Academic Games as a Form of Increasing Student Engagement in Remote Teaching

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CHALLENGE STATEMENT

The COVID-19 pandemic has affected all segments of the educational systems dramatically, with the distinctive rise of online learning, whereby teaching is undertaken remotely and on online platforms without an in-person component. Students in remote classes have fewer opportunities to be engaged with their classmates and instructor. Hence, it is crucial to create multiple opportunities for student engagement in the online environment.

Engagement in online courses is very important to student learning and has been previously explored in remote and online instruction literature; see Refs. 2,21,25,29 and references therein. According to Newmann et al. the student engagement is defined as the student's psychological investment and effort directed toward understanding and mastering the knowledge, skills, or crafts that academic work is intended to promote.¹⁷ Student engagement increases student satisfaction, enhances student motivation to learn, reduces the sense of isolation, and improves student performance in online courses.¹¹ Since remote education has become necessary to slow the spread of COVID-19, instructors need to find new strategies and adjust their teaching approach to incorporate academic engagement opportunities. A great way to start is by thinking about how to make classes as flexible, engaging, and successful as possible, in whatever modality they may be taught. In particular, instructors shall plan for including activities to help students feel more strongly connected with each other and with the

instructor, and to involve students in their own learning,³¹ see Fig. 1.

This paper presents some planned efforts for increasing student engagement in an online university classroom using academic games. In particular, the manuscript provides some examples and detailed instruction in which games can be used for more engaging course delivery, which can create a more effective learning community among students. The motivation is to spark a discussion on adding academic games to remote teaching of biomedical engineering (BME) courses.

NOVEL INITIATIVE

This section proposes the methods to include games in remote teaching of a university course in a biomedical engineering program using an online learning tool. Pedagogy and active-collaborative approaches to learning through games is the heart of this approach. In fact, the use of games in education must be driven by the pedagogic goals and needs of the learners, rather than by the game itself.³⁰ During the spread of COVID-19, the student's engagement in the classroom may have been negatively impacted due to fewer opportunities to engage with peers, and incorporating gaming is a powerful way to reduce some learning anxiety while promoting their motivation to learn.^{26,27} Our goal is to improve general engagement. We provide a description of how to incorporate academic games as a method to promote student engagement in remote learning, with a detailed plan for using a game in a BME online classroom. Engagement is measured as interest in the activity and subject matter.²⁴ We would like to highlight that most previ-

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ous studies do not address engagement in a remote learning environment. Moreover, although gamification is a popular educational strategy, it has not been widely explored or adopted in BME.

It is important to first demonstrate how academic games can improve students' attentiveness. A survey-based study in Ref. 20 examined various engagement strategies used in online courses according to Moore's interaction framework which is based on the learner-to-learner, learner-to-instructor, and learner-to-content engagement strategies. Moore's framework is modified by Anderson¹ to include learner-to-learner interaction which is one of the most important components (Fig. 1). This strategy promotes student-student interaction and helps break the social isolation of distance learning.¹⁸ Icebreaker activities, introduction discussions and working collaboratively using online communication tools were rated the most beneficial engagement strategies in the learner-to-learner category.²⁰

In this context, games can improve all three types of engagement strategies. When designed correctly, academic games have been found to increase engagement and participation among students.^{5,7,10} The positive impact of games in an online context on the promotion of academic dissemination has been demonstrated in Ref. 16, and the purpose of increasing engagement and motivation is achieved. The psychology behind using academic games and implementation details for a computer science course is provided in Ref. 22 and a statistically significant improvement in student performance is found. Moreover, the study in Ref. 4 intended to reveal the effect of gamified instructional process to student engagement and the relationship between engagement and academic performances in a real classroom. Some other literatures integrate the lecture delivery using games with social media to enhance student's engagement, in particular with Twitter²⁹ and Facebook⁸ which resulted in relative success.

There are a variety of ways to introduce the classroom to the academic games and a few ideas are provided in Table 1. These games require little to no equipment and can be played in small groups or individually on services such as Zoom or other video communications. They can also be used as a part of homework to encourage informal learning. In general, these game activities can be placed into different categories: Puzzles are designed such that missing information must be identified and used in a strategic way to solve a concept. In Guessing games, a single answer or concept must be identified, and trivia games require the student to answer specific content questions.¹⁹

Several key elements must be present in an academic game³; and these six elements to sequence the activity are depicted in Fig. 2. More precisely, the games start

with the instructor establishing a well-defined learning objective. This goal addresses what the students need to learn by engaging in the gaming process. The second and third steps involve the design of the activity. Instructors can record themselves and post a video to deliver a message to the class about the planned game and its goal. Part of preparation also includes creating appropriate tools to play the game such as hand-out and virtual materials required for the game (third element). Instructions for the use of breakout rooms or uploading instructions about the tools into Blackboard Learn management system ahead of time are helpful. The key for implementing the games into a BME environment is in the "preparation" stage to involve BME content. Table 1 shows how games can be adapted for a BME classroom.

The fourth phase in Fig. 2 involves the ways the game is initiated, and the activity unfolds. It is valuable to use a synchronous meeting tool to connect with students in real-time and allow them to see their fellow classmates all together. Active student participation in the breakout rooms and revealing oneself on camera in small groups should be promoted to enhance remote teaching experience. While students are playing the game, it is helpful to observe students' performance and intervene when necessary to ensure the students are playing the game in the desired manner (phase 5 in Fig. 2). If students are working in groups, the instructor should visit all the breakout rooms to promote students' interactions and orient the students toward the solutions as needed. Finally, the class reunites to discuss the activity. One or more representatives from each breakout room will share their group's activities by verbalizing the findings or by annotating on the whiteboard feature in Zoom. Instructors can also have each group send their answer in the Zoom chat at the same time. The sixth phase in Fig. 2 is the assessment. Quantitative data can also be collected from pre-, mid-, and post-surveys. Games can be built on methods of assessments through the scoring system. Part of students' letter grades can be determined by the amount of points they have accumulated at the end of the course, in other words, by how much they have accomplished. Alternatively, instructors can implement a class-wide reward system where students achieve something as a team. That way, students are working to master the material together instead of competing, and the highest-achieving students will help those around them.

In this paper, an example for Bingo game is provided to illustrate the detailed implementation process of an academic game activity (Fig. 3). The plan is to incorporate this activity in a third-year level biomedical engineering core course. The course teaches cardiovascular biofluids which discusses mass, energy,

and momentum conservation principles in biological systems, and is an introduction to identify various flow characteristics and apply them to biology and medicine. However, the idea of choosing a list of keywords obtained from vocabulary, formulas, and important concepts, can be used in any course or subject matter. For this cardiovascular biofluids course, the instructor utilizes Zoom and Blackboard to communicate with students during synchronous remote class. The objective for students is to practice cardiovascular mechanics concepts using a custom Bingo game that revolves around the course subject.

The instructor chooses the keywords appropriate to the course topic and uses an online Bingo card generator, such as myfreeBingocards.com, to create the cards and put them in a shared folder. Students access the Bingo cards in one of two ways: in an online link from the instructor after creation with the card generator or in a downloadable PDF that any device can open. The draw or insert shape tools in general text editing software can both be utilized to virtually mark keywords on the PDF Bingo cards. To play Bingo in a virtual format, the instructor asks each student to select a random Bingo card to play. Bingo cards can be used for any content area to reinforce definitions. A picture can also be used instead of the keyword to create the cards; for example, photograph of a particular situation such as the viscosity of a biofluid, or the static pressure in a hospital blood pressure machine. The instructor then specifies the manner in which students mark the keywords on their Bingo cards. Three possibilities are listed here, but creativity in the game play is most easily implemented in this step. For traditional Bingo game play, a free online Bingo Game Manager paired with the card generator selects a random keyword from the list input by the instructor. Students mark this keyword on their card and the instructor provides a description or example problem of the keyword for conceptual review. However, the instructor does not have control over the order of keywords reviewed. A second method involves solving problems while students cross off keywords as they notice definitions, formulas, or concepts applied in the problem. To clarify for students, instructors write a list of the marked keywords after problems are solved or concepts are discussed. Lastly in a more challenging game, instructors show a formula or say a definition of a keyword. Students mark the keyword they think matches the description given by the instructor. Instructors review the keywords and their descriptions after a student has five concepts marked in a straight line indicating “Bingo.” This method requires students to have a strong previous understanding of the material because there is less explicit keyword guidance from the instructor.

All students enrolled in the course (38 students) were invited to participate in the game activity during the class session; 35 completed the game activity during the class and responded to the post-survey questions (92% of the total class enrollment). The results indicate that students responded positively to the game and were motivated to play it. In this study, to foster authentic student motivation, participation was voluntary, and we did not offer any reward to evaluate if students have intrinsic motives for participating in the game. While the use of rewards in educational systems is controversial,¹⁵ it can increase motivation for active participation by offering an incentive in a normally apathetic virtual classroom. For instance, if students fill their entire Bingo card and all keywords are reviewed, the instructor can offer a bonus question or bonus points on an upcoming assignment.

EVALUATION AND REFLECTION

Class engagement can fall into three categories: emotional, behavioral, and cognitive.⁶ Our goals in playing the Bingo game were to increase engagement in the virtual classroom, within the biofluid mechanics' course. Engagement is evaluated as interest in the game activity²⁴ and by collecting the student feedback in an anonymous survey.²² We distributed the survey after playing Bingo to determine if students felt more engaged and attentive in the class while participating in the game. We asked students to rank their perception of engagement with the Likert Scale, where 1 represents “strongly disagree” and 5 represents “strongly agree”. The statements students were asked to rank, and the results of the survey are presented in Fig. 4.

While emotional aspects of engagement are extremely difficult to intuitively observe in a virtual setting, 89% of students agreed or strongly agreed that they had fun while playing Bingo. Also, 72% of students felt that the game instructions were easy to fol-

FIGURE 1. Modes of interaction for a meaningful and engaged learning in distance education.

FIGURE 2. Steps to implement an academic game in the online environment.

FIGURE 3. Diagram of the Bingo game outline and workflow process.

low and did not distract from course material. Moreover, behavioral engagement encompasses energetic actions such as active class participation in discussion, asking questions, and socialization among students, all of which are crucial to academic achievement.⁶ If students did have a question about reviewing the course material, they felt comfortable enough to unmute and ask or type their questions in the chat feature on zoom. In addition to this contribution, 68% of students said

they were more likely to ask questions and participate when a game is played during remote class. Finally, measures of cognitive engagement involve demonstration of comprehension of material, such as when students successfully understand and follow instructions or correctly answer a question.⁶ Although we have not measured the cognitive aspect directly in our survey due to logistical and ethical concerns, 94% of students either agreed or strongly agreed that the game simu-

FIGURE 4. Results of the survey representing the percentage of students participating in the game and responding in each category to the statements.

lated their thinking and helped them to focus on the concept. Because of these agreeable survey results in different categories of engagement, we can conclude that gamification in remote environments increased engagement.

Based on our experience, an academic game can be used to improve memory of terms and facts, review of relevant course concepts, or preparation for in-lecture discussion. This method can be incorporated when the instructor plans to break the routine of teaching and making teaching fun. It is also an opportunity for the instructor to evaluate their pedagogy and teaching strategy while they are designing the game. Gamification in the remote environment seems more complicated than an in-person environment. The main difference for both instructors and students alike is that remote learning environments lack emotional and social aspects. Students often absorb energy from the social aspect of school, and their reactions likewise respond more energetically to learning. One vital challenge we encountered was finding materials for the game that can be easily distributed virtually. Through our exploration of this issue, we realized that the materials and opportunities for games in a virtual format are not as available as those for in-person education. For example, it is very easy for an instructor to design his or her own Bingo cards in a text editing software and physically distribute them to the class. However, making the Bingo cards virtually interactive, where students can mark the cards on their devices, proved to be much more difficult. Sometimes monetary payment is required to complete this task or

obtain enough Bingo cards for the entire class, which may not be feasible for some instructors. The next challenge we experienced was choosing whether to have a reward system, and if so, deciding what reward should be offered. Our goal was to motivate students to learn and be more engaged in a virtual format, but we had to avoid students only being motivated and engaged when playing the game and having the reward. We had to carefully design the mechanics of the game with an incentive to inspire students while not discouraging learning when the incentive and game are removed. This decision also ties into our desire to ensure that the course material was still credible and grasped seriously by students during gamification. Analysis of the benefits of the incentive was not completed and would be a suitable option for further investigation of remote gamification in pedagogy. The reward must be designed to promote intrinsic motivation (see Ref. 15 for some ideas) and completion of mastery-oriented goals.²⁸ This positive correlation boosts engagement and social interactions^{15,23} which can depreciate through purely online learning. By rewarding students for reviewing crucial material, they feel a sense of accomplishment and mastery. This increases student motivation to partake in the game and will consequently aid in their collective engagement.

In the future, success of the game approach will be measured using course marks, lecturer evaluations, lecture attendance, and student's feedback. Student feedback will be obtained using reflection assignments, course surveys, and individual meetings with students.

TABLE 1. Example of different games in BME related topics.

Game idea	Description	Example
Pictionary	Instructors present a picture and students explain the meaning and application of the picture	<p>In biofluids, students would name this picture as laminar flow that corresponds to the fluid flow behavior in arteries</p>
WebQuest	Students follow steps and incorporate information solely from online sources to gain new knowledge and accomplish a goal	<p>For instance, students can follow a step-by-step online tutorial demonstrating how to design a model of blood flow in a vessel</p>
Puzzles	Instructors create word searches, crossword puzzles, or jigsaw puzzles to review vocabulary	<p>Instructors first make a keyword list relating to thermodynamics concepts, such as heat, work, conservation of energy, reaction rates, <i>etc.</i> Those keywords can then be incorporated into a word search or crossword puzzle with the definitions of the concepts as clues to help students identify the keywords. After all concepts are reviewed, students will have a completed puzzle</p>
Trivia	Students form teams and instructors make questions relating to course material and vocabulary. Teams take turns answering questions to earn points	<p>Instructors can follow online tutorials to make a Jeopardy board. In a biomaterials class, the categories could be different types of materials, such as metals, polymers, ceramics, natural, implantable devices, <i>etc.</i> Questions are created about the materials in each category with the harder questions worth more money</p>
Role play	A game in which students take on non-traditional student roles to accomplish tasks or learn abstract concepts	<p>Students are assigned roles within a group project to design a medical device. Examples of roles can include team lead, risk management chair, FDA agent, and prototyping lead to understand how teamwork is used to create medical devices in the industry of biotechnology</p>
Picture/experiment of the day	Instructors perform a demonstration or show a video of an experiment relating to course concepts	<p>Instructor shows a video of how honey has a higher viscosity than blood. The students will search for another picture related to the same subject</p>

TABLE 1. continued.

Game idea	Description	Example
Top 10-list of concepts	Students complete an assignment to rank the concepts they have learned in the course based on a variety of factors such as most interesting or most difficult to learn	<p>In human anatomy and physiology, students could rank the systems of the human body based on their enjoyment and interest while learning them. Submitting the assignment could be done in the form of a discussion forum or blog to encourage student interaction</p>
The 1-min paper	Instructors assign a paper to read for homework. During the next class period, students explain the paper and its application of course material in 1 min	Papers can be selected for a variety of biomedical courses. Examples include mathematical modeling of biological processes, new imaging techniques, or a computational fluid dynamics research project evaluating blood flow with a stent

Some other evaluation methods to assess the effectiveness of game activities proposed in Ref. 13 including an engagement scale and activity evaluation rubrics. More questions for blinded surveys are proposed in Fig. 3 to cover key aspects of the remote game involving engagement and understanding of the material. We would like to mention that in this study we only asked four questions to increase the participation in the survey as students are unlikely to respond to long surveys, however, our assessment would be strengthened by incorporating established engagement scales and measures.^{12,14} The engagement-disengagement scale in Ref. 14 includes 39 agree/disagree statements which multiple questions are considered to evaluate each aspects of student's motivation and engagement styles, such as emotional, cognitive, and behavioral. Another comprehensive scale provided in Ref. 12 includes 59 statements focused on student engagement in higher education and the connection to their learning. We will take these established measurement tools into consideration to design questionnaire items in our future surveys, to ensure that gamification meets course outcomes and enhances student engagement. However, further analysis tools must be balanced against the costs, both monetary and time, required to successfully implement the game activity. The extent of student participation and effectiveness of motivators and rewards can also be gauged by direct observation and student feedback. This information helps to re-tune game components for future implementations.

This paper does not propose that games can be used for everything; there are some situations where games might offer no useful elements at all (see Ref. 9 for details on controversy). For example, game can make the concepts seem less serious to students and the implementation must be carefully selected to target intrinsic motivation. Moreover, integration with the curriculum is a key challenge. It might be difficult at times for the instructor to match the game with instructional goals and a poor fit will hamper learning.³⁰ Games tend to be time consuming and often require a great amount of time to create and implement. Academic games can also require special materials or facilities to which faculty may not have access. Finally, motivation is both a driver and challenge for the use of games and learning. While some students share an interest in games, not everybody plays games or would find a game within their course a wholesome element. Moreover, relying on games for course assessment and student performance without an understanding of course objectives can be detrimental to intrinsic motivation. Games cannot be used to replace pedagogy but can be integrated into the course delivery to enhance the overall learning experience.

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DECLARATIONS

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

ETHICS APPROVAL

Not applicable.

AUTHORS CONTRIBUTIONS

RZ conceived the idea and was responsible for the course instruction that had to transition to remote learning. ND contributed to the design and implementation of the post-survey assessment and analyzed the results. Both authors drafted the manuscript and prepared the figures.

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DATA AVAILABILITY

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