Enhanced Student Engagement through Teamwork, Gamification, and Diversity & Inclusion Best Practices in an Electromagnetics Course

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***Abstract*— In this Innovative Practice Full Paper we present an approach where we coupled several proven pedagogical practices to enhance student engagement during the time of remote/hybrid instruction due to the COVID-19 pandemic. One of these approaches was team-based learning throughout the entire semester which aided in student motivation. A second practice implemented was game-based learning to drive student engagement and excitement. This game-based learning approach used a semester-long scoring system which allowed students to compete for bonus points both on an individual and team basis. This enabled students to practice their teaming skills. Lastly, there was a major focus on diversity & inclusion in addition to teamwork in the course. Students were arranged into teams in an optimized manner by the CATME software. The optimization constraints were chosen using best practices for diversity in race & ethnicity, gender, skill levels, and leadership philosophy, while also considering students with similar schedules for availability purposes. The course also contained instructional modules on effective teamwork as well as contributions in the field of electrical engineering by underrepresented minorities. This paper details the innovative coupling of these practices and how they fit into the course's overall plan. Classroom activity and student perceptions associated with these practices were assessed via structured classroom observation using the COPUS protocol and collection of survey/focus group data, respectively. Assessment results are discussed, along with challenges encountered in this electromagnetics course in the hybrid/remote learning environment.**

Keywords—motivation, team-based learning, gamification, diversity inclusion

I. Introduction

Remote instruction has become the norm for many students over the last year due to the COVID-19 pandemic restrictions placed on faculty and students alike. During this time, there has been a significant drop in student motivation and engagement as discussed in the literature and apparent from recent studies.

In the end of term survey data collected from students in the spring, summer, and fall semesters of 2020, students reported that remote instruction was not only affecting their ability to learn, but it was also taking a toll on their mental health. Students reported that they would often find their minds wandering while sitting at home watching lectures delivered using Zoom or other educational technology platforms. The lack of human interaction that students experienced was usually the reason reported for some of the negative outcomes of the virtual learning experience.

Usually, we like to slowly integrate new practices into our pedagogical repertoire by first piloting them in some small section of a course and assessing their effectiveness. We will often make several tweaks before bringing these new practices to full use as a course staple. However, the instructor felt that students were in immediate need of an experience which leveraged modern 21st Century solutions and applied them to the course to enhance the remote learning experience.

While students may have been feeling isolation, which affects their ability to learn in a virtual environment, many of these same students have been connected to the rest of the world through gaming for several years now. There is roughly an average of two video gamers in each U.S. household and many of these gamers forge friendships that span the globe [1]. Video game manufacturers seem to be able to put out a product that not only engages people but does so to the point where it is addictive in a remote environment. Gaming has received criticism over the years but there are many who have proposed that gaming brings people together and keeps them connected as they learn together [2]. This sparked the idea that bringing a gamification aspect to the course could be exactly what students needed during remote instruction.

There are numerous studies that show effective teamwork can promote student motivation. Teams inherently are a way for us to feel connected to one another. In a team environment, not only do we feel connected through a common goal, but we also feel a sense of responsibility to our team members. In previous semesters of this course, students were put into teams for a final project. The team experience usually spanned the final three weeks of the course or so. However, we considered that a full semester team-based experience would be more impactful for the students and their motivation in a remote environment. This would give them a sense of belonging early in the semester which would carry on throughout.

Lastly, the year of 2020 was a whirlwind time for all. There were racial tensions and political turmoil throughout the United States. This had a significant impact on students, and students showed that they wanted change for the better [3]. We therefore wanted to bring diversity & inclusion to the forefront of this course to instill a sense of belonging for all.

In summary, in the spring semester of 2021, we attempted to bring the proven pedagogical methods of gamification, team-based learning, and teaching with diversity & inclusivity in mind together to motivate students and give them the best learning experience possible despite the downsides of remote instruction.

In this article we will discuss student motivation and how it was impacted by the COVID-19 pandemic. We will then discuss how we implemented a teaching solution based on gamification, team-based learning, and diversity & inclusion. We will follow that by our methods of data collection and results. Lastly, we will provide a thorough discussion of this experience and a plan for improvement going forward.

II. Literature on Student Motivation

Motivation has been extensively studied in the field of education and impacts learning by influencing the intensity, persistence, and quality of student behavior [4]. Educational psychologist Paul Pintrich identified coursework relevance, self-efficacy, perceived control over outcomes, interest, performance goals, and social goals as key motivating factors for students [5], [6].

Academic motivation has been a primary concern during the pandemic and promoting student motivation was likely a necessary instructional activity [7]. An ASEE survey distributed shortly after the start of remote instruction revealed that 61% of student respondents agreed it was difficult to remain engaged and motivated when studying from home [8]. In an NSF-funded study, all sophomore, junior, and senior engineering students at the authors' institution were asked to rate their motivation during the fall 2020 semester compared to before the switch to remote instruction [9]. Approximately 78% of the 929 student respondents said their motivation was less or much less compared to before this switch. When asked to indicate their top three reasons for the decreased motivation, students responded most-frequently with "remote, not-in-person coursework that was less engaging," which received 26.4% of the votes. Thus, decreased motivation was a widespread problem among this diverse group engineering students several months after the start of remote instruction. Likewise, at the very start of the crisis, a study of over 2,500 students at seven universities across the U.S. revealed that the most-frequently-experienced student change was a "lack of motivation and decreased productivity," as reported by over 21% of respondents in an open-ended question [10].

III. Pedagogical Methods

In this section we will detail the pedagogical methods used and how they were implemented in this course.

A. Team-Based Learning

Team-based learning was one of the core pillars for the class. We have been slowly gravitating towards using team-based instruction as a part of all courses to some degree but reported feelings of isolation due to the COVID-19 pandemic led to the decision to implement a semester long, team-based learning strategy for this course.

Students were formed into 11 teams consisting of four students each. The formulation of these teams was done using CATME. CATME, or the Comprehensive Assessment of Team Member Effectiveness, is a system of web-based tools that enable instructors to use best practices in managing student teams [11], [12]. CATME gives instructors the ability to weight certain categories to optimize the creation of teams. The categories used for team creation were time zone, gender, race, GPA, schedule availability, software skills (MATLAB), leadership role preference, and leadership structure preference.

Teamwork was first addressed in the course through a lecture presented on high functioning teams, which the students also received during their freshman year as part of a school-wide teamwork instructional initiative. The topics of this lecture were characteristics of high performing teams, addressing team conflict and social loafing, and establishing a team charter. After this lecture, students scheduled a start-up meeting where they would work on their team charter. Students were encouraged to reflect on the teamwork lecture while developing their charters. In addition, a team building event was also recommended.

The teamwork aspect of the course was left completely open ended, and autonomy was given to the students so that they could implement whatever structure they saw fit. They worked on homework, some quizzes, and the final project in teams. There was one submission per team for each team-based assessment.

B. Gamification Using Kahoot!

Gamification in courses has been shown to be an effective teaching tool [13]. In an effort to make the course both more enjoyable and more engaging, gamification was employed using Kahoot!. Kahoot! is a web-based software tool which allows for trivia-based gameplay in a live setting [14]. Users are given a numerical score for both correctness and quickness in responding. Initially, between two and three Kahoot! games were played per lecture, but this was reduced to just one Kahoot! game per lecture based on student feedback from a midterm survey. The one Kahoot! game was played at the beginning of class and the focus of the game was a review of the topics from the previous class session. Each game was focused on likely misconceptions and consisted of three to four multiple choice questions. This gave instant feedback because students would see the correct answer instantly after answering questions. This also gave the instructor and TA instant feedback on which concepts were misconceived. We used this initial feedback to add impromptu lecture material on concepts that a large majority of the class had answered incorrectly.

An example of a Kahoot! game is shown in Figure 1. In this game, students were given 20 seconds to answer a true or false question based on an open-source simulator output. This simulator allows users to simulate the electric field lines for several different charge distributions. Students were instructed to use the simulator in advance of this lecture. This question gave the instructor the chance gauge the depth of their understanding and correct any discovered misconceptions.

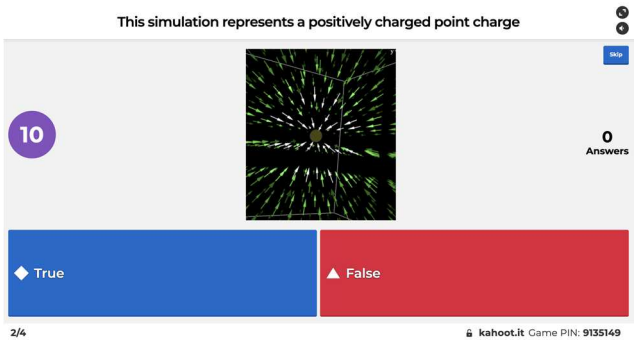

Figure 1: Kahoot! Game Showing True or False Question

The gamification of the course also enhanced the team-based-learning aspect as well. We developed a MATLAB

algorithm which created a running total of per-game Kahoot! scores for all the games students had attempted. Using these scores, we were able to keep track of a running total for each student. Two leaderboards were displayed on a Canvas Page each week. There was one leaderboard for the top 10 individual players and a second leaderboard for the top 5 teams. This allowed students to compete against other students at both an individual and team level. An example of the leaderboard is shown in the figure below.

Individual Leaders

Rank	Name	Team	Week Score
1	Student 1	Crawfords	6799
2	Student 2	Eagles	6150
3	Student 3	Giants	6001
4	Student 4	Eagles	5795
5	Student 5	Eagles	5778
6	Student 6	Wolves	5768
7	Student 7	Wolves	5447
8	Student 8	Giants	5280
9	Student 9	Stars	5234
10	Student 10	Keystones	4797

Team Leaders

Week 3 Leaderboard

Team Rank	Team Number	Team Name	Week Score
1	6	Stars	19251
2	4	Crawfords	17891
3	7	Eagles	17020
4	11	Wolves	15337
5	3	Giants	15168

Figure 2: Leaderboard Showing Individual and Team Leaders

Students were rewarded for their performance in the Kahoot! game. When the semester ended each student was assigned bonus points for their individual performance. The maximum bonus points of 1.5% toward the final grade was awarded to the top performer and the bottom performer received 1.5% divided by the total number of students. Students in between received points in equal increments of 1.5% divided by the total number of students up to the 1.5% maximum. Students were also awarded for their team performance. All members of the top performing team received 1.5% toward their final grade and the bottom performing team received 1.5% divided by the total number of teams. Again, the teams in between were assigned between the minimum and maximum based on their ranking. Lastly, students received between 0% and 2% based on participation. Students who participated in every game received the maximum of 2% toward their final grade, and points were subtracted in equal amounts for each game missed. In total students were playing for a potential 5% bonus added to the final grade. This related the game experience to achieving a better final course grade. In turn this potentially improves student motivation through relatedness, which is the concept of connecting what is being done in the classroom to something which will benefit students beyond the respective course. This has been shown to be effective through research [15].

C. Diversity & Inclusive Teaching

There was a specific focus on teaching that valued diversity & inclusion to enhance student motivation through a sense of belonging. This included diversity & inclusion with respect to both the students themselves as well as accomplished professional engineers throughout history. The teams that were created using CATME were formed with diversity in mind, which has been shown to be an effective method of team making [16]. These teams were set up to not isolate (where possible) students based on their race or gender. Diversity of skillset was also addressed using CATME. There were CATME team making questions which included students' GPAs and their ability to use software (MATLAB in particular). Using these questions, CATME grouped students with dissimilar scores on both GPA and software skills to make well-rounded teams.

In addition, we added a component to the course which celebrated the electromagnetic engineering achievements from underrepresented groups. For example, during Black History Month, we presented the contributions of Granville Woods, who was often referred to as the "Black Edison" [17]. Granville Woods was an African American electrical and mechanical engineer whose work in electric powered transit systems was years ahead of its time [18].

IV. Results: Classroom Observation and Focus Group

A. Methods

The COPUS observation protocol was used by the second author to observe two class sessions in the remote environment [19]. The COPUS, or Classroom Observation Protocol for Undergraduate STEM, is often used to assess active learning and interaction during class, both of which were important for promoting student engagement and motivation in the remote instructional environment. The first observation session was conducted in-person in the classroom, and the second observation session was done asynchronously via a Panopto video. With the COPUS, the total class period is divided into a series of two-minute observation segments. The observed activities of the students and instructor were recorded for each two-minute segment. The second author has extensively used the COPUS protocol as part of previous research and evaluation activities and achieved inter-rater reliability scores of $\kappa = 0.83$ and $\kappa = 0.96$ with other analysts, which indicated reliability via strong agreement with other analysts [20].

To gather more in-depth data on engagement, learning, remote-environment challenges, and teamwork in the course, a Zoom-based focus group was conducted by the second author, in which 10 students volunteered to participate during class time.

B. Results

For the two class sessions, a total of 82 two-minute segments were observed, for a total observation time of 164 minutes, or approximately 2 hours and 45 minutes. Table 1 provides the percentage of these segments in which various teaching and learning activities associated with the COPUS protocol were observed to have occur. As shown in Table 1, Kahoot! clicker questions were posed (CQ) by the instructor during 11%, or 9, of the two-minute observation segments. Likewise, each student actively worked on (Ind) the clicker questions during 13% of the observation segments. The students revealed during the focus group that these questions were engaging, motivating, fun, and informative about key concepts and provided a break from continuous online lecture, which was a primary instructional goal at the time.

Key to student learning, the instructor provided immediate feedback on the clicker activities (FUp), which occurred during 21% of the two-minute segments. Students also asked questions (SQ) during 12% of the segments and responded to the instructor's verbal questions (AnQ) during 6% of the segments, using either the Zoom chat window or an audio response. Thus, although lecture (Lec) with real-time writing (RtW) was the predominant instructional approach, student active learning and interactivity with the instructor occurred.

TABLE 1. COPUS PERCENTAGES

Student Actions			Instructor Actions		
L	Listen & take notes	99%	Lec	Lecture	74%
Ind	Individual thinking/ problem solving	13%	Rt W	Real-time writing w/ e-pen	62%
An Q	Answer question	6%	FUp	Follow-up/feedback on student activity	21%
SQ	Ask question	12%	PQ	Pose question verbally	9%
			CQ	Pose clicker question	11%
			An Q	Answer question	15%
			D/V	Show demo/video	6%
			Adm	Administrative	11%

V. RESULTS: INDIRECT ASSESSMENTS VIA SURVEYS

The course overall was seen as a tremendous success. The primary instructor (i.e., first author) experienced a dip in course evaluation scores from about 4.6 out of 5.0 to about 4.3 out of 5.0 throughout the period in which COVID-19 restrictions forced instruction into either a fully remote or a hybrid remote setting. However, with these newly implemented methods, the course evaluation was back to a 4.51 out of 5.0 with n=37, which was on par with pre-COVID-19 restrictions. With a few modifications based on lessons learned we believe that this will achieve a 4.6 or greater.

A. Indirect Assessment from Course Evaluation Survey

The course evaluation survey was used to indirectly assess some of the outcomes for the course. This survey was used to assess the degree of overall teaching effectiveness for the course, the degree to which students felt comfortable participating, the level of difficulty caused by remote instruction, and the degree to which in the instructor created an inclusive environment for students.

As was previously stated, the overall teaching effectiveness was rated at a 4.51 out of 5.0. This was much higher than the instructor's average during previous semesters of the COVID-19 pandemic. For this rating 26 out of the 37 respondents rated the overall teaching effectiveness as excellent (i.e., score of 5), 4 of 37 rated this as very good (score of 4), 7 out of 37 rated this as competent (score of 3), and 0 of 37 rated the effectiveness as fair or ineffective. This data point is worth noting because other than these new pedagogical implementations, the course remained nearly identical to previous offerings.

We also indirectly assessed the degree at which students felt comfortable participating in the course. Over 90% of the students either strongly agreed (17 of 37) or agreed (18 of 37) they were comfortable participating, while only around 5% (2 of 37) neither agreed nor disagreed. These data points were encouraging because they were very similar to pre-COVID-19 ratings. This means that students were at least as comfortable participating in the course despite the hybrid remote learning environment.

The level of difficulty that students had due to the remote instruction aspect of the course was one of the most interesting points taken from the course evaluation survey. For this question, the students were able to rate difficulty from 1 – much more difficult to 5 – much easier. Just under half of the students (16 out of 37) rated the course at a 3 – a mix of easier and more difficult, while 11 out of 37 rated it as more difficult, 7 rated it as easier, and 1 of 37 rated it N/A - no difference. We read through the student comments related to this question to gain more insight. Students pointed to the benefit of the Kahoot! game and recorded video lectures as what made learning easier in this environment. Some students pointed to motivation as being an issue, but many did add that that this course promoted motivation. One of the comments that stood out regarding motivation and difficulty due to remote learning was the following:

"As with most remote classes, the motivation to go to class and do the work is less. Although this class was the best remote course I have taken thus far."

Another indirect assessment result from the course evaluation survey that we examined was that related to diversity & inclusion. The students were asked to rate the degree at which the instructor created an inclusive learning environment for all students. The ratings range from 0 – strongly disagree to 5 – strongly agree. The mean rating for these questions was 4.68 out of 5.0. The vast majority strongly agreed (24 out of 37) or agreed (9 out of 37), while only 1 response was neutral. There were no students who provided a negative rating for this question.

In addition, there were many comments in this survey which supported the idea that the gamification aspect of the course was beneficial and served as a great motivator. Over half of the comments referenced the gamification of the course using Kahoot! as something they would like to let their instructor know was helpful. Many of these comments also directly referenced Kahoot! when it came to student motivation as is stated in the following student comment:

"*The kahoots were a really nice addition to the course and I hope to see them in other courses because it incentivizes me to stay engaged and on track to understand each lecture. It is always a great gauge of how well I know the content before each midterm*"

It should be noted that there was one negative comment regarding the Kahoot! games. One of the students added while the effort to add Kahoot! was admirable, the timed aspect of the Kahoot! games added stress and anxiety to an already stressful situation. This one comment was an outlier though and there was no pattern to support this. However, this still may be an area address in the future.

B. Indirect Assessment from CATME Peer Assessment Survey

We also used the CATME peer assessment instrument for indirect assessment. Students worked in teams throughout the semester on both homework and projects, and a portion of the assessment of teamwork was done using this tool. For the peer assessment survey, the instructor let students know that anonymous comments could be provided to the instructor directly.

Many students pointed to the benefit of working with a team throughout the semester. Students stated that they felt a sense of responsibility and accountability to their teams, which drove them to stay committed throughout the entire semester. One comment that resonated with us was the following:

"The group aspect of the class made it less stressful to complete assignments and gave me more motivation to complete them on time."

This statement supports the concept that working in teams throughout an entire semester on both homework and projects, as opposed to just projects, may help with student motivation.

VI. Discussion

When we first conceptualized the idea to quickly enhance the course, we had no idea as to whether it would be successful or not. This enhancement was done out of necessity to aid the many students who were feeling the negative effects that the COVID-19 pandemic brought to their educational experience. These techniques alone are not novel but combining them for the specific purpose of increasing student engagement and motivation for remote and hybrid instruction may be an innovative practice. At a minimum, we conclude that the effort was successful, although there were certainly many lessons learned from this experience.

One of the main takeaways was that formally establishing teamwork early and often promoted motivation. Students felt a sense of obligation to their teams to participate in homework, to do well in Kahoot! games, and to be there when their team members needed them from the start of the course until the end of the course. This benefited the students both in the short-term with student motivation and in the long term with the team-based approach that they will inevitably experience in industry or graduate school.

The gamification aspect of the course made the course enjoyable and promoted motivation. It is certainly something that we will add to the course for future offerings. It would be interesting for us to investigate whether adding this gamification aspect to a fully in-person experience would be similarly effective. We adjusted the Kahoot! games from multiple games per lecture to just one game based on student feedback from the midterm survey. This adjustment was met positively by the students while minimizing technical difficulties, as relayed by students during the focus group.

Kahoot! worked well for a first attempt at gamification. It was straight forward and easy to use. However, we had to develop our own algorithm to export the Kahoot! data and populate a running semester-long leaderboard. Ideally, a gamification application which allows for a running total of points and integration into common learning management systems would be desired. We plan to continue to explore options for the best possible gamification solution.

Celebrating diversity & inclusion in the class also made for a very positive experience for both the students and instructor. In our initial literature review on engineers from underrepresented groups who've contributed to electromagnetics, we learned a great deal and plan to continue to investigate the works of these great engineers and add further to the course.

There is certainly room for improvement with respect to diversity & inclusion relative to student teamwork. We did our best via CATME to create teams which were diverse and inclusive. Two students pointed to the need for a "nontraditional student" question on the CATME team making survey. This made us consider other questions to increase diversity & inclusion, such as veteran status, as many students who identify as veterans would be considered nontraditional students. We plan to investigate other ways of expanding the data set we use for team creation to strengthen our efforts to create a diverse and inclusive environment. In addition, one student expressed anxiety and stress about the Kahoot! quiz games. By no means did we intend for this to be stressful, and perhaps increased communication early in the semester would alleviate this stress. It is important that we strive to be as inclusive in our approach as possible.

VII. Conclusion

Combining team-based learning, gamification, and teaching with diversity and inclusion in mind was used to promote teaching effectiveness and increased student motivation. This strategy may benefit many instructors who would like to add a new and lively component to their courses to improve their results. In implementing such a strategy, several moving parts must be considered. A team formation tool is required to make effective teams with diversity and inclusion in mind. In addition, a game-based learning platform is needed to carry out the gamification aspect of the course. The game-based software used for this study was adequate, but there were a few drawbacks regarding a semester long game experience and ongoing data collection. It would be ideal for this pedagogical approach to scale to a wide range of instructors around the world. One way to do this would be to develop algorithms that integrate the teams formed into the game-based software tool. This could be done by developing a central hub which acts as an interface between the team forming software, the game-based software, and common learning management systems. If the coupling of the required technology could be mostly automated to carry out the pedagogical methods described in this article, we believe that the combination of these techniques could scale to a wider audience.

Lastly, we would like to study the effectiveness of the combination on student motivation in traditional, in-person course offerings. If there are also promising improvements in student motivation in the in-person course offerings, this combination of team-based learning, gamification, and diversity/inclusion may improve overall teaching effectiveness.

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