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From Bored Games to Board Games: Student-Driven Game Design in the Virtual Classroom†

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Classroom assessments needed to be rapidly modified at the start of the COVID-19 pandemic, as instruction transitioned from an in-person to virtual format. Yet, a significant obstacle among instructors during this time was developing online assessments that were useful, engaging, and accessible for students. We implemented a game design project in our introductory ecology course in spring 2020, in which students were required to develop a novel game based on ecology topics discussed in class. The learning objectives of this assignment asked students to (i) design a game for their peers based on an important ecological topic or concept from a specific unit or lesson in a creative manner; (ii) encourage critical thinking and discussion of ecological topics and concepts in the game; and (iii) judge their peers on the quality and enjoyment of their games. We found that while students developed various game formats and focused on different unit learning objectives, including nutrient cycling, climate change, and community dynamics, instructor and peer review indicated that the games created for this assignment were both conducive to learning and highly accessible. We suggest that a student-developed instructional games project is an effective way to engage students in an assessment that is enjoyable, collaborative, and requires creative application of the course content, in many possible biology courses and in-person and online learning environments.

INTRODUCTION

When the COVID-19 pandemic upended in-class instruction across higher education in spring 2020, assessments needed to be quickly modified for the virtual classroom. With the unexpectedness of this shift from in-person to online, a significant challenge that many instructors faced was how to develop engaging and effective assessments for students while being cognizant of accessibility. How do we encourage creativity and collaboration among students while simultaneously providing a means for students to review, apply, and synthesize course-specific material?

Game play and gamification are commonly employed across education levels to support student learning (1–3). Reports of gamified learning, primarily in computing fields, have grown rapidly since its conception roughly a decade ago (4). While gamification uses "game design elements, game mechanics, and game thinking in nongame activities to motivate participants" (5), game-based learning encourages students to engage in playing a game to increase enjoyment of the learning process (6). Both approaches can promote cooperative behaviors, enjoyment of a topic, increased retention and performance, and self-efficacy among players (3, 4, 7). Gamification has been broadly reported in college biology curricula (8–13) and often incorporates technology-enhanced elements (e.g., computer simulations, clickers, adaptive online homework). Likewise, serious games (i.e., games with goals beyond entertainment) are prolific in the biology higher education literature. Since 2013, in the *Journal of Microbiology & Biology Education* alone, 24 articles report on game-based learning activities, spanning from improvisation games (14), board games (15, 16), physical matching (e.g., Twister) (17), and competitive drawing games (18, 19). Examples of instructor-developed games to improve learning in higher education biology classrooms are not lacking. However, most of the educational games described in these articles require in-person interaction or shared game materials, both of which were not possible in the sudden transition to all online learning in spring 2020. While online game activities certainly exist (e.g., instructional video games) (20, 21), most are developed for particular content and cannot be adapted to different curricula. During this rapid transition, we were seeking a creative alternative to

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classic exams to make a now socially distant course more interactive, engaging, and collaborative.

Through a constructionist lens (22), we hoped to use assessments to both measure performance and engender deep learning. Learning-by-design meshes cognitive theories of reasoning and problem-based learning so that students learn through achieving design challenges and produce a meaningful artifact (23). Most published research on design-based learning in the sciences stems from engineering (24, 25) and computer science (26) or is focused on pre-service teacher training (27), and there are limited examples within biology (28–30). The intersection of these two pedagogical approaches (i.e., game-based learning and design-based learning), where students are situated as game designers, in contrast to game players, is far less common in undergraduate biology education (31), and these activities can rarely be translated into online environments.

In the midst of the rapid shift to all online instruction, we sought to develop an assignment that would assess learning of topics taught since the transition while simultaneously and creatively engaging students' learning in our virtual introductory ecology course in spring 2020. To meet the course goals and at least a subset of the unit learning objectives (Appendix 1), students chose two of three assignment options. One of the possible assignments, and the one selected by 94% of our students, was a game design assignment. The other assignment options are not described here, yet each addressed several course goals and subsets of unit learning objectives. A further assignment, in addition to those mentioned above, was to play and peer review at least two student-created games from our class.

Intended audience

While this assignment was developed for and implemented in an undergraduate introductory ecology course, it can be modified for virtual learning in any biology course, including those for both majors and nonmajors.

Learning time

Students choosing to complete this assignment as part of their out-of-class assessments spent varying amounts of time on game development. Aside from briefly discussing the assignment guidelines and scoring rubric during the first virtual synchronous class session and inviting students to communicate with the instructors for additional clarification, the majority of this assessment was completed independently by student groups. Students had approximately five weeks to form groups, generate topic ideas, and develop an ecology-based game for their peers.

Prerequisite student knowledge

This game design assignment is suitable for any student level, as the topics of the games can be modified for both majors and nonmajors, and introductory and advanced students. Students did not need to have content knowledge beyond what was presented in the class sessions and textbook to succeed on this assessment, and were truly limited only by their own creativity, as the game format was open-ended.

Learning objectives

The assignment described in this paper was situated within an introductory ecology class (see Appendix 1 for course goals). The learning objectives for the assignment itself, on which students were evaluated, are detailed below.

Upon completion of this assignment, students will be able to:

1. Design a game for their peers based on an important ecological topic/concept from a specific unit/lesson in a creative manner
2. Encourage critical thinking and discussion of ecological topics/concepts in their game
3. Judge their peers on the quality of their games and how much they enjoyed playing peers' games
4. Prevent temporary boredom during COVID-19 self-isolation

The broad justification of this assignment that we provided in the student guidelines was: "Learning games of any kind is designed to allow you to strengthen your understanding of a particular subject or concept in a fun, enjoyable, and creative way" (Appendix 2). Students had the choice to identify specific unit learning objectives (Appendix 1) to theme their game and align what players of the game may learn through play. Students also had freedom to determine their game format (e.g., board games, card games, scavenger hunts, role playing) to best suit the game they collaboratively designed in a group of three or four peers.

PROCEDURE

Materials

To ensure accessibility, we did not require students to use a specific set of materials for this assignment. However, in the assignment guidelines we did stress to students that materials and/or pieces necessary for their group's game must be easily accessible by their peers due to the virtual format of the course. While supporting materials differed depending on each group's chosen format, we suggested that students consider documents that could be easily printed or viewed online, and game pieces that could be found in most homes, so that peers reviewing and playing their game would be able to do so without purchasing or gathering items outside their home. We also asked students participating in this assignment as creators or reviewers to complete an optional survey at the start of virtual instruction, so that

we could gain a better idea of what resources students had access to (e.g., printers, internet, laptops, family/friends to play games with) and/or what resources each game required (including whether games could be played virtually, in-person, or both). We then assigned games to review based on reported accessibility.

Student instructions

Game creators. A detailed set of assignment guidelines for students is outlined in Appendix 2. Once students formed groups of three to four, they were required to choose an ecology topic/unit from the latter six weeks of the course and identify at least two relevant unit learning objectives (Appendix 1) upon which to base their game. These unit learning objectives covered introductory ecology topics including ecosystem ecology, community dynamics, biogeography, nutrient cycling, decomposition, and climate change (Appendix 1). The open-ended assignment guidelines encouraged creativity in terms of game design and format, though we did not allow students to use a simple question-and-answer trivia format. The latter was prohibited partially to minimize students simply compiling facts that only assessed low Bloom level learning, and partially to limit redundancy because another optional assignment was to participate in a final synchronous trivia game with the entire class. Topics and formats had to be approved by one of the course instructors before the group could proceed with game development.

To encourage learning beyond general course content and the textbook, we required students to research their chosen ecology topic and include a minimum of five reliable sources in a citation list as part of their final submitted materials. Students had learned and practiced how to identify reliable sources earlier in the course; thus, this assignment also served as a means to apply that skill. Once students had sufficiently researched their ecology topic, they were directed to begin planning their game. We asked them to reflect on the alignment of their topic and preferred game format, as well as how to ensure that their game was enjoyable and fun, while also covering the relevant unit learning objectives they were trying to address. We further recommended that each game take approximately 30 to 60 minutes to complete by up to four players, though recognized this would be challenging for students to estimate since game play dynamics can differ drastically among groups. In addition to materials necessary to play the game, students were also required to submit a set of clear instructions that could be easily interpreted by their peers. Students completing this assignment were allowed to choose their group members, although it was the responsibility of each group to schedule meetings and allocate time to work on the game outside of class. All final assignment materials were submitted to our course's learning management system (LMS).

Game reviewers. Once game creators had submitted their assignments to our LMS, students who had signed up to review one, two, or three games were granted access to their assigned yet anonymized group's game materials. Peer reviews of games consisted of reading the provided instructions, playing the game with family, friends, or peers (depending on whether the game was able to be played in-person or virtually), and subsequently completing a Game Assignment Peer Review rubric (Appendix 3). Game creators did not revise their games due to time constraints, the primary purpose of game reviewers being to contribute to the score that the game creators earned, encourage collaboration, and extend learning of certain class topics. We should note that this rubric (and the Instructor rubric described below) were both partially adapted from the Board/Card Game Design and Construction available from iRubric (https://www.rcampus.com/rubricshowc.cfm?sp=yes&code=V5C274&). At the bottom of the Game Assignment Peer Review rubric, peer reviewers were further asked to write a short game review similar to those posted online to inform others interested in purchasing the game about its pros and cons. In the assignment guidelines, we also required students reviewing games to keep track of how long the game took to play after set-up, and to take a photo of themselves playing the game—both to document students having fun during the age of virtual learning and to provide evidence that students had actually played their assigned game prior to reviewing it.

Faculty instructions

Aside from providing foundational course content about each ecology topic that students were allowed to base their games on, clear assignment instructions, and measurable unit learning objectives for each topic/unit, the instructor's role in this assignment is primarily centered on logistics and checking in with groups periodically about their progress. Once the assignment has been introduced, instructors will need to approve each group's game topic and format; as mentioned above, we would also recommend administering an optional survey to students asking about their accessibility to certain resources—whether the course is being taught virtually or in-person—to more equitably assign peer reviews.

Before giving out this assignment, instructors should consider the number of students allowed in each game creator group, and how they want to assign peer reviews of games. In our ecology course, students had other assessment options beyond this game assignment, so not every student created and/or reviewed a game; however, important considerations include how many peer reviews students will be required to complete, how to ensure students involved in both game creation and review are not reviewing their group's own game, and how to guarantee that all games are being reviewed approximately the same number of times. We used our course's LMS to assign peer reviews, thus granting each reviewer access to only the game materials for their assigned group(s), though other formats (e.g., direct

emailing) may be more effective depending on the size of your course. If students are required to submit their game materials to the course LMS, be sure that various formats of submission uploads are allowed (e.g., Word documents, PDFs, PowerPoint slides, videos, etc.).

Suggestions for determining student learning

To determine whether students achieved the desired learning objectives for this assignment, we developed a game review rubric (Appendix 3). This rubric helped assess the first two assignment learning objectives (i.e., did they design a game based on unit learning objectives, and did the game promote critical thinking and discussion of ecological topics?). Students had access to this rubric from the start of the online transition and were scored in various categories including alignment of game with relevant unit learning objectives, application of ecology content, use of evidence (i.e., sources) in game development, clear rules and objects of the game, game design, game timing, game materials, and learning during the game. Each game was reviewed and scored by at least one instructor. Each game was also reviewed by at least seven peers who were not in the group that created the game. Each group's final assignment grade was determined by an average of peer review scores and the instructor scores.

As game reviews were worth a lower number of points for the purposes of our course, we, as instructors, scored peer reviews using a simple 0-5-10 system (i.e., 0 indicating they did not complete the assessment; 5 indicating that they partially completed the assignment with some meaningful feedback; and 10 indicating that they completed the entire assignment and provided effective and meaningful feedback).

Sample data

The games that students developed covered a broad range of formats. Some groups developed more "classic" board games loosely based on Monopoly that required players to acquire species, populations, and biomes while avoiding natural disasters, or a Chutes-and-Ladders style game where students needed to answer questions related to nutrient cycling to proceed. One group created a matching card game with the end goal of sorting organisms into ecological niches, while another developed a game requiring students to draw sketches related to climate change topics that their teammates had to guess correctly. Students' creativity was diverse—particularly those who provided flexibility to play their games both in-person and virtually, and novel game formats and designs would certainly be generated if this assignment were implemented in other biology courses.

Safety issues

We did not anticipate any safety issues associated with this assignment, as all game development and review took place at students' homes, and supplementary game materials/pieces—if the game was not fully available online—were expected to be common household items.

DISCUSSION

Field testing

We rapidly adapted our in-person ecology course to a virtual format in spring 2020, and this game assignment was an assessment we developed to engage students in creatively learning about the remaining course topics while still fostering collaboration. Thus, we have only included this assignment as part of our curriculum once. While we developed this assignment for an introductory ecology course enrolling 66 undergraduates, including both biology majors and non-biology majors, we believe this assessment could be easily adapted for other introductory or advanced biology and STEM courses. We had 16 groups, each consisting of three to four students, participate in this assignment as game creators. All students peer reviewed at least one game. As reported by peer reviewers, the mean time to complete games was approximately 39 minutes (SD = 8.43).

At numerous points during the virtual part of our course, students conveyed their gratitude for this creative, fun assessment that still allowed them to interact with their peers. Many noted that the format of their virtual classes was often boring and unengaging, and that this game assignment was unique among more common virtual assessments like online textbook homework and exams.

Evidence of student learning

When developing this game design assignment for our ecology course, we tried to meticulously ensure the assignment learning objectives aligned with both our broad course learning goals and the more specific unit learning objectives for each topic/unit (Appendix 1). Thus, we expected that the Peer Review and Instructor rubrics would provide an effective measure of how strongly students achieved the game design assignment learning objectives, and how well each group's game content aligned with the relevant unit learning objectives they identified for their assignment. The mean score across all 16 game creator groups was 84.4 (SD = 0.06) out of a possible 100 points (inclusive of both instructor and peer reviews). Students did not seem to overwhelmingly exceed or falter on any of the rubric categories, but rather the mean score on each category was around four out of five possible points. Based on these scores, it appears that students generally met the assignment learning objectives.

While the mean score across all game creator groups was relatively high, we would suggest additional iterations of peer and instructor feedback for student-developed games that were not as effective at achieving learning objective

alignment (i.e., the rubric category with the lowest mean score across game creator groups). To improve the feedback process, instructors could scaffold the assignment and require students to turn in portions of their game (e.g., instructions, game materials) at distinct points throughout the term to provide focused feedback on each game portion over a longer period of time, something which was not possible during the hastened spring 2020 term. Additionally, with regard to improving learning objective alignment, instructors could introduce their students to backward design prior to assigning this game assignment, so that students were more familiar with backward design. While students in the current study had the opportunity to receive feedback and discuss the nuances of their games with the course instructors at any point during the virtual portion of our course, most students did not take advantage of this supplemental game review, though this is unsurprising, considering the heightened stress and anxiety caused by the pandemic both in and out of the classroom.

CONCLUSION

We suggest student-developed games are an effective way to engage your class in learning that is enjoyable, collaborative, and requires creative application of the course content. While students developed various game formats and focused on different unit learning objectives, instructor and peer review indicated that the games created for this assignment were both conducive to learning and highly accessible. The guidelines for this assignment can be easily adapted for other biology and STEM courses. While game-based learning, and even game design, is not new in undergraduate biology education, its application in a virtual classroom has not been reported elsewhere. It can be challenging to encourage ingenuity and collaboration among students in an online environment while simultaneously providing a means for students to review, apply, and synthesize course-specific material. We found a game-design assignment was successful in accomplishing these goals in an introductory ecology course and recommend other instructors consider this assessment approach in their classrooms to improve student engagement and promote creativity in the virtual environment.

SUPPLEMENTAL MATERIALS

Appendix 1. Course learning goals
Appendix 2. Ecology game project guidelines
Appendix 3. Game assignment evaluation rubric used by the instructors and peer reviewers

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