed envelope. Then a bid opening should be held in the classroom to announce the team with the lowest bid.
2. Different case studies were given to each team. All the cases were related to the process of submitting and pricing a proposal for the construction of a specific project. For each case, students had to discuss and select a choice of action to bid the project based on the scenario circumstances. Then, the pros and contras of selecting each option were analyzed and discussed in class.

Negotiation Role Play: A simulation about a win/lose bargaining was performed to develop and to strengthen students' negotiation skills. This activity was based on the two-dollar game. The class was divided into pairs which had to divide \$20 between the two players. Each student had a specific and secret instruction that inclined them toward competition, accommodation, or compromise strategies. This negotiation role play helped students to understand the basic tools of negotiation theory such as win-lose, in which one person wins and the other loses and distribution, in which both players win.

Research Integrated with Education: A poster session was held in the classroom to increase awareness of contemporary construction issues and prompt class discussion about these topics (See Figure 4). Students should explain the significance/impact of the contemporary topic on industry and on professional careers. Since the classroom has multiple screens for projecting at the same time, three rounds of 15 minutes each to accommodate all the teams were held. In each round, all students should visit each team's display and evaluate each team's presentation.

ENGINEERING TEACHING IS STUCK IN THE PAST: HOW TO MOVE FORWARD FROM THE TRADITIONAL AND OBSOLETE APPROACH?

By evaluating others student's work, students realized what should be improved on their own work. Similar to a real poster session, the top three team earned a reward.

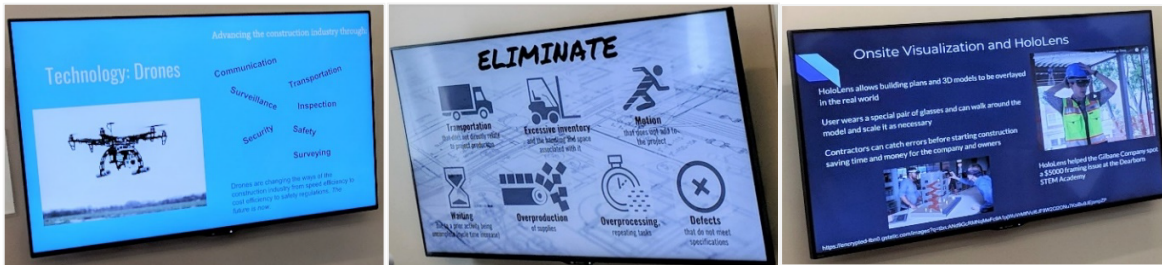


Figure 4. Students' Displays during the Poster Session

Knowledge in the field of civil engineering changes at a rapid pace. Sharing research findings adds value to the class material. It is vital to show students why these results are important and the impact that these may have in the specific field. Nowadays, companies care about research and for that reason, students should be up to date with cutting-edge research.

Networked Learning: Mentimeter was used in the class to gauge the status of students' understanding. Mentimeter is an online interactive presentation software that allows students to actively participate in class. Students were able to use Mentimeter using their laptop or smartphone. During the lectures or after teamwork activities/exercises, short questions were posted using Mentimeter (see Figure 5).

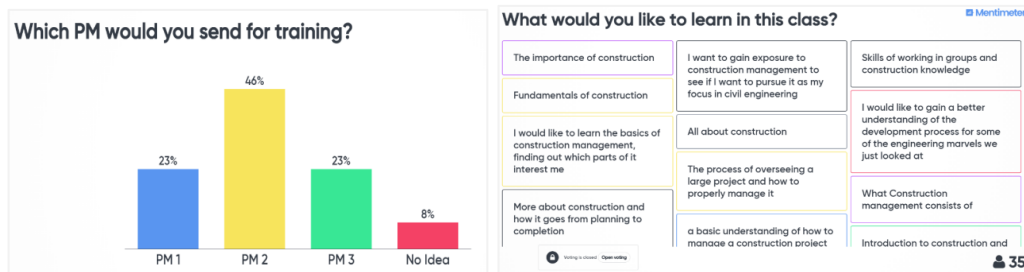


Figure 5. Use of Mentimeter

By having the students' outcome in real time, the wrong questions or doubts were clarified. As shown in Figure 5, one of the options of the in-class short questions was "I have no idea". Since the participation was anonymous, students felt free to say "I don't know". In fact, one of the students said: "With anonymous class participation through Mentimeter there is no pressure to be right or lie or say what you think people want to hear".

4. Results: Students' Performance

According to students, the active learning-based activities performed in class helped them: 1) understanding the key concepts about construction management, 2) figuring out what they knew about the topic and what they needed to work on, 3) reinforcing the concepts, and 4) getting

better at the calculations. Additionally, students agreed that the activities engaged and broke up the class because sometimes the lecture material is difficult to make interesting. Students said that these activities made the class time go by faster and made studying for the test easier. This can be seen not only in the active participation of students in class but also in their grades. The average score on the exams was 90.5 and that on assignments was 94.0.

5. Final Remarks

Currently, active learning should be around the corner in Higher Education. Unfortunately, this approach is far from being implemented on a daily basis in a classroom, especially in the engineering field (Campbell, 2016). As mentioned by Langer (2000), "teaching is stuck in a single drawn distinction from the past". Some of the reasons why active learning has not been not fully applied in higher education are described below.

Assessment System: All engineering disciplines are different by nature, which makes each student's learning experience diverse. In the current education system, grades are all that matters for students and for professors. However, students' performance should be assessed in terms of how well they are prepared for the demands of this century's workplace instead of their score on a test.

Students' Perspective: Engaging students in class is not an easy task. The fact that students may not participate or may not learn the content as planned is a latent risk when trying to apply active learning (Bonwell, 1991). At first, students may feel uncomfortable in this environment because they cannot anticipate the outcomes. Instead, they will have to improvise and get out of the comfort zone. Some comments of the students about this approach were: "I had a very enjoyable time every class and never knew what to expect", "Learning was fun".

Professors' Perspective: At present, professors face the challenge of figuring out how to manage their time in the classroom, and the challenge of keeping students motivated and interested in class. Moving forward from the traditional and obsolete educational approach is not yet a priority in the faculty's bucket list. This change requires will and a significant amount of work since the process of re-thinking and re-designing the engineering classes is very time-consuming (Bonwell, 1991).

Despite these obstacles, active learning is needed in the classroom so students enjoy the process of learning. Some aspects that should be considered when re-designing the course content under a more active learning approach are described below.

Foment an Inclusive Environment: Diversity is everywhere, especially in a classroom. There are students from different disciplines, socio-economic status, cities, countries, etc. As a result, each student understands the concepts/ideas in a different way. Having a diverse group of students working together during the class makes a big difference. It is not only the background what has a significant impact, there are the experiences and philosophies what bring to the table different perspectives and ways to think, to understand, or to solve a problem. Furthermore, some course

topics, rubrics, and/or schedules should be built collaboratively with students (Mays, 2017). This practice re-assures that the course content will help students in their future professional career (Mays, 2017).

Foment a Critical Environment: Memorization and repetition are not the most suitable approaches to learn. Teachers cannot expect students to memorize an enormous amount of information that sometimes seems to be irrelevant to what they need as future professionals (Thomas & Brown, 2017). Instead, teachers should incentive students to relate the class' concepts to their career practice.

Foment Educational Experiences: Outreach is considered as an active learning activity because students learn by doing (Campbell, 2016). This experimental learning not only has a positive impact on student's life but also adds a significant value to the class. It gives students the opportunity to apply what they learned in class to a real-world context. In addition, students discover or strengthen additional skills that will help them to succeed in their future careers. Students want more real-world examples and activities in class. More opportunities for students to apply what they are learning in class and at the same time to serve the community are required (Mays, 2017).

Foment Team-based Work for Problem-Solving: A team-based work promotes a safe class environment where making mistakes is acceptable. Students feel comfortable working with a partner and they do not feel the pressure of being evaluated. Instead, they generate discussions and feel free to ask questions. One student said: "It was great to have the experience to work with groups because that is how it usually works out in the real world. We have to help each other in our teams/company to succeed. This type of activities helps with developing skills to effectively communicate with other teammates."

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