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Augmenting Large-enrollment Instruction With Game-based Mechanics

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Synopsis:

Gamification is the application of game mechanics and elements in non-game contexts to engage and motivate users. A case study was conducted on a large-enrollment introductory computer science course that applied game mechanics in instruction. This paper details the setup, implementation, and outcomes of the study.

Augmenting Large-Enrollment Instruction with Game-based Mechanics

Abstract

In postsecondary science lecture classes, the traditional lecture approach remains the prevailing method of teaching (Deslauriers, Schelew, Wieman, 2011). There are a growing number of studies indicating that other instructional approaches are more effective. The use of multi-section models (Twigg, 1999), teaching assistants (Shannon, Twale, Moore, 1998), flipped classroom pedagogy (Lage, Platt, Treglia, 2000), and peer learning (Deslauriers, Schelew, Wieman, 2011) are some of the approaches that increased learning.

Another emerging approach that has seen some positive results in education (Domínguez, 2012; Sheldon, 2012) is gamification, which is the use of game mechanics and elements in non-game contexts to engage and motivate users. Essentially, gamification is about considering what makes games engaging, fun, and captivating, and applying those aspects to non-game contexts.

Selecting and implementing game mechanics in higher education is a challenging task due to cost, personnel, and technology. These considerations are further complicated in large-enrollment courses because the student population can easily increase any one of these factors. With this in mind, the researchers conducted a study on a large-enrollment introductory computer science course, which applied game mechanics in instruction. Since this study was a pilot implementation, the researchers conducted a user-feedback and design survey to identify possible game mechanics for the study. Subsequently, they conducted focus group interviews with teaching assistants to refine the instructional strategies.

The final implementation consisted of an online component that included badges and avatar evolutions, while the face-to-face component focused on social activities. Preliminary results from surveys and focus group interviews demonstrated that students had a neutral-positive alignment towards specific elements such as badges and avatars. In addition, the researchers observed an increase of completion for non-graded assignments when compared to previous semesters. Students also felt an increase in confidence levels by completing activities that involves social interaction, which helped students to build confidence in learning to apply concepts. Teaching assistants also indicated that there was increased engagement in their laboratory sessions when compared to other units of instruction that were not gamified. While student achievement decreased as compared to previous semesters, the researchers feel this is due to the initial implementation of gamification and the challenges of training a team of teaching assistants to implement new instructional approaches.

Introduction

Improving large-enrollment instruction is important to consider, as Twigg (1999) highlights the advantages of making modifications to large introductory classes:

1. Prime candidates for technology-enhanced redesign due to standardized curriculum and streamlined content.
2. Clear the stigma of being an ineffective teaching method.
3. Successful learning at the introductory level will influence students to persist in key disciplines.

4. Having a deeper foundation at the introductory level will improve students' transition to more advanced study.

A study conducted by Leslie (2002) indicated that despite higher extrinsic rewards and incentives towards research, postsecondary faculty prefer the intrinsic rewards of teaching. Therefore, improving large-enrollment courses can be beneficial for both students and faculty.

Student-led discussions and peer learning are attempts to move from passive learning to active learning in the classroom. Using recommendations outlined by Maier (1971) on conducting peer discussions, Diamond (1972) conducted a study where students wrote discussion essays in groups in addition to regular course work. Diamond notes increased motivation by students to keep up with readings to contribute to group discussions. In a more recent study, Deslauriers, Schelew, and Wieman, (2011) used discussion groups in a physics class coupled with a "student response system" or clicker technology to facilitate learning. Results showed increased engagement, achievement, and attendance.

Innovations in technology opened an alternative approach to learning. Berret (2012) and Davies, Dean, and Ball (2013) look at the idea of "flipped" classroom, the concept of switching events that would have normally taken place in the classroom to outside, and vice versa (Lage, Platt, Treglia, 2000). Students learn material outside of class, and work on solving homework-like problems with their teachers and peers inside the classroom. Berret shares the experiences of professors whom have successfully "flipped" their lecture classes. When students are actively participating in class, they are highly engaged in solving problems. The study by Davies, Dean, and Ball (2013) showed increased student achievement when compared to regular classroom using a quasi-experimental method between flipped and regular classrooms.

These approaches highlight very important aspects of learning in large-enrollment courses. Factors that seem to contribute to the success of these approaches are social interactions and in-class participation. Outcomes of these approaches note increased motivation to learn and increased engagement in class. The usefulness and practicality of an alternative teaching strategy should also take these factors into account.

Gamification

Gamification is about considering games, what makes them engaging, fun, and captivating, and applying those aspects to non-game contexts. Gamification is most commonly associated with marketing strategies to attract and maintain customers. An example of this is the popular mobile application, FourSquare, a location-based social networking service that uses badges and short tasks to engage users and offers rewards to maintain loyalty. Gamification considers motivation and fun to create an engaging experience (Werbach, Hunter, 2012). Lazzaro (2004) categorized fun into four major themes: hard fun, easy fun, altered states, and people fun. Hard fun derives from the pleasure of completing a challenging or difficult task. Easy fun focuses on maintaining attention through the experience of enjoyment rather than the pleasure of winning. Altered states, also known as experimental fun, involves trying new personas or experiences. Lastly, people fun, which relies on social interactions, even if competitive.

There are many resources that are available when choosing gamification as a motivational approach to education (Gee, 2007; Raymer, Design, 2011; Smith-Robbins, 2011). Gee (2007) and Smith-Robbins (2011) provide general principles and guidelines to follow when considering gamification. Raymer et. al. (2011) and Werbach et. al. (2012) provide recommendations for specific game mechanics. Despite having these resources, there are less practical examples.

Lee and Hammer (2011) believe that "gamification can motivate students to engage in the classroom, give teachers better tools to guide and reward students, and get students to bring their full selves to the pursuit of learning." Previous methods aimed at improving large-enrollment courses looked at motivation and engagement as side effects to their successes. However, gamification can shift the focus to these areas as priorities.

Domínguez et. al. (2012) focused their efforts on developing a gamification plug-in for a computer technology course on an e-learning platform. The game mechanics incorporated into the design were a tracking system that included awards, badges, and a leaderboard. They provide quantitative data showing increased achievement for students being able to complete skill-based tasks; however, they performed poorly on concept-based written assignments. Social aspects were left for future research and was not incorporated into their study; however, their data analysis revealed that competitive social mechanisms seem to resonate with students.

Sheldon (2012), who taught a course on game design at the time of his experiment, changed his course curriculum to immerse his students in a game-like environment. Points were renamed to experience points (XP) and final grades were based on 12 levels, one being an F and 12 being an A. Assignments were planned and shown up front to students. Students could choose to complete individual or group assignments with various amounts of XP.

Due to the many considerations on applying game mechanics, knowing how and which specific approaches to implement is another challenge for educators wanting to use this teaching strategy. Therefore, it is important to make an informed decision based on the needs of students and the availability of resources. The focus of this research is to implement game-based mechanics by first considering student needs, preferences, and feasibility.

Methodology

Setting

The study was conducted in a large-enrollment, introductory Computer Science course at the University of Hawaii at Manoa. Approximately 300 students enroll each semester from over 50 majors. The course is divided into 10 to 12 sections based on the specific enrollment. A course instructor, coordinator, graduate assistant, and teaching assistants work together to teach the course.

The course curriculum is split into two components: lecture and laboratory (lab). The lecture component consists of a face-to-face lecture and an online video lecture. Each week, a general computing topic is covered to give students a broad overview of computing and its impact on their lives. After initially meeting in a lecture hall for a face-to-face lecture, a complementary online video lecture and quiz is provided.

The lab component of the course consists of two face-to-face sessions with a teaching assistant in a computer lab each week. The amount of time allocated per unit varies based on the difficulty of concepts. Activities include hands-on opportunities to learn how to use different computer applications on two levels: 1) understanding how to perform tasks (skills) and 2) understanding how to apply skills to real-world situations. Lab units cover the following topics in order:

1. Introduction to the computer, Windows basics – 1 session
2. Boolean searching and email – 1 session
3. File management – 1 session
4. Word processing – 3 sessions
5. Presentation software – 3 sessions
6. Spreadsheets – 6 sessions
7. Photo editing – 2 sessions
8. File Transfer, Text-based operating systems – 2 sessions
9. Web Design and HTML – 3 sessions

Developing a Gamification Approach to Teaching and Learning

This study applied game-based mechanics to the lab component due to the ability to integrate a wider variety of instructional strategies with a smaller class size. To create an informed decision on the specific game strategies to be implemented, the researchers conducted an anonymous, open-ended survey with students in the fall 2013 semester aimed at identifying general types of in- and outside-class activities, which helped students learn and enjoyed performing. After the initial survey was analyzed, the researchers implemented the game-based mechanics in the spring 2014 semester.

The main themes for in-class activities included working and discussing in groups, performing hands-on activities, and completing activities that were relevant on a personal, academic, or future career level. One theme emerged for the outside-class activity: participation in real-world situations. The researchers reviewed the themes to identify the best approach to integrate student feedback into the gamification design. They felt that it would be too logistically challenging to integrate field experiences in real-world situations out of class with a large student population. Therefore, the researchers decided to focus their efforts on developing in-lab gamified activities for each session that included relevant group activities with a hands-on component. These activities were applied to an area where students typically had difficulty - the application of skills. The researchers decided to apply game-based mechanics to the spreadsheets unit of instruction because 1) students typically had the most difficulty learning content in this unit and 2) the unit included the most sessions for TAs and students to learn and utilize the learning strategies.

The course coordinator, graduate assistant, and teaching assistants worked together to develop in-lab gamified activities for students to work in pairs that focused on the application of skills within the spreadsheets unit. Teaching assistants assessed student performance on the activity and gave feedback immediately. The activities were integrated into the unit curriculum as part of normal instruction, not graded for credit, and participation was voluntary.

Since the lab includes instruction on both skills and application of skills, and the in-lab gamified activities focused on application, the researchers implemented a tracking system with badges and avatars to help students improve their skills (Domínguez, 2012). Badges have also been shown to increase motivation (Antin, Churchill, 2011), which is an issue in large-enrollment courses (Twigg, 1999). The graduate assistant setup and maintained individualized HTML pages for each student in the course which tracked and displayed the student's progress throughout the spreadsheet unit. Students were able to access their own pages through the course's content management system. The progress pages contained badges for completing graded and non-graded assignments, a progress bar for badge collection, an avatar picture that evolved with more badges earned, formalized feedback from the in-lab gamified activities, and model answers for the activities. There was a total of 15 badges a student could earn for the duration of the unit: five graded assignments, five in-lab gamified activities, and five non-graded assignments. Graded assignments contained bronze, silver, and gold level badges depending on the score of the assignment. In-lab gamified activities and non-graded assignments only included gold level badges for completion.

Results

To measure the overall effectiveness of the game-based instruction, the researchers analyzed three major sets of data: 1) assignment scores for graded assignments and completion rates for non-graded assignments from previous semesters, 2) survey data of student perceptions and attitudes towards the implemented game mechanics, and 3) perspectives from the teaching assistants.

The study was conducted in the spring 2014 semester. Fall 2012, spring 2013, and fall 2013 assignment data were used for comparison.

Student Achievement

Two assignments were evaluated for the spreadsheet unit, practical assignment (skill-based) and a project (application-based). Assignments with a score of 0 were excluded in the data analysis as they represented students who did not submit an assignment. Both assignments were given at the end of the spreadsheets unit. The practical assignment focuses on the students' ability to execute skills, and the project focuses on the students' ability to apply the skills they learned to a real-world situation.

Mean scores for practical, skill-based assignments, show a slight increase as compared to previous semesters (Table 1). The study was conducted in the spring 2014 semester and practical assignments had a mean score of 80.89% with 263 submissions. Although the previous three semesters of data show a slight increase, the experimental semester had a sharper increase than expected.

	FA12	SP13	FA13	SP14
N:	304	317	278	263
Mean:	74.56%	75.73%	75.76%	80.89%

Table 1 – Summary of mean practical assignment scores from fall 2012 to spring 2014.

Mean scores for application-based projects, show a slight decrease as compared to previous semesters (Table 2). Students achieved a mean score of 81.67%, the lowest out of all other semesters, with 240 submissions.

	FA12	SP13	FA13	SP14
N:	281	290	227	240
Mean:	85.91%	87.17%	85.65%	81.67%

Table 2 – Summary of mean project scores from fall 2012 to spring 2014.

Completion percentage for non-graded assignments show increase from previous semesters, and is the highest compared to previous semesters (Table 3). Out of 288 students, 10.83% of non-graded assignments were completed. Averaging the percentages of the previous three semesters gives an overall increase of 8.84% from previous semesters.

	FA12	SP13	FA13	SP14
N:	326	327	289	288
Completed:	2.88%	1.90%	1.18%	10.83%

Table 3 – Summary of non-graded assignment completions from fall 2012 to spring 2014.

Student Perceptions and Attitudes

A retrospective survey was given to students after the unit was completed. The survey included Likert-scale questions that focused on students' confidence levels before and after the spreadsheet unit, and their perceived motivation and enjoyment of the game mechanics. An open-ended question was included to capture additional feedback from students if they had additional insights that was not covered by the Likert-scale questions.

Since the game-based strategy was implemented midway through the semester, students had a base line for instruction without the new approach. The first set of questions were retrospective questions that asked students to rate their confidence levels before and after the in-lab gamified activities. Confidence levels increased from 2.63, before game-based instruction, to 3.88, indicating an increase of 1.25 out of a 5 point scale (Table 4). Students perceived the effectiveness of teaching assistant feedback from the in-lab gamified activities to be generally positive at 3.73.

Item	N	Mean
Confidence level of applying skills, before in-lab activities.	230	2.63
Confidence level of applying skills, after completing activities.	229	3.88
Effectiveness of feedback from in-lab activities.	222	3.73
Enjoyed working with partner.	220	3.94
Effectiveness of working with partner.	219	3.89
Badges motivated me to complete work.	217	2.88
Enjoyed receiving badges.	215	3.23
Avatar evolutions motivated me to complete work.	215	2.98
Enjoyed watching avatar evolutions.	215	3.10

Table 4 – Summary of survey responses given after the spreadsheets unit.

Open-ended responses further validated the increase in confidence levels with common themes such as practicing more and working with partners. Representative comments from students included:

- "By working on the application documentation activity in class and with partners, it provided a clearer understanding of what we had to do."
- "Due to the many practice application documentations we did in class, I felt able to do better on the project and am confident in what and how I was answering."

The next set of questions assessed the perceived effectiveness and enjoyment of the implemented strategies. When working with a partner, students were in agreement that they enjoyed working with a partner, as shown by a mean score of 3.94. The effectiveness was also a close match to enjoyment with a mean score of 3.89. Badges as a motivational tool did not seem to positively resonate with students, as it had a mean score of 2.88. However, students had a slight positive disposition towards receiving badges, as indicated by a mean score of 3.23. The avatar evolutions based on the badges earned did not appear to resonate with the students, as they had a mean score was 2.98, which is similar to the rating for badges as motivational tools. Watching avatars evolved for completing work had a mean score of 3.10, which is fairly similar to the rating for receiving badges.

Lastly, an open-ended question about general comments from the unit revealed that many students felt that credit should have been awarded for completing the different assignments associated with badges and avatar evolutions. However, the researchers did not want the implemented game-based mechanics to be worth credit because the researchers felt that would not demonstrate the effectiveness of applying a gamified strategy.

Teaching Assistants Perspective

A focus group interview with teaching assistants was conducted after the spreadsheet unit to gain additional insights from the teaching perspective. Open-ended questions were used to allow teaching assistants to provide rich descriptions of their experiences. The major themes that emerged were: 1) Students had increased engagement and discussion throughout the in-lab gamified activities, 2) students spent additional time with teaching assistants outside of lab sessions to gain additional feedback, and 3) students wanted in-lab gamified activities to count for credit.

Responses from teaching assistants indicated that students were engaged because students were given the opportunity to discuss with a partner. Representative comments from teaching assistants included:

- "They [the students] actively discussed with their partners how they would write the documentation and how the elements of the sheet related to the documentation for the skill.
- "They [the students] wanted me to give them feedback so they could change it [their answer] to be better and have me check them off."

Despite having no credit assigned to the in-lab gamified activities, teaching assistants noted that students stayed after lab to gain feedback from their progress. A comment from a teaching assistant demonstrated this finding:

- "I had most of my students email me their documentations, but some in class did ask me to give feedback about it and were willing to stay after lab to discuss it."

Parallel to the survey responses given by students, teaching assistants also noted that students verbalized to them that they wanted credit for completing in-lab gamified activities.

Overall, teaching assistants felt that the in-lab gamified activities had the greatest impact on student motivation. They rarely had students spend extra time with them outside of class hours to receive feedback. Therefore, they felt that this aspect of gamification was the most valuable for students and would like to continue the in-lab gamified activities if given the opportunity.

Limitations

Since this study was a pilot implementation of game-based mechanics, more data would be required to create generalized findings. The implementation also occurred midway through the semester, therefore, students may have had difficulty transitioning to a new mode of instruction.

When working with the in-lab gamified activities, feedback was meant to be instantaneous and individualized for each pair. However, many teaching assistants ran out of time and shifted their feedback to be online via e-mail.

The student progress tracking system had approximately a 24-hour update delay, as it required manual input of badges and avatar evolution. Therefore, the updates hinged on teaching assistants updating grade sheets and the graduate assistant modifying HTML pages for each student. Due to the time delay, the researches feel that the instantaneous feedback that students would have expected, lowered the value and possible motivation for earning badges.

Discussion

The quantitative data involving practical assignments and non-graded assignments show increases in performance possibly due to the tracking system with badges and avatar evolutions. The increase in completion rates for non-graded assignments could be related to the increase in practical assignment scores since both assignments emphasize learning skills. Therefore, this finding was parallel to Domínguez et. al's (2012) findings that tracking systems help to improve students' skill set.

Improving the application of skills to real-world situations is still unclear from this implementation. Although the focus of the in-lab gamified activities was aimed at improving the application of skills, the resulting scores from projects decreased slightly and was the lowest when compared to the last three semesters. The course coordinator, graduate assistant, and teaching assistants all worked together to ensure the activities would work in practice; however, the outcome was opposite of what was expected. The researchers feel that since this was the first time teaching assistants' implemented socialized game-based instruction in their lab, more practice would be needed to become proficient with this teaching style.

Implications for Practice

For a large-enrollment course, there are many possibilities when the support system includes a course coordinator, graduate assistant, and teaching assistants. The support for the course affords more opportunities to test and improve methods of instruction. The researchers believe that providing instantaneous feedback, socialization activities, and using a team approach to development can help improve the implementation of game-based mechanics when teaching large courses.

The HTML tracking pages, badges, and avatar evolutions were created by the graduate assistant and required manual inputs. If other large-enrollment courses would want to implement such mechanics, it would be most advantageous if the system was automated and integrated into the course content management system. This would allow students to get instantaneous feedback and reward them when they complete their activities.

The paired socialization activities had the most positive affective feedback in this study. Therefore, practitioners should consider implementing this method of instruction with their students. However, the amount of time given to complete the activity needs to be carefully planned and the activity itself doable by students.

When working with a team of teaching assistants, the researchers recommend including everyone in the development process. Weekly meetings with teaching assistants were helpful, since additional concerns can arise and be accounted for effectively and efficiently.

Implications for Future Research

Specific game-based mechanics were not included in this implementation of gamification, such as leaderboards. In the literature, leaderboards have been shown to bring out the competitive nature of people and thus increase motivation (Sheldon, 2012; Werbach, Hunter, 2012). However, additional considerations need to be taken due to legal reasons such as Family Educational Rights and Privacy Act Regulations (FERPA) that could potentially be violated through the use of a leaderboard. Therefore, the researchers would like to explore this mechanic through the use of pseudo-names, which are similar to gamer tags.

Even though results of this study demonstrate that achievement in application-based assignments decreased, additional research is needed to determine if improvement in teaching assistant training and implementation of in-class gamified activities can improve student achievement. Therefore, it is possible to create a more comprehensive training program to determine how it impacts teaching assistant instruction and student learning.

Due to the increase in completion for non-graded assignments due to the implementation of a tracking system with badges and avatars, the researchers would like to explore the integration of these game mechanics into other parts of the course. For example, the researchers intend to integrate the tracking system in the lecture portion of the course to promote students reviewing lecture material more often.

Additional feedback from students and teaching assistants indicated that students wanted to have many opportunities for practice with feedback in a safe environment. Therefore, the researchers would like to integrate gamification activities, where there are low stakes and a high opportunity for rapid feedback. This idea is consistent with Gee's (2007) learning principle of "Psychosocial Moratorium" where learners can take risk in a space where real-world consequences are lowered. It also integrates Fernández-Alemán, Palmer-Brown, & Jayne's (2011) response-drive feedback approach, where feedback is instantaneous and based on user input.

Conclusion

The researchers conducted a pilot implementation of game-based mechanics in a large-enrollment introductory computer technology course. Working with the course coordinator, graduate assistant, and teaching assistant, the researchers developed teaching strategies that accounted for difficulties students typically had in the previous iterations of the course. In-lab gamified activities consisted of socialization, practicing vital skills, and feedback. The activities are also consistent with Gee's learning principles of Practice and Transfer.

A tracking system with badges and avatars was implemented as recommended by Werbach and Hunter (2012) and Raymer and Design (2011). The advantages of a badge system outlined by Antin and Churchill (2011) can be seen in the increase in non-graded assignments; however, students perceived them as neutral-positive based on the Likert-scale survey responses.

Findings demonstrate that students resonated well with components such as social interactions. They perceived the interactions to be effective in learning and enjoyed completing in-lab gamified activities with partners. Teaching assistants also noticed increased engagement through discussion in their labs.

While students did not feel strongly towards earning badges and evolving avatars, completion percentages of non-graded assignments was the highest when compared to previous semesters even though students had a desire for tangible rewards such credit. Overall, it appears that the first implementation of gamification was successful and the researchers intend to continuously improve upon the design.

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