2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33630

You Teach Us: Peer Teaching in the Engineering Classroom

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Abstract

Peer teaching, an instructional technique which promotes both student interaction and active learning, is explored in this evidence-based practice paper. Both in-person and virtual classrooms necessitate that instructors carefully consider mechanisms of content delivery in order to retain student engagement. The You Teach Us, a peer teaching method described in this paper, enables students to learn from one another through structured activities and can be utilized in courses of varying sizes. In the engineering course in which this method originates, students prepare a 15-minute lesson to teach a small group of their peers. These lessons are not one-sided student presentations. Students must apply the creative process to an educational context and develop lessons that include pertinent content in an engaging activity and a mechanism for summative assessment (e.g., discussion, individual or group quiz, quality of activity outcome). To further understand the effectiveness of this instructional activity in terms of student engagement and outcomes, student self- and peer-assessments are qualitatively analyzed. Findings indicate that students were reflective, consistent, and fair graders who reported high levels of student engagement both in their own, and in their peers', lessons.

1. Introduction

Learner-centered pedagogy has become increasingly popular in engineering education and is explored in this evidence-based practice paper. "By incorporating active learning methods into the classroom, instructors can create opportunities for learning instead of allowing students to sit passively and learn by absorbing information passed on by the instructor [1]." Active, collaborative learning techniques include in-class discussions, activities and labs, as well as formal team projects [2]. Despite the benefits of this pedagogy, it is not always clear how to incorporate active learning strategies into courses with a high emphasis on technical content or in large classes. This paper describes the effectiveness of one such strategy and discusses its applicability across courses with varying content and formats.

Called You Teach Us (YTU), the active learning activity described in this paper is based on peer teaching, a cooperative strategy with roots in constructivism [3], [4] used in many higher education settings [5], [6], most notably in medical education. Peer teaching can offer opportunities for new knowledge or skills to be learned by the student teachers [7], [8] and their peers [9]. However, this strategy is infrequently reported in engineering education [10].

The purpose of this paper is two-fold. First, it provides a detailed description of the peer teaching activity assigned within the context of a creativity course taught within an engineering program and reflects on the applicability of the activity in a wide range of engineering courses. Second, it describes a qualitative study to answer the research question, *to what extent is the YTU activity effective in terms of student engagement and connection to the course objective?* Data was collected from two groups of students who participated in this creativity course and completed two peer teaching activities. Each student taught a 15-minute lesson to a group of peers, submitted a detailed lesson plan, and wrote self- and peer-assessments after class. These lessons included both content sharing (i.e., presentation about the topic) as well as an activity and a final assessment tool to ensure that their peers had met the student-defined learning objectives. The

self- and peer-assessments prompted students to reflect on what each peer teacher had done effectively in their respective lesson and what could be improved.

There were three primary goals for the inclusion of these assessments. First, they were used as a mechanism to encourage active listening and participation by the students while they were in their peer teaching groups. Second, with more peer teaching groups working simultaneously than the number of instructors, the assessments were used by the instructor(s) to gain further insight into each student's lesson. Third, they further promoted the role of students as *teachers* through reflection and assessment of the quality and content of the lessons of both themselves and their peers. The results from these assessments were coded using an inductive approach to provide insight into each of these objectives.

Peer teaching is not a new instructional, active learning technique. However, this paper aims to describe a particular method used in an engineering course with the objective of demonstrating its overall effectiveness, particularly in terms of student engagement.

2. Course Background

The peer teaching activity discussed in this paper is assigned to students in a creativity and innovation course. This course is housed in the Grainger College of Engineering at the University of Illinois Urbana-Champaign. It is typically offered each fall and spring semester as a 4-credit hour, 16-week course and is open to both undergraduate and graduate students from all colleges and departments across campus. It is an elective for most students who enroll, but is also a required course for the degree of Bachelor of Science in Innovation, Leadership and Engineering Entrepreneurship. Periodically the course is also offered as a 4-credit hour, 8-week summer course. In this format, the learning objectives and content remain the same. The course has been offered for more than a decade and, in the eight offerings from Spring 2018 to Spring 2021, has had an average enrollment per class section of 34 students.

The purpose of this course is to facilitate the development of students' creativity, innovation, and vision skills. This is done through a framework of creativity as (1) having novel ideas and (2) bringing them to be, which is depicted in Figure 1. The content of this course aims to work in conjunction with a student's primary degree by enhancing their creativity through increasing their ability to find opportunities, ideate and develop innovative solutions, and implement them successfully. These skills are vital to the 21st century engineering student [11] - [13]. Students enhance their creativity – their abilities to have ideas and bring them to be – by (a) learning techniques, (b) practicing with feedback, and (c) developing a mindset that promotes creativity. In this course, this is done both in the classroom through a variety of active learning techniques as well as through readings and reflections, team projects, the development of a creativity log (i.e., a compilation of identified problems/opportunities for improvement, ideas, implementation plans, and reflections), and peer teaching activities.

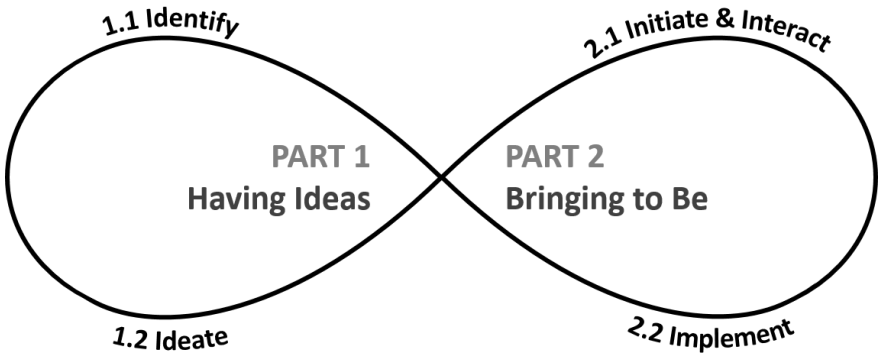

Figure 1. Framework for creativity.

2.1 Peer Teaching Activity

The peer teaching activity assigned in the creativity course is called the You Teach Us (YTU). In this assignment, students are asked to individually prepare a 15-minute lesson to teach a small group of their peers. Unlike many peer teaching activities, YTU is a completely open, student-directed activity. While students are encouraged to provide initial context to their topic, their topics are of their own choosing. Moreover, these lessons are not merely student presentations. Students apply the creative process to an educational context, develop a lesson plan that includes pertinent content in an engaging activity, and a mechanism for summative assessment (e.g., discussion, individual or group quiz, quality of activity outcome). Prior to completing this assignment, students are given a template to create a lesson plan and a brief (5-10 minute) description of the assignment during a class period.

Rather than diverting instructional responsibility onto students, this activity allows students to make explicit connections between their outside interests and studies to this class, a course on creativity. Assessment of this activity occurs in a variety of ways. The instructor and teaching assistants visit group during each round of student lessons to observe the instruction and student engagement. Students submit their written lesson plans and provide a justification for how their lesson furthers the aims of the course. All students write self- and peer-assessments. The differentiation, in terms of the student lessons and multiple forms of assessments, allows for variety in the presentations, and diminishes the likelihood of peer disengagement during the lessons. Peer assessment all but ensures this (e.g., [14] - [17]). Further, research in higher education indicates that students enjoy the learning "atmosphere" of peer-teaching [18], find their peers to be useful adjuncts to the instructor-led content [19], and report confidence and skill development as a result of participation in the activity [10], [20], [21].

There are three learning objectives for this assignment. As a result of completing the You Teach Us, students will be able to:

- develop and present a unique and effective lesson plan to teach others,
- justify whether teaching facilitates a deeper understanding of your own material,
- describe new content from the different topics taught by peers and determine how they each support creativity development.

Each semester, students are asked to complete two to three You Teach Us assignments, each with a different prompt. The number of You Teach Us assignments in a given semester is dependent on the quantity and requirements of other assignments to ensure consistency in workload across iterations. Since Spring 2018, more than 270 undergraduate and graduate students have participated in the course and completed at least two You Teach Us assignments. The following variations of the assignment have been assigned to students throughout the course iterations and are briefly described in Table 1:

- You Teach Us – What You Know
- You Teach Us – Who You Know
- You Teach Us – What You Learn
- You Teach Us – How I Built This
- You Teach Us – Creativity and Innovation

Name	Brief Description
What You Know	This is your opportunity to teach others about something you already know. Choose a topic that you are familiar with (e.g., something that you are passionate about, relates to your major, or a hobby). You should choose a topic that is relevant in a class about creativity, innovation, and vision and that you can justify teaching in a 300-level course.
Who You Know	Choose a person with whom you are familiar (personally or from history) and who has had an impact on your life and the enhancement of your creativity. Using their personality, significance, and/or style, design a lesson that you believe they would teach to the class. Challenge yourself to learn more about this person's life and prepare activities that are in line with their life's work. This is your opportunity to share why someone is important to you, and share the inspiration they gave you.
What You Learn	Individually pick a creativity topic that is new to you and prepare a lesson to teach it to your fellow classmates, OR go somewhere new where creativity is evident and prepare a lesson to teach about it. This is your opportunity to learn something or go somewhere that you are interested in and share the information with classmates and peers that depicts your learning and growth over the semester. Examples of places to visit will be given in class (e.g., businesses, community spaces, etc.). *This assignment was originally entitled You Teach Us – New Experience but was modified after the pilot to be more comprehensive.
How I Built This	Choose and listen to one of the available podcasts from NPR's *How I Built This* series, which are available for free on multiple platforms. Then teach your classmates about what you learned. Who was the innovator and what did they build? What challenges did they overcome? What process did they take to develop their idea? Turn their idea into reality? What did you learn that was surprising? Helpful?
Creativity and Innovation	Individually pick a topic that directly relates to creativity, innovation, entrepreneurship, or a similar subject and that is new to you and prepare a lesson about it to teach to your classmates.

Table 1. Brief descriptions of You Teach Us peer teaching assignment iterations.

This study analyzes student feedback from two iterations of the course in 2018 and 2019. The first YTU assigned in both these semesters, You Teach Us – What You Know, required students to make connections between the course and a topic of which they were already familiar. Examples of student-selected topics include data visualizations, pediatric nursing, advertising, and automotive mechanics. In each of these lessons, students needed to make explicit connections to the themes of the course; creativity, innovation, and vision. The second YTU, You Teach Us – What You Learn, gave students the opportunity to select any topic that

they believe fit the overall objectives of the course and that would advance theirs and their peers' creative abilities. For instance, while the course covers many ideation and implementation techniques, students provided novel content in areas such as makerspaces, ethics, the connection between creativity and sleep science, brainstorming techniques, and creative habit formation.

The topics that students can select to teach for this assignment are intentionally open-ended for this course on creativity and innovation. By being introduced to a wide variety of topics, students are able to build upon their existing knowledge, develop their curiosity, and learn about new problems and opportunities that exist in the world. This enables students to make new connections as they learn to enhance their ability to have ideas and bring them to be. However, other science, technology, engineering, and mathematics courses could utilize this peer teaching activity with more specific constraints on the topic selection. Instead of all students teaching on the same day, the assignment could also be spread across the semester with students selecting a teaching day and topic area that corresponds with the primary course content being taught at that time.

For both assignments, students gave their lesson to a group of 3-5 peers in-class and subsequently submitted a detailed lesson plans topic rationale, and self- and peer-assessment. These assessments consisted of assigning a score out of 10 points and 4-6 sentences of text describing what went well in the lesson, how well it connected to the course objectives, and what improvements could have been made.

Tables 2 and 3 provide an itemization of how these components were graded for the YTU – What You Know and YTU – What You Learn, which are worth 5% and 6%, respectively, of the overall course grade. Traditionally, these assignments have been graded by the primary course instructor(s) and/or teaching assistants. However, there is room for modification in the grading procedure to place a greater emphasis on the self- and peer-assessments to increase their significance in the final grade and lessen the grading burden of the instructors. This could be especially helpful in courses with large enrollments or when the size of the instructional team or quantity of other graded assignments limits what can added to the grading load.

Component	Description	Points
Lesson Plan	Clear lesson plan with lesson objectives, detailed outline, activity, assessment tool	15
Topic	Unique, imaginative, thoughtful, effective	5
Rationale	1 paragraph rationale describing how this topic is connected to creativity, innovation, and vision	5
Lesson Presentation	Clear and engaging lesson, well-prepared, participation from students	15
Self-Assessment	4-6 sentences on what you did well and what you could improve	5
Peer-Assessments	4-6 sentences on what each of your group members did well and what they could improve	5
Total		**50**

Table 2. You Teach Us – What You Know grading itemization.

Component	Description	Points
Lesson Plan	Clear lesson plan with lesson objectives, detailed outline, activity, assessment tool	20
Topic	Unique, imaginative, thoughtful, effective	5
Rationale	1 paragraph rationale describing how this topic is connected to creativity, innovation, and vision	5
Lesson Presentation	Clear and engaging lesson, well-prepared, participation from students	20
Self-Assessment	4-6 sentences on what you did well and what you could improve	5
Peer-Assessments	4-6 sentences on what each of your group members did well and what they could improve	5
Total		**60**

Table 3. You Teach Us – What You Learn grading itemization.

3. Methods

During two 16-week semesters in 2018 and 2019, 83 students were enrolled in an in-person version of the creativity and innovation engineering course. 12 of these students were at the graduate level (either Masters or Ph.D.) and 71 were undergraduates. Of these students, 51 consented to have their work analyzed for this study, a participation rate of 61%. Prior to data collection, approval for this study was obtained from the University of Illinois Urbana-Champaign Institutional Review Board.

In both course iterations, students were required to complete two YTU assignments. The resulting self- and peer-assessments were qualitatively analyzed using inductive content analysis. This was accomplished in two stages. The first step was an "open" reading of the assessment responses without predefined codes to allow for variable discovery [22]. The second step used the codes defined in the previous step for analysis of each self- and peer-assessment response.

4. Results

The average final scores for the first YTU (What You Know), as scored by the instructors, in 2018 and 2019 were 48.9 (98%) and 48.4 (97%), respectively, both out of a total of 50 points. The averages for the second YTU (What You Learn) were 58.5 (98%) and 57.9 (97%), out of a total of 60 points. The self- and peer-evaluations were also analyzed for each YTU.

4.1 Self-Assessment

An average of 3.7 codes per self-assessment were applied to the first YTU, and 3.5 codes to the second YTU. Most frequently, students stated that they had done a good job explaining their topic (18% of students). An example of a student assessment of their explanations was evident in comments such as "Overall, I think I did a good job of explaining the complex concept of heel-toe downshifting to an audience that had a limited understanding of how manual transmissions work" and "The ability to explain something very technical to people from outside my major was very beneficiary [*sic*]. I had to understand the things I knew from a basic level to be able to explain it in an easier way. I think the connection I made with the technical concept and us as human being [*sic*] made it very interesting."

Students were also reflective when evaluating the elements of their lessons that needed improvement. Commonly acknowledged was the need for more planned interaction in their lessons (18%), "However, I definitely think that I could have made my presentation more interactive and engaging. I think for next time, I will try to incorporate several different activities

into the lesson instead of just one at the end." Similarly, "I think I could have had more specific instructions" or "I could also improve by providing relatable examples so that the audience can better understand the topic" indicated that students recognized that they needed to go more in-depth or explain their key concepts better (18%).

Many made mention that discussion and Q&A sessions were successful as assessments (17%), "I feel that I had a well thought out topic that connected well back to content of this class. The presentation that I prepared was engaging and easy to follow, with good conversation between students and teacher. I could have had a bit more enthusiasm while presenting. Overall, I felt the students learned something new through a fun activity" and to promote student interaction, such as "I did really well on getting everyone at my table involved in the presentation, with a lot of questions and a lot of conversation."

On the second YTU, these same topics were evident as shown in Figure 2. More attention was paid to elements such as the successful use of a hands-on activity (24%), "I think starting by an activity was a good thing to get their attention. Letting them do the experience to lead them to draw their conclusion from it seemed effective." The use of slides or other visual aids (18%) became more important after having been through the first YTU, "Learning from my presentation last time, I worked hard on the visual layout of my PowerPoint to make a more effective presentation with fewer words and more images. The included video was a great way to keep the attention of my peers." Students were also cognizant of peer interaction and engagement (15%) as shown by these student responses, "I believe I spoke well and was engaging to my peers who were listening," and "I think there was a good balance between lecturing and audience participation," and "I made sure everyone was involved in the activity and answered questions that they asked." Several students explicitly noted an improvement in their delivery from the first YTU.

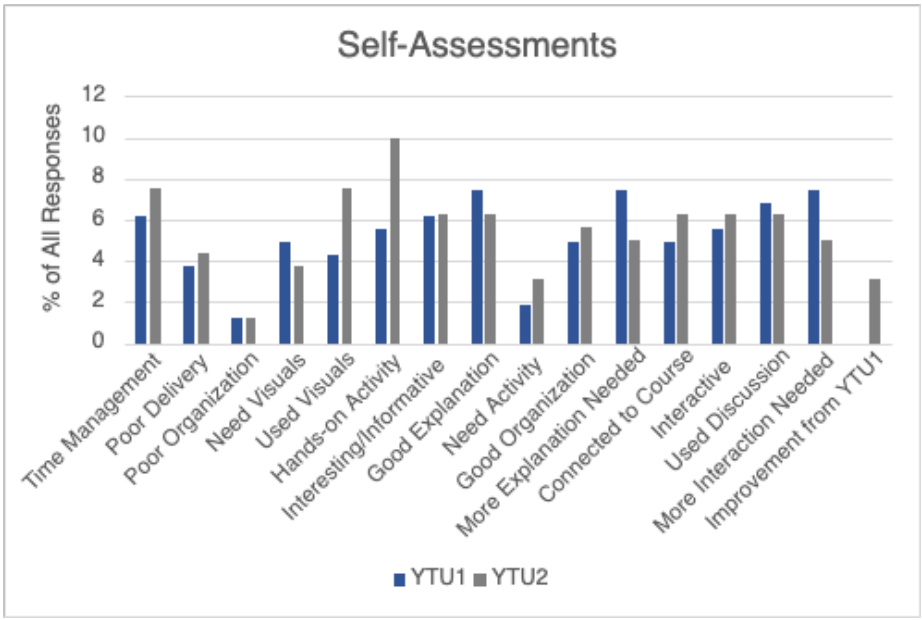

Figure 2. Common responses on self-assessments for each YTU.

Students' self-assessment scores are significantly lower than those given to them by the instructors, based off their submitted materials. The average score, out of 10 points, that students gave themselves on the first YTU was 8.74 (SD = 1.14) and 8.76 (SD = 1.09) on the second YTU. These scores are not significantly different across the two YTUs, as shown by a paired t-test $t(38) = 0.11$, $p = .716$.

Only one student across both YTU activities assessed themself as not having made an explicit enough connection to the course.

4.2 Peer-Assessment

Students evaluated 2-4 of their peers in each YTU. In the first, the most common codes given to peers were to acknowledge good explanations (9% of all codes), that the topic was interesting or informative (9%), "[Student's] lecture on Software Prototype is easy to understand. He perfectly explain [*sic*] the terminologies in the concept to be understood by people without background."

Like in the self-evaluations, a focus on peer interaction and the use of a hands-on activities (8%) and the use of slides or other visual aids to enhance the lesson were important to students. For instance, one peer review mentioned that "I liked how [Student] brought in a worksheet that we would be able to follow. The diagrams made it easy to follow what he was trying to teach us as well as see the transition from a linear to loop system. The activity we did afterwards was awesome, we got to think about a product that we'd be able to produce in a loop system."

Students were also able to see explicit connections to the topics of creativity and innovation in the second YTU. For instance, peer evaluations noted "I loved [Student's] lesson on making mood boards. She had really good examples! Her topic helped enhance my creativity and was also something I can use to help me with projects in the future" and "He did a great activity that promoted creativity."

In the second YTU, the most common codes identified in peer-assessments were similar to the first as shown in Figure 3. The average score given to peers was 8.94 (SD = 0.76) and 8.83 (SD = 1.04) on the second YTU. There is not a significant change in the average peer-assessment scores across the two YTUs as shown by a t-test, $t(37) = 0.37$, $p = .716$.

Across both YTU activities, just 3% of all peer evaluations, of which there were 2-4 for each student, or 300 in total in this study, made note that there was not a clear connection to the course topics.

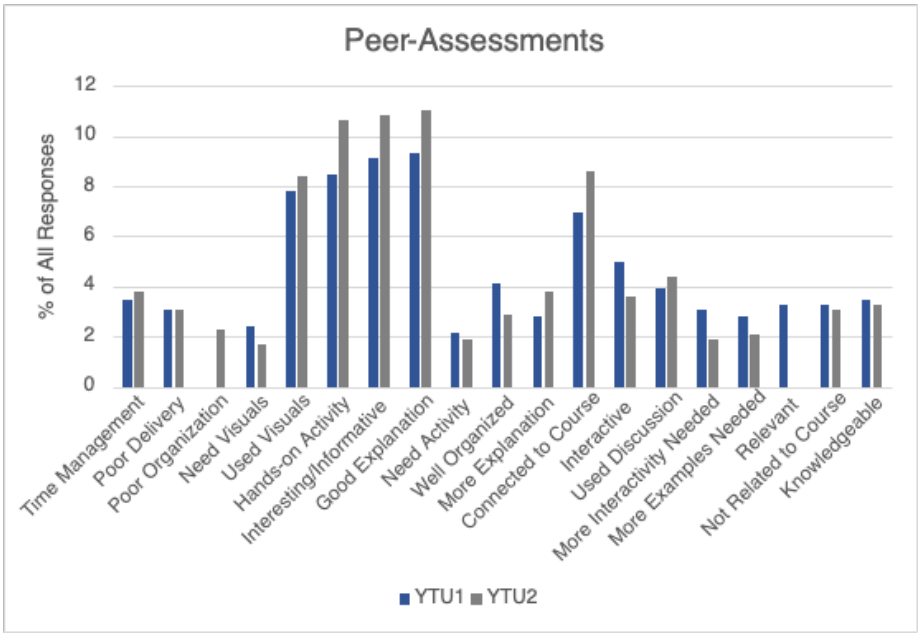

Figure 3. Common responses on peer-assessments for each YTU.

4.3 Comparison of Self- and Peer-Assessment Scores

Students did not significantly give themselves ($M = 8.67$, $SD = 1.22$) higher scores than their classmates ($M = 8.94$, $SD = 0.76$) in the first YTU as shown by a paired t-test, $t(44) = 1.76$, $p = .086$. The same was true for the second YTU, $t(43) = 0.33$, $p = .745$. Similarly, across both semesters of students, there was not a significant difference in the scores that students gave themselves and the scores they received from their peers, as shown by a paired t-test on the first YTU, $t(43) = 0.72$, $p = .473$, and on the second YTU, $t(40) = 0.69$, $p = .497$.

This can also be seen in the types of responses students wrote in their evaluations. For instance, one student noted that "I think I did a good job explaining how I am going to innovate the way we reuse carbon and limit its existence in the atmosphere. I did a good job providing scientific research as to how my product will work and why it works. I could have had a better lesson plan and had a better activity for my peers to work on." This student's peers echoed his assessment stating "[Student] did well in terms of speaking on a topic that is extremely relevant to today's environment. He was very informative and well-educated regarding his topic. He facilitated a great discussion as well. In terms of improvement, [Student] can provide more metaphorical examples of his topic next time" and "[Student] had a really cool idea about how to get rid of the mass CO_2 production that happens when the exhaust leaves our cars. He didn't have a visual but the discussion was enough for us to be well informed ... We were able to come up with our own ideas about to stop global warming."

5. Discussion

Unlike student presentations of instructor selected topics, a common teaching strategy in higher education, the core of YTU is to enhance students' creativity by removing boundaries or restrictions on topics so long as the student can justify its relationship to creativity, innovation, or vision. Further, unlike typical student presentations, YTU activities are enacted lesson plans that include an activity and a formative assessment, as well as ample opportunity for self-reflection and peer-assessment. It is this last piece that supports active engagement during peers' lessons.

As shown in the self- and peer-evaluations, students are reflective about their own teaching and that of their peers. While instructors evaluate submitted materials (e.g., lesson plans, slides) and brief observations of the lessons, students are tasked with completing more detailed assessments of their own, and their peers', lessons. As a result, students gave themselves and their peers scores substantially less than those given by the instructors. These scores and assessments are consistent in several ways. First, students do not grade their peers harsher than they grade themselves. Second, scores received by peers are not significantly different that self-evaluation scores. Third, while there were 35 different categories of codes identified in the peer assessments, there were recurring themes, as shown in Figure 3, present across both YTU activities. Taken together, this consistency suggests a level of engagement with their peers' lessons such that they were able to provide constructive feedback and fair assessments. Just 3% of peer evaluations made mention that of a lack of appropriate or explicit connection back to the course, suggesting that the vast majority of the students were able to justify their topic as advancing the course's objectives.

Because a primary objective of this assignment is to enhance student engagement, increase interaction, and give students the opportunity to explore a course-related topic that is of interest to them that would not otherwise be covered, its format can be used in a variety of disciplines and course topics. Students can utilize virtual breakout rooms and can present on instructor- or student-selected topics or prompts. Subsequently, this assignment could also be utilized at any point during a semester, including presentation of foundational material or areas of content application. Graduate-level courses could also benefit from this assignment structure as a means of having students practice academic teaching, particularly if content is derived from scholarly sources.

There is room for additional modifications, including having groups share summaries of their breakout sessions with the entire class or selecting specific activities to do with the class at large. Additionally, students could submit or create other deliverables, such as presentation slides or specific activity and assessment materials. Finally, it is important to note that the course in which this instructional technique was utilized in this paper is unique. In order to ensure the preservation of course learning objectives and the accuracy of the delivered content in a variety of academic contexts, lesson plans could be reviewed and then modified before student presentations.

6. Conclusion and Future Work

Historically, this creativity course has been offered in an in-person format in a classroom with tables and dry erase boards. This has provided a learning environment that supports student socialization, allowing them to become better acquainted with each other, a key component of a course that relies heavily upon collaboration for projects and activities. However, the wide-spread transition to virtual instruction for traditionally in-person courses in response to the COVID-19 pandemic brought many instructional questions and challenges surrounding the preservation of learning objectives and student engagement. It is worth noting that the peer teaching activity described in this paper continued to be assigned without modification even in the context of a synchronous, virtual classroom. In this format, students were assigned to breakout rooms within the course's virtual video conferencing platform and took turns sharing

their lessons. Anecdotally, students continued to produce lessons of high quality and have found interesting and novel methods of developing and administering activities and assessments with the knowledge that their peers have access to both a computer and the internet. Due to the ongoing discussion surrounding the future of course delivery on college campuses, the effectiveness of this peer teaching activity in a virtual, synchronous format is worth further exploration and formal study.

Peer teaching is an effective learner-centered pedagogical tool in the engineering classroom. The YTU activity positions the student as an actual teacher, requiring detailed lesson plans, learning objectives, and assessment mechanisms. Formal reflection through self- and peer-assessments promoted stronger engagement from the students and is a key component of the success of this active learning technique.

The structure of this activity supports student engagement and the advancement of the course's core mission of enhancing the engineering student's creativity. Instructors across multiple engineering disciplines could modify and utilize this active learning assignment within their own classrooms to similarly enhance student creativity and engagement.

Acknowledgement
The authors would like to thank Dr. Bruce Elliott-Litchfield for envisioning this creativity and innovation course, the instructional staff that has helped with development and teaching throughout the years, and the many students who have taken the course and aided in its continued refinement.

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