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ENHANCING MOTIVATION TO LEARN IN A BIOLOGY LABORATORY COURSE THROUGH GAMING: A DESIGN CASE

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In this design case, we describe our work to develop a gameful learning design for use in an introductory, undergraduate biology laboratory course for science majors. Our design team included three university-based mathematics and science educators and a biologist responsible for the management of curriculum and instruction in the course under study. The gameful learning design was employed during the four weeks of plant evolutionary life history instruction. Key challenges to the design and implementation of gameful learning included the adaptation of instruction from teacher-centered to student-centered and establishing novel learning conditions in the eight laboratory sections so as to determine the value of two different elements of game design, repeat-testing and leaderboard with badges.

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INTRODUCTION

Proponents of gamification suggest that the inclusion of game design elements, such as a leaderboard with badges and repeat-testing, can enhance motivational outcomes and in formal learning environments (Deterding, Dixon, Khaled, & Nacke, 2011; Domínguez, Saenz-de-Navarrete, De-Marcos, Fernandez-Sanz, Pages, & Martínez-Herraiz, 2013; Dondlinger, 2007). Leaderboards naturally exemplify performance goal structures, as they emphasize social comparison and promote competition (Elliot, 2005). Alternatively, the trial-and-error learning characteristic of repeat-testing typifies a mastery classroom goal structure (Dweck, 1986). Achievement goal theorists generally agree that mastery classroom goal structures lead to adaptive motivational outcomes. Debate ensues, however, as to whether the inclusion of performance goal structures, such as the leaderboard, is motivationally beneficial (Senko, Hulleman, & Harackiewicz, 2011). In this design case, we describe our work to develop and implement a gameful learning design to better understand its motivational effects in formal academic settings. The purpose of our research was to determine whether the inclusion of the repeat-testing element alone, or in combination with the leaderboard, was more motivationally advantageous than a control condition. Our goal for this design case is to describe the *design* used for our study and how it came to be.

DESIGN MOTIVATION

Motivation for considering the gameful learning design first arose for David (the first author) as a graduate student in a mathematics and science education doctoral program. As part of a required educational technology class, he became interested in the potential for gamification—the inclusion of elements of game design in non-game settings (Deterding et al., 2011)—to positively contribute to learning outcomes. Scholars who have advocated the motivational potential of games generally did so in somewhat general and theoretical terms when extoling the potential for gameful learning to promote the development of mastery and motivate learning (Gee, 2005; Lee & Hammer, 2011; Squire, 2003, 2006). The fact that national reports cite that individuals are spending an increasing amount of money and time on video game play (Rideout, Foehr, & Roberts, 2010), and the personal experience David had playing videogames from a young age and observing his nephews do the same, supported the claims of the motivational capacity of gaming. However, a search of the literature revealed little empirical support for the benefits of including gaming elements in academic settings, particularly in the context of collegiate biology laboratory courses. Furthermore, achievement goal theorists were torn as to the motivational potential of performance goal structures, such as those represented by the leaderboard and badges. Thus, an interest in gaming and its potential for motivating student learning outcomes led David to seek a better understanding of gameful learning and motivation.

At that point, David had taught undergraduate biology laboratory courses for three semesters as part of his graduate teaching assistantship. It was in the context of teaching that class that his understanding of gaming and motivation, as well as the brainstorming of creative endeavors that might put those theories to use, were manifested. Emerging literature indicated that students' motivation to study biology at the university level and complete biology degrees was declining, and an increasing number of students were choosing to leave the sciences, in general. An undergraduate biology setting seemed to be an appropriate setting for a motivational intervention like gameful learning. As a result, David conducted a pilot study in two of the laboratory sections that he was teaching, the results of which supported its potential. He shared his interest in using gameful learning to enhance students' motivation to learn biology, as well as the findings from the pilot study, with three individuals that would form the design team: Cindi, an advisor and biology outreach and teaching specialist; Angela, the Director of the Mathematics and Science Education Ph.D. program; and Dennis, a biology professor and the supervisor of the introductory biology courses and the Graduate Teaching Assistants (GTAs) responsible for teaching them. The game design would be developed and tested for its contribution to students' motivation to learn biology as part of David's doctoral dissertation study.

PRECEDENT IN GAMING DESIGN

Games continue to motivate individuals to dedicate increasing hours to game play. As teachers look to develop learning environments that contribute to students' motivation to learn, a carefully designed gameful learning environment could be one effective vehicle for doing so. Therefore, better understanding the motivational potential of games in more formal learning environments and the manner in which those gaming environments can be designed are of interest. With this design case, we seek to share our experience with designing a gameful learning environment that includes the leaderboard with badges and repeat-testing as gaming elements in a non-game setting—in this case, an undergraduate biology laboratory course.

RIGOR IN CASE DESIGN

Rigor in a case design is established when authors are able to provide a detailed description of the designed product and clarify value of the case in terms of its utility and the trustworthiness (Boling, 2010). The utility of any design case is not determined by the designers, but by those individuals whose creation and implementation of gameful learning in the future might benefit from our recollection of the design process and the decisions that we made throughout (Smith, 2010). As such, it is difficult to predict the needs that future designers may have, or what of our experience may be applicable in their case. However, we do know that a rigorous, trustworthy case design is more likely to be of use to designers in the future (Smith, 2010). We seek to establish trustworthiness by addressing the following: disclosure of each author's involvement in the design case; salient elements of the project and resulting design; negative case analyses; and identification of the stakeholders involved in the gameful learning design and its implementation, as well as the inclusion of multiple sources of data and design artifacts from which to triangulate an account of the design that is both accurate and credible. Though it is impossible to eliminate bias, we have mitigated bias to the best of our abilities by subjecting the account of the design process herein to extensive peer review, including evaluation by each member of the design team, a graduate teaching assistant who implemented instruction resulting from the design, and scholars from outside of the design team that have a keen perspective in this field, as well as the peer-review associated with publication in this journal.

Individuals identified as stakeholders in the gameful learning design and its implementation are listed in the next section, along with their position at the time of the design and its implementation and their role in the process.

David Owens, PhD candidate in mathematics and science education (biology education concentration). David was the lead designer. He developed the gameful learning design, tested an early iteration of the design as a pilot study, and after evaluating student responses to the design, worked with co-designers to enhance the design for the purpose of conducting his dissertation study. Additionally, David managed all aspects of the gameful intervention, which included leading weekly professional development to prepare GTAs for managing active-learning environments, as well as managing the gaming elements throughout implementation. His perspective framed the design case study.

Cindi Smith-Walters, Professor of Biology. As David's dissertation co-advisor, Cindi served as a co-designer. Her perspective is included to inform the decisions made over the course of the design and implementation of the gameful learning experience.

Angela Barlow, Director of the Mathematics and Science Education Ph.D. Program. As David's dissertation co-advisor, Angela served as a co-designer. Her perspective is included to inform the decisions made over the course of the design and implementation of the gameful learning experience for dissertation study.

Dennis Mullen, Professor of Biology, Assistant Biology Departmental Chair and Supervisor of Instruction for the undergraduate biology laboratory course, Dennis served as a dissertation committee member and a co-designer.

GTAs were responsible for implementing the active learning instruction that undergirded the gameful learning experience. Four GTAs taught two sections each of the undergraduate biology laboratory course for the duration of the study.

Participating Students, enrolled in the undergraduate biology laboratory courses, provided their perspectives via open-ended questionnaires and interview. Their input that contributed to improvements in the gameful learning design is also included.

COMPONENTS OF THE GAMEFUL LEARNING DESIGN

The gameful learning design was comprised of several components (see Figure 1). First, the content of the course provided the parameters for what learning objectives should be achieved as a result of the gameful learning experience. A series of implementations of different iterations of the delivery of the content both with and without gameful learning, accompanied by lead-designer observations and student input and evaluation, enabled evolution of the game design. The result of said iterations resulted in the refinement of the gameful learning structure, as well as products that enabled gameful learning to be carried out. These structures and assessment tools, along with the computers and online learning platform students used to engage with the course, as well as the information students accessed to inform course products, contributed to the gameful learning environment experienced by the students. This experience yielded products in the way of relevant, higher-level questions developed from the content, as well as the thoughtful answers that accompanied them.

Course Description

The gameful learning experience was implemented in a second semester biology laboratory course for science majors. Students were concurrently enrolled in the laboratory course and a complimentary lecture course, each meeting once a week for 2:45 hours. Laboratory sessions dealt with plant and animal evolutionary life history, anatomy and physiology, and the identification and classification of organisms. GTAs taught the laboratory course.

Evolving Game Design

The game design grew out of David's experience as a GTA in the undergraduate biology laboratory course while

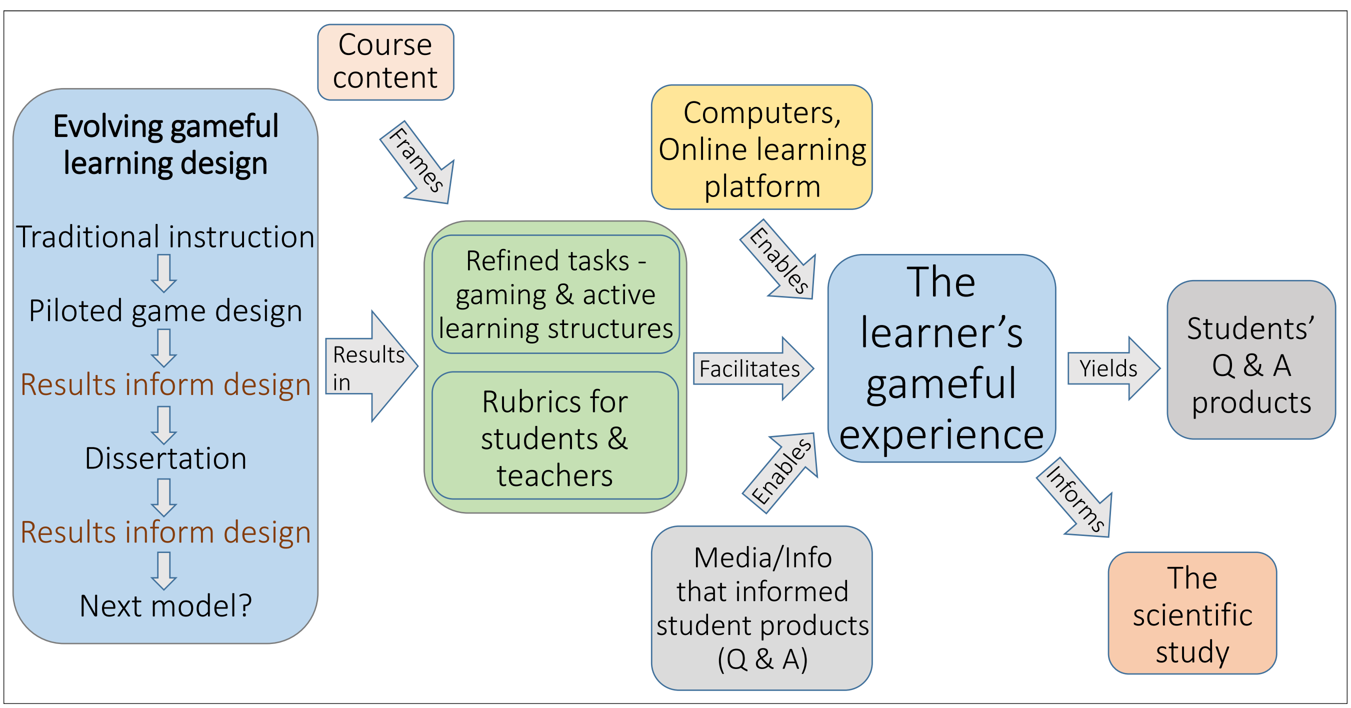

FIGURE 1. A graphic organizer artifact to aid in conceptualizing the components that comprise the gameful learning design.

implementing the traditional design of instruction. After gaining familiarity with gameful learning and its purported motivational benefits, he developed a prototype design and piloted it in two sections of the week 10 laboratory session about vertebrate tissues. David recorded observations and received feedback from students, which he used to inform and enhance the game design, which forms the case understudy. Each step of the evolution of the game design is discussed in detail next.

Traditional Design of Instruction

The traditional design of instruction was as follows. On the Friday prior to week of labs, Dennis would host all GTAs to discuss the content for the upcoming lab. Emphasis was placed on referencing those teaching specimens that were especially interesting or useful for examining the week's topic, such as the absorptive nature of *Sphagnum* moss and its use in dressing wounds, or the *Limulus* amebocyte lysate present in horseshoe crab blood that is valued for its ability to indicate the presence of endotoxin. GTAs' questions about content or management of laboratory activities were also addressed.

Undergraduates enrolled in the course were expected to read four to six pages of content prior to each laboratory session. Upon arrival, students completed a five-question quiz that covered the assigned reading. After reviewing the correct answers, the GTA would give a lecture concerning the important information from the assigned content. Upon conclusion of the lecture, students were given open laboratory time where they had the opportunity to become familiar with the specimen that they would need to be able to identify for future exams. This was often seen as free time by the undergraduates and individuals would spend varying amounts of time examining the specimens. GTAs were given leeway to simply monitor the session, or lead a class review of the specimens, while others made themselves available for student questions as students reviewed specimens at their own pace.

Pilot Study—Gaming Design

After engaging in the gameful learning literature, David was keen to see how students would respond to the change of instruction. He conducted a pilot study with two laboratory sections. Each section was informed that instead of taking the usual five-point quiz, groups would compete for quiz points by playing a game called *Issues with Tissues* (Owens, 2017).

Groups of up to four students teamed up at one of six laboratory tables. Each team was randomly assigned a vertebrate tissue (e.g., connective, muscle, nerve) along with corresponding content from the assigned reading. Teams considered their content as well as the microscope slides and available specimens that corresponded to their tissue, decided on a team name that represented and/or advertised their tissue, and developed three higher order thinking questions (i.e., analysis, synthesis, or evaluation). After each team presented their questions and answered them with the help of the slides and specimens provided, the peer audience evaluated the presenters and provided verbal and written feedback based on the creativity of their team name, the quality of their questions, the involvement of all group members in the presentation, and whether they promulgated any misconceptions over the course of the presentation. Each team ranked the groups based on their evaluations. The team receiving the highest average ranking won, and quiz points were assigned to each individual according to his or her team's rank. The winning team and final ranking were announced the following week. Additionally, students were able to recoup points lost by providing David with feedback that might enhance the game design.

The pilot study suggested that the gameful learning intervention was well received by participating students and the question-development strategy with peer feedback using a rubric appeared to be a viable means for enhancing the active nature of the learning environment in the context of a game. Findings from the pilot study contributed to the decisions made concerning the next iteration of the game's design.

DESIGN DECISION: *Content covered by student-developed questions*. In the pilot study, each team was randomly assigned one type of animal tissue from the assigned reading. After the gaming event, students indicated feeling confident in their understanding regarding the tissue they were assigned and about which they developed questions. However, they did not feel as strongly about their grasp of the tissues that other students were assigned. Some students felt they would have had a better grasp of all of the content if they had been assigned the entire content from which to develop questions.

DESIGN DECISION: *Preparation of GTA instructors to conduct active-learning instruction.* All of the pilot study participants that provided feedback reported positively regarding the game. However, a few high-achieving students remarked that they did not like leaving the class period with a feeling that they could not trust the information that the other teams presented. Those individuals' preference would have been receiving the information directly from the GTA who was more knowledgeable. These comments suggested that teachers who use this gameful design in the future should certainly be prepared to identify and dispel any alternative conceptions as they arise, as well as emphasize and clarify key points from the assigned reading.

DESIGN DECISION: *Ensuring that students arrived in class prepared to actively learn*. One participant in the pilot study indicated that had he known the laboratory session would be carried out as a game, he would have actually read the assigned reading. This suggested that the quiz by itself was not enough to prompt him to prepare. Future iterations of the game might task students with creating relevant, higher-level questions as homework prior to the start of the laboratory session to increase the likelihood that students arrive prepared.

Gaming Design

The gameful learning design was implemented during the first four weeks of the semester and covered the plant portion of the course content. Participants were 140 undergraduates from one of eight sections of a second semester biology laboratory course. The gameful learning design consisted of two parts. The first part included the active learning instruction in which all individuals took part. The second part was the gameful learning. These are described in detail next.

Active Learning Instruction

The active learning instruction described in the following paragraphs was received by students in all eight sections of the laboratory course.

Prior to Lab. In order to ensure that students were prepared for active-learning when they arrived in class, they were tasked with reading approximately five pages of content from the laboratory manual (Vodopich & Moore, 2014) concerning the upcoming laboratory session and creating two questions that extended the concepts from the reading so that it was made relevant to their lives and required higher-level thinking according to Bloom's revised taxonomy (apply, analyze, evaluate, or create). Students were to thoroughly answer both questions, providing evidential support from outside resources (e.g., media, science journal articles, etc.), and submit their questions and answers to the online grading system at least 12 hours prior to the start of the lab.

Upon Arrival to Lab. Students were randomly assigned to a team of four individuals and dispatched to one of six laboratory benches. The tables were marked 1-6, and each seat at the tables 1-4.

During Lab. Within each team, students were tasked with sharing the questions they had created and then selecting from among them or developing the two best group questions. Teams had 30 minutes to prepare a presentation for each question and corresponding answer using the microscope slides and specimens available. Once presentations were prepared, a playing card was drawn (1-4) to identify each team's presenter. At that point, groups had five minutes to ensure that their presenter was prepared. Upon conclusion of the preparation period, another card was drawn (1-6) to indicate the group that would present. The presenter offered the question and its answer, while teammates served in supporting roles by drawing on the whiteboard, showing specimens to the class, or focusing slides on the microscope attached to the document camera. Upon conclusion, the peer audience provided written feedback as a team using a rubric (Appendix A) as a guide. There was also the opportunity to offer verbal feedback to the presenting team. The same procedure was repeated for a second round of question presentation, resulting in two presentations per laboratory session. During the last 20 minutes of each session, students completed an eight-item multiple choice quiz that covered the entirety of the assigned content.

After Lab. After each laboratory session, the GTA was tasked with grading student-submitted questions and providing feedback as to their quality. Additionally, the GTA was responsible for using his or her own rubric (Appendix B) to evaluate the feedback each team had provided to the presenters. Comments were written directly on the student-completed rubrics and posted in the room the following week for students to see upon arrival. By evaluating students' feedback and providing that information to the students, the GTA was able to aid in the development of the students as critical consumers of information—an important characteristic of scientists, but also of citizens in a democracy.

Planning Decisions for Active-Learning Instruction

DESIGN DECISION: *Navigating the change from the teacher-centered instruction that had historically been employed to instruction that was learner-centered.* The manner of instruction supported by the active-learning literature ran counter, in many ways, to the traditional design of instruction. Thus, a shift to a new instruction strategy could be misconstrued as an affront on the existing structure and potentially offend the individual responsible for the manner in which instruction had previously been delivered. In this case, Dennis was a seasoned biology professor from whom David had taken a class as an undergraduate, and who had also supervised David as a GTA instructor for two years. He also served on David's doctoral committee. David used literature from the science education field to support the manner of active learning that would undergird the game design. It was clear that Dennis had misgivings regarding the proposed active-learning strategy, and perceived its proposal as questioning the value of the traditional instruction he had provided over the course of long career. However, he was willing to entertain the new design of instruction.

DESIGN DECISION: *Encouraging preparation, participation, and the sharing of ideas.* In order to foster student preparation prior to each laboratory session and participation in the sharing of ideas during, we decided that each group's presenter, as well as the group that would eventually present, would be randomly selected. The idea was that group discussion would lead to a best question and answer from among the team. A presenter would be selected, and then team members would prepare and support that individual in presenting the question. It was expected that this approach would increase communication between and among individuals in each team, as the presenter that was eventually selected would need to be briefed as to the question with the question and understanding necessary to answer it effectively during the presentation rather than the group counting on the most prepared student to do the presenting. Upon conclusion of the intervention, a number of students credited the surprise presentations with increasing their motivation to prepare for class (Owens, Sadler, Barlow, & Smith-Walters, 2017). However, some reported experiencing anxiety about being selected as a presenter, especially considering that they might not be presenting the questions and answers they themselves had prepared prior to class.

DESIGN DECISION: *Preparation of GTAs to implement active-learning instruction.* GTAs continued to meet the Friday before each new laboratory session to prepare for instruction. The focus of the meeting, though, expanded from a review of content to include a brainstorm of student misconceptions that might be expected in the upcoming lab. GTAs were urged to condense the upcoming week's content into those aspects of understanding that could be addressed quickly after each presentation and feedback sessions to both clarify the student-delivered information and ensure that any key concepts that were not addressed in the students' presentations were discussed.

Gameful Learning Conditions

Two gaming elements, leaderboard with badges and repeat-testing were employed as part of the game design. Because we were interested in whether a mastery (repeat-testing only) or multiple goal perspective (leaderboard with badges and repeat-testing) were more motivationally adaptive, we needed to have different learning conditions. Using a total of eight laboratory sections, two sections each were randomly assigned to a control group, a repeat-testing condition, a leaderboard with badges condition, and a leaderboard with badges and repeat-testing condition (see Table 1).

Repeat-Testing. Students in all sections took a quiz during the last 20 minutes of each laboratory session. Individuals in laboratory sections that included repeat-testing (i.e., repeat-testing and leaderboard with badges and repeat-testing conditions) took their quiz on laptops retrieved from a mobile laptop cart. These students signed in to the online grading portal and completed the eight-item quiz. Upon completion, the students received feedback for each missed question. The feedback was directed at the misconception that likely influenced selection of the incorrect answer. Students were allowed to repeat their tests in this manner until either satisfied with their competence or the 20-minute time allowance lapsed. Individuals in laboratory sections that were not assigned to the repeat-testing condition (i.e., control and leaderboard with badges) also had 20 minutes to complete their quiz using pencil and a bubble-in Scan Tron, but they were only allowed to take the quiz once. Feedback on each question was provided to those students during the following week's laboratory session.

Leaderboard with Badges. Individuals in laboratory sections assigned to the leaderboard with badges group observed a leaderboard projected on the screen at the front of the room via the document camera upon entry. The leaderboard was developed using Microsoft Excel and included each student's anonymous pseudonym in order of their rank. Rank was determined by the total number of points each individual had received up to that point. Also included were the badges each had accumulated, their team, individual and total score for the week, overall cumulative score, weekly rank, and change in rank from the previous week (see Figure 2). Each individual's weekly score was determined by averaging their team score with their individual quiz score.

Individual score. Each participant's weekly individual score was determined by their quiz grade. For those participants in the leaderboard with badges and repeat-testing condition who took their quizzes via computer, individual scores were determined by how they finished as compared to others in the class, with the top finisher receiving 24 points and the bottom finisher receiving 1 point (for a class of 24 students). The top finisher was determined first by having answered the most questions correctly on their final attempt (8 possible), then by having required the fewest number of quiz

CONDITION	LABORATORY SECTIONS	GAMING ELEMENTS INCLUDED
Control	3, 5	Neither leaderboard with badges nor repeat testing were included
Leaderboard with Badges	1, 6	Included leaderboard with badges but not repeat-testing
Repeat-Testing	4, 7	Included repeat-testing, but not leaderboard with badges
Leaderboard with Badges & Repeat-Testing	2, 8	Included both leaderboard with badges and repeat-testing

TABLE 1. Gameful learning conditions.

Genus	Evo Status	Grp Ave	Quiz3	wk 3 score	Total	wk3 rank	rank^
Quercus		5	23	28	78.5	1	2
Pinus		4	22	26	77	2	0
Salvinia		5.5	13	18.5	72.5	3	-2
Selaginella		5.5	21	26.5	72	4	1
Gnetum		6	20	26	71	5	1
Lycopodium		5.5	24	29.5	70.5	6	3
Eucalyptus		3	19	22	64	7	1
Equisetum		5.5	12	17.5	58	8	2
Polytrichum		6	11	17	55.5	9	2
Isoetes		3	6	9	55.5	10	-6
Zea		3	14	17	50.5	11	3
Azolla		4	19	23	49.5	12	4
Sphagnum		5	16	21	46	13	7
Capsella		4	16	20	46	14	4
Zamia		5.5	6	11.5	45.5	15	-2
Ginkgo		5.5	5	10.5	45	16	-4
Marchantia		0	0	0	44.5	17	-10
Ranunculus		5	8	13	42.5	18	-3
Lilium		4	10	14	39.5	19	0
Helianthus		6	7	13	39	20	-3
Psilotum		0	0	0	20	21	0

FIGURE 2. Sample image of the leaderboard (adapted from David C. Owens, "Overcoming Motivational Barriers to Understanding and Accepting Evolution Through Gameful Learning", published 2019 by Springer and reproduced with permission of SNCSC).

attempts, and finally by the least amount of time required to receive that score (via the time stamp provided by the computer). Because individuals in the leaderboard with badges condition that did not include repeat-testing took their quiz on Scan Tron forms, a time stamp was not available, so their individual quiz scores were the number of correct answers (8 points possible).

Team score. Team scores were determined by presentation and presentation feedback quality. There were two presentations, as well as the opportunity to provide feedback to each, during each weekly laboratory session. The two presenting teams were ranked at the end of the laboratory session, with the first-place finisher receiving 6 points and the second-place finisher, 3. Scores for individuals on the five teams comprising the peer audience were determined by the quality of feedback they provided to the presenting team. After the GTA instructor used his or her own rubric to evaluate each team's feedback, the teams were ranked in terms of the quality of their feedback, with the highest quality feedback receiving 6 points and the lowest quality receiving 2. Thus, each team's weekly score was the average of two scores.

Badges. At the end of each laboratory session, students anonymously voted for the individual that was most valuable to their team by writing their name on a slip of paper and submitting it to the GTA. An individual might be most valuable for having the greatest contribution to the question development, presentation, or feedback. Each team's most valuable member received a badge next to their anonymous pseudonym on the leaderboard the following week. Each badge was the image of a plant feature that was the most important its success in terms of evolutionary life history. Weekly badge examples included the vascular system, height enabled by organic polymers such as lignin that increase the rigidity of plants, and the development of flowers that used insects to transport pollen.

Planning Decisions for Gameful Learning

DESIGN DECISION: *Number of repeat-testing attempts allowed.* In video games, individuals are able to play a level as often as they like and without risk. This provides the player freedom to explore and become familiar with all aspects of the game—an important aspect of a mastery classroom goal structure. However, the academic literature suggests that affording individuals unlimited opportunities to repeat tests had the potential to impede motivation and learning outcomes. In considering study participant's comments we found the majority of student responses to items concerning repeat-testing on open-ended questionnaires were positive, although some indicated that having unlimited attempts at the quiz reduced their motivation to prepare. In fact, some indicated having simply guessed until getting the right answers, rather than carefully consider each question.

DESIGN DECISION: *Publicizing students' scores on the leaderboard without violating the Family Educational Rights and Privacy Act (FERPA)?* Each individual in laboratory sections that included the leaderboard with badges was represented on the leaderboard with a scientific pseudonym. These pseudonyms were the Latin name of one of the species of plants that the students would encounter in the course. The repeated exposure to the Latin names of plants was expected to contribute to students' ability to recall them in the future. More importantly, the use of anonymous pseudonyms enabled the study to avoid FERPA violation.

DESIGN DECISION: *Calculation of leaderboard scores.* The availability of computers for quizzing in laboratory sections assigned to the leaderboard with badges and repeat-testing condition enabled a finer parsing out of individuals based on their quiz score and time to finish. This was not possible in sections assigned to the leaderboard with badges conditions where quizzes were completed using paper and pencil. We chose to take advantage of the scoring enabled by the computers because the time to finish factor made the performance goal structure more salient—not only were individuals trying to answer the most questions correctly, they were attempting to do so more quickly than their peers. It is not clear how the time factor affected individuals in the leaderboard with badges and repeat-testing condition in comparison with those in the leaderboard with badges-only condition.

DESIGN DECISION: *Inclusion of badges in the leaderboard condition.* We wanted to make the performance classroom goal structure as salient as possible. The leaderboard made salient the expectation for individuals to attempt to out-perform one another via individual and team score. Badges added yet another layer to the performance-oriented nature of the learning environment, as only a quarter of students could earn a badge, and the badge served to draw attention to their outperforming others in earning it. We chose to include badges in the game design, though literature exists that indicates badges do not enhance students' motivation. Students' responses indicated that the badges were not seen as meaningful, echoing the literature. Future iterations of the game design might consider assigning value to the badge, such as a free homework grade or bonus points on a quiz.

Next Generation of Game Design

As is generally the case, the implementation of a game and the learning that results serve to inform the next iteration of design. Student feedback provided via open-ended questionnaires and interviews, as well as researcher observations, provided insight for further consideration as to how the game design can be maximized for the next generation of implementation. Decisions that will need to be made in the future are discussed next.

DESIGN DECISION: *Random selection for student presentation (to motivate preparation).* Some students indicated feeling anxious while awaiting the selection of the presenter, especially considering they might be presenting a question that they did not create and thus, were not very familiar with. Perhaps, student assignment to teams, and their negotiation of a team's best question, could be undertaken prior to lab, so that once students arrive they are already familiar with each of their teammates' questions and, if called upon, would not feel like they were presenting an unknown entity. This may also enhance the quality of information being presented.

DESIGN DECISION: *Ensuring that the gameful learning experience is conducive to the efficiency and effectiveness of the instructors charged with implementing it.* The designers had hoped that by requiring students to submit their questions and answers 12 hours prior to the start of each laboratory session that the GTA instructors might have time to look over them as a formative assessment and adjust their instruction accordingly. This did not turn out to be a realistic expectation. Furthermore, GTAs indicated that grading 48 higher-level questions and answers each week, as well as providing feedback on students' critiques of the presentations, was difficult and time consuming. Their time commitment did not include management of the gameful learning conditions, including the calculations of each score that enabled the leaderboard and badges, which was done by the lead-designer. In this case, future iterations of this game design might streamline the evaluation processes that enabled gamification or develop the technology to do so.

DESIGN DECISION: *Course offering that enables individuals to select into gaming or non-gaming sections.* While the motivational outcomes were most positive in the leaderboard with badges and repeat-testing condition, there were still a few individuals even in laboratory sections assigned to that condition that did not feel that the competition that ensued was appropriate for an academic learning environment. Future iterations of the game might consider providing students with the option to select into or out of the gamified course.

DESIGN DECISION: *Democratic selection of the question to be presented, rather than at random.* Analysis of participant interviews and open-ended questionnaire responses indicated that some of the presentations were poor or the presenters unprepared, which reduced the effectiveness of the game design. Although the random selection of presenters motivated some to prepare, it clearly did not have that effect on all participants. Might motivation be enhanced, and presentation quality increased, if the individuals comprising the class voted on which of the six teams' questions they would most like to see presented?

CONCLUSION

The design team considered the process of the gameful learning design, as well as the design implemented in the undergraduate biology laboratory course, to be a success. Study results suggested that the inclusion of gameful learning in laboratory classes for biology majors at the collegiate level can enhance students' motivation to learn when compared to a control group, and that the inclusion of both mastery and performance classroom goal structures (repeat-testing and leaderboard with badges) was more motivationally adaptive than either on their own. As with the development of any learning environment, the implementations of the game design discussed in this case informed a number of areas in which the gameful learning design can be improved for future use. It is our hope that this design case will serve to inspire, inform, and support others in their creation of games for learning.

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REFERENCES

Boling, E. (2010). The Need for Design Cases: Disseminating Design Knowledge. *International Journal of Designs for Learning, 1,* 1-8. doi: https://doi.org/10.14434/ijdl.v1i1.919

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: defining gamification. In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments* (pp. 9-15). ACM. https://doi.org/10.1145/2181037.2181040

Domínguez, A., Saenz-de-Navarrete, J., De-Marcos, L., Fernandez-Sanz, L., Pages, C., & Martínez-Herraiz, J. J. (2013). Gamifying learning experiences: Practical implications and outcomes. *Computers & Education, 63*, 380-392. doi: https://doi.org/10.1016/j.compedu.2012.12.020

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of Applied Educational Technology*, *4*, 21-31

Dweck, C. S. (1986). Motivational processes affect learning. *American Psychologist, 41,* 1040–1048. doi: https://doi.org/10.1037/0003-066X.41.10.1040

Elliot, A. J. (2005). A conceptual history of the achievement goal construct. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation*, 52–72. New York, NY: Guilford.

Gee, J. P. (2005). Good video games and good learning. *Phi Kappa Phi Forum, 85*, 33-37.

Lee, J., & Hammer, E. (2011). Gamification in education: What, how, why bother? *Academic Exchange Quarterly, 15*, 1–5

Owens, D. C. (2017). Issues with Tissues: A tale of gameful learning in an introductory undergraduate biology laboratory course. *Journal of College Science Teaching*. doi: https://doi.org/10.2505/4/jcst17_047_01_38

Owens, D. C. (2019). Overcoming the motivational barriers to understanding and accepting evolution through gameful learning. In U. Harms & M. J. Reiss (Eds.), *Evolution Education Re-considered*. New York: Springer.

Owens, D. C., Sadler, T. D., Barlow, A. T., & Smith-Walters, C. (2017). Student motivation from and resistance to active learning rooted in essential science practices. *Research in Science Education*, 1-25. doi: https://doi.org/10.1007/s11165-017-9688-1

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). *Generation M2: Media in the lives of 8-to 18-year-olds.* Menlo Park, CA: Henry J. Kaiser Family Foundation.

Senko, C., Hulleman, C. S., & Harackiewicz, J. M. (2011). Achievement goal theory at the crossroads: Old controversies, current challenges, and new directions. *Educational Psychologist*, *46*(1), 26-47. doi: https://doi.org/10.1080/00461520.2011.538646

Smith, K. M. (2010). Producing the Rigorous Design Case. *International Journal of Designs for Learning, 1,* 9-20. doi: https://doi.org/10.14434/ijdl.v1i1.917

Squire, K. (2003). Video games in education. In *International journal of intelligent simulations and gaming*.

Squire, K. (2006). From content to context: Videogames as designed experience. *Educational Researcher, 35,* 19–29. doi: https://doi.org/10.3102/0013189X035008019

Vodopich, D. S., & Moore, R. (2014). *Biology laboratory manual* (10th ed.). New York, NY: McGraw Hill Education.

APPENDIX A

Group Feedback Form for Student Presentations

Group feedback form for student presentations

Date: ____________________________

Presenters' name: _________________________ Observers' names: ____

Directions: Groups will complete one feedback rubric for each group presentation. Each category will be scored 1-10, then a brief explanation for the score will be provided for each of the 4 categories. Each group's final score will be average of the four scores.

1. Group correctly categorized question using Bloom's taxonomy. Rate: 1 2 3 4 5 6 7 8 9 10

Explain:____

____

2. All content material covered, including slides and specimens. Rate: 1 2 3 4 5 6 7 8 9 10

Explain:____

____

3. The relevance and importance of the concept was related. Rate: 1 2 3 4 5 6 7 8 9 10

Explain:____

____

4. Presenter clearly understood concept. (If presenter had a misconception, take away points and explain their misconception)

Explain:____

____

Final score: ____________/ 4 = ____________

APPENDIX B

Instructor Ranking of Students' Peer Feedback

Instructor ranking of students' peer feedback

Date: ___________________________

Directions: Instructor will complete one feedback rubric for each group. Each item will be given a score of 1-10, based on the on the group feedback forms turned in by each group. A brief explanation of the score will be provided for each of the 3 categories. Each group's final score will be average of the three scores.

Presenters' name: _________________________ Observers' names: ____

1. Group identified error in question construction using Bloom's Taxonomy? Rate: 1 2 3 4 5 6 7 8 9 10

Explain:____

____

2. Group identified any misrepresented concepts by Presenter? Rate: 1 2 3 4 5 6 7 8 9 10

Explain:____

____

3. Group offered a better/alternative question or enhanced the connection/relevance of content? Rate: 1 2 3 4 5 6 7 8 9 10

Explain:____

____

4. Group provided written feedback for all items on rubrics for each group? Rate: 1 2 3 4 5 6 7 8 9 10

Explain:____

____

Final score: ____________/ 4 = ____________