Enhancing Learning of Engineering Graphics through Gamification

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Introduction

Generation Z, who were born after 1997 are the majority in today's college classrooms ([1]–[3]). Comparing to millennial predecessors, they grow up immersed in technology, regularly play video games, have an even shorter attention span, and prefer engaged and interactive learning ([4]–[7]). As college professors, how do we face challenges posed by tech-savvy Gen Zers and engage their learning using new technology? Gamification, also known as serious game, is the use of game thinking and game mechanisms such as points, levels, challenges, leaderboard, badges, or even rewards in a non-game context to engage learners in solving problems ([8]–[12]). It is believed that gamification with careful thought and planning can be an ultimate way to motivate student success ([13], [14]). Gamification can include the application of animation, simulation, and game elements and represents a shift from learning by listening to learning by doing. It also represents a shift from recalling information to finding and using it. From passive learning to positive learning, by including an instructional context, gamification can enhance the learning process. Since fall 2018, game elements including points, competitions, leaderboard, and rewards have been incorporated into a freshman-level engineering graphics course in a flipped classroom. It was hoped that through game-like activities, students could be motivated to solve problems in a simulated environment. The paper described a three-semester study involving engineering students in an engineering graphics course. Students' perception survey was conducted at the end of each semester and the results were analyzed to understand the effectiveness of gamification.

Methods

The engineering graphics course covers freehand engineering drawing, and fundamentals of computer-aided design (CAD), CATIA. Classes meet in a computer laboratory twice a week for one hour and forty-five minutes each to fulfill the requirements of the three-credit-hour semester-long course. Students' final weighted grade is determined by homework, online quizzes, class participation, final project, and three in-class tests. The most common course issue previously was the lack of enough practice time in class. With the flipped classroom innovation, there was more time to practice in class, however, how to motivate students to study online by themselves and how to enhance their understanding in the class time was still a challenge. It is hoped that by earning gamification points through various online and classroom activities including online interactive study, online quizzes, classroom teamwork, test practice problems, and individual competitions including using polleverywhere.com and popup questions in the class time, students can be motivated to solve problems, clarify their misconceptions, and enhance their understanding.

- **Online Interactive Study**

The course was implemented as a flipped classroom. Students were required to study materials posted online before coming to the class on the second day. Online materials included videos, audios, PowerPoint files, and interactive study developed under Rise 360 by Articulate. Students could earn up to 2 points if they finished quizzes embedded in the interactive study and earned a score of 80% or above.

- **Online quizzes**

A formal assessment including multiple-choice questions was given to the students to test their understanding after their self-study online. Before fall 2019, students were given three attempts

to finish online quizzes before the deadline. The highest score of the three attempts was recorded in their grade book. However students were not in favor of the online quizzes since they either overlooked the deadline, which caused their low quiz scores in the grade book or complained about the difficulty of the quizzes. Starting fall 2019, students were encouraged to take the first attempt as the pre-test before the self-study, and take the second attempt as the post-test after the self-study. Students earned up to 4 gamification points if they finished the quiz before the deadline and earned a score of 60% or higher. The quiz was closed in the morning on the next class day and reopened at the start of the class so that students could take the third attempt during class time. The highest score of the three attempts was recorded in their grade book.

- **Classroom Teamwork**

Students formed a team of 2 to 4 in the class time to collaboratively solve various problems in 10 to 15 minutes' time window. After the completion, all teams were given the opportunity to pick a number between 1 and 6. A six-sided die was used to determine the winning team whose selected number must match the generated number on the die. When more than one team had the same generated number on the die, a rock-paper-scissors game was used to determine the final winning team. The winning team got the chance to present their work in front of the class. If the team got a fully correct answer, each team member earned 2 points. If the team did not get the correct answer at all, the rest of the students in the class got an opportunity to steal full points. If the team got the partially correct answer, the rest of the students could correct their mistakes and split the points with the team.

- **Polleverywhere.com Individual Competition**

Polleverywhere.com was used to encourage individual competition. Multiple-choice questions were created online to test their understanding of the certain course topics. Students used either classroom computers or their cell phones to answer each question in 20 seconds time window. Students earned more points for responding quickly. After each time window was closed, their real-time responses with the correct answer were exposed to the whole class. A leaderboard was generated to show the top ten winners with most points earned from that question. Depending on the numbers of questions created on polleverywhere.com, multiple leaderboards gave students opportunities to compete and show them where they stood relative to their peers each time.

- **Gamification Points**

Gamification points students earned from the online study, online quizzes, classroom teamwork, and polleverywhere.com individual competition were accumulated and posted on Canvas. The points helped determine the monthly top three gurus on the leaderboard. They were either added to student's assignment grades or used to replace their low-class participation grades at the end of the semester. The gamification points could improve student's grades but not exceed 3% of the final weighted grade.

- **Leaderboard**

By the end of each month, the top three students with most points earned during the month were determined and announced on Canvas. All students could find their accumulated points on Canvas in their grade book. Candies as a reward were given to the top three gurus during class time to acknowledge their achievements and encourage continuous competition. The purpose of

the leaderboard was to keep students engaged in the various activities so that they were eager to earn more points next time.

Results

The student perception survey was conducted at the end of each semester in the last three semesters. There were 200 students from 9 class sections who completed survey questions with a response rate of 80%. The average class size was 25. The male to female ratio was 3:10. 5-point Likert scale was used to analyze their perceptions of gamification application in the class.

Figure 1 shows students' perception of online interactive study. The majority preferred online interactive study since the animation, videos, flashcards, and embedded quizzes kept them engaged and they could get immediate feedback after the completion of the embedded quizzes [15]. One student commented, "I felt like the interactive materials and embedded quiz were a great way to help us familiarize ourselves for the impending class it pertains to; it was not like we were going in blindly."

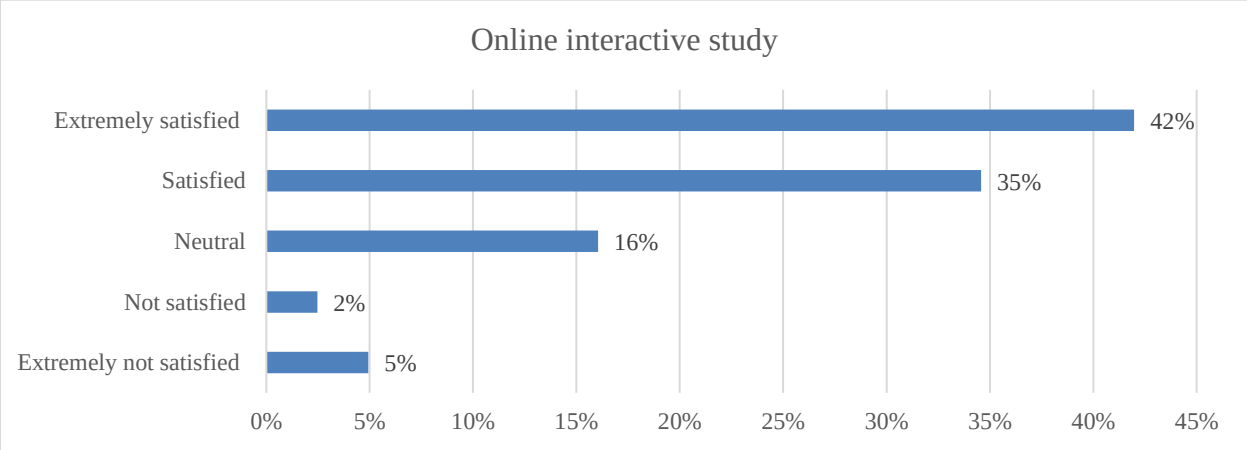

Figure 1. Students' perception of online interactive study

Figure 2 shows students' perceptions of the online quizzes, which was the formal assessment and only reflected students' feedback in fall 2019. Before fall 2019, online quizzes must be taken before their face-to-face class as a formal assessment and no incentive was given. Starting fall 2019, students could earn gamification points as an incentive to encourage taking online quizzes, almost 90% students were in favor of the online quizzes. The only reason behind was that gamification motivated students to earn points but not penalize their mistakes during the online study.

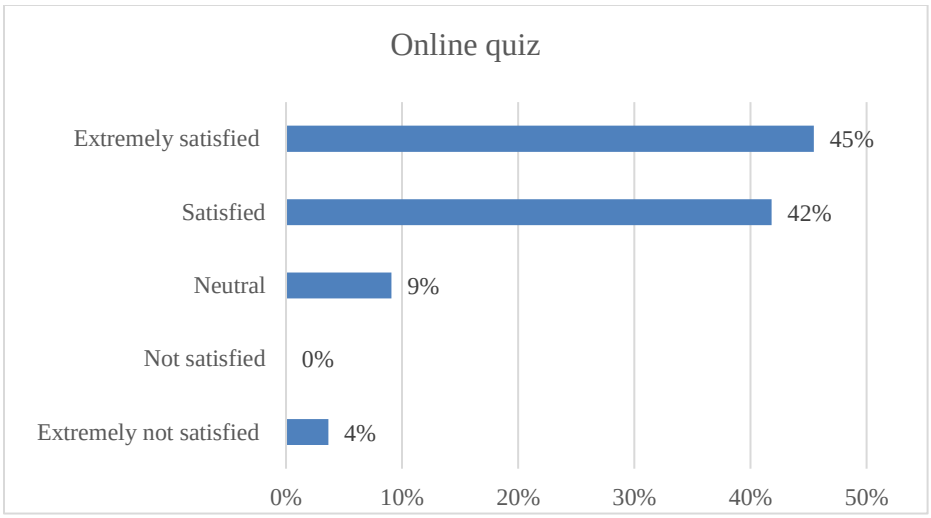

Figure 2. Students' perception of online quizzes

Figure 3 shows students' perceptions of classroom teamwork. The majority liked to work with their classmates and helped each other understand exercise problems. One student commented, "I think that my favorite one was the in-class teamwork. This really motivated me to learn the material because I didn't want to bring town my partner. It also made it simple to communicate with my partner to discuss the problems if I did not understand one." One student also commented the importance of team with equal in knowledge, "For the group work where we volunteered to give our solutions for points please make sure that the groups are equal in knowledge as some groups knew everything while others didn't so it was stacked in the odds of the smartest to win this game."

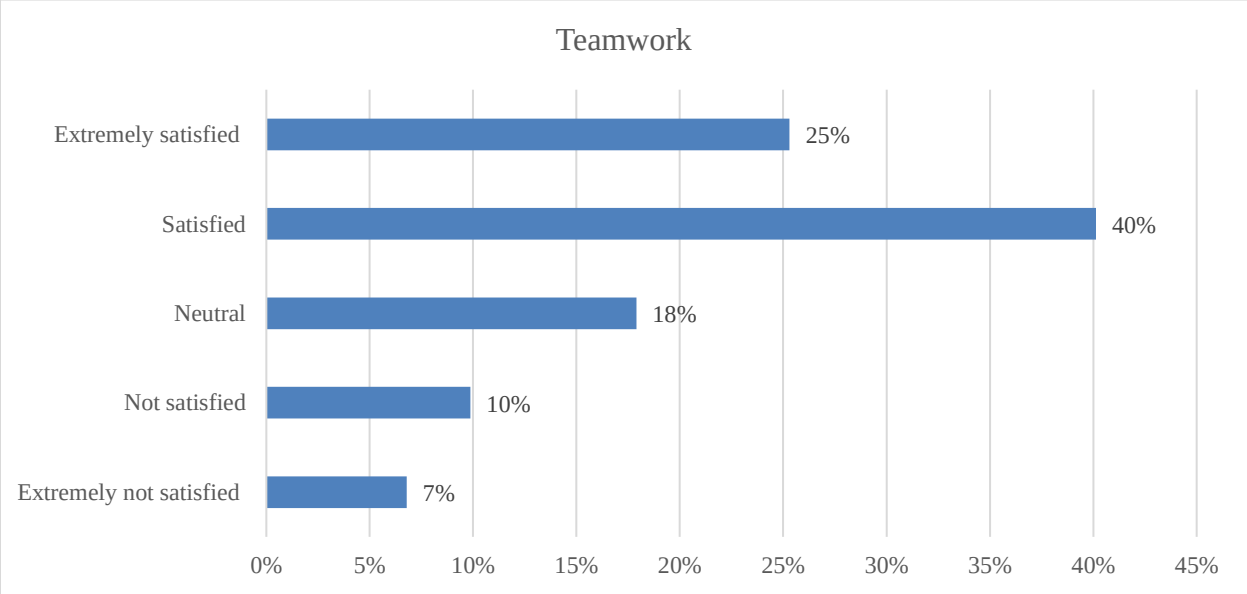

Figure 3. Students' perception of classroom teamwork

Figure 4 shows students' perception of polleverywhere individual competition. Compared to online interactive study and classroom teamwork, this one seemed less popular. Since it was just

a trial, only one individual competition was implemented in each semester. Some students showed their interest such as, “i really enjoyed the polleverywhere competition. I wish we would've done that more often rather than just one time in the class. it was definitely helpful towards my learning.”, and “I still thought that this was a good activity for class Polleverywhere- I would have liked this if we had done it more often because i thought it was like the online quizzes but timed which could help in practice for the tests.”

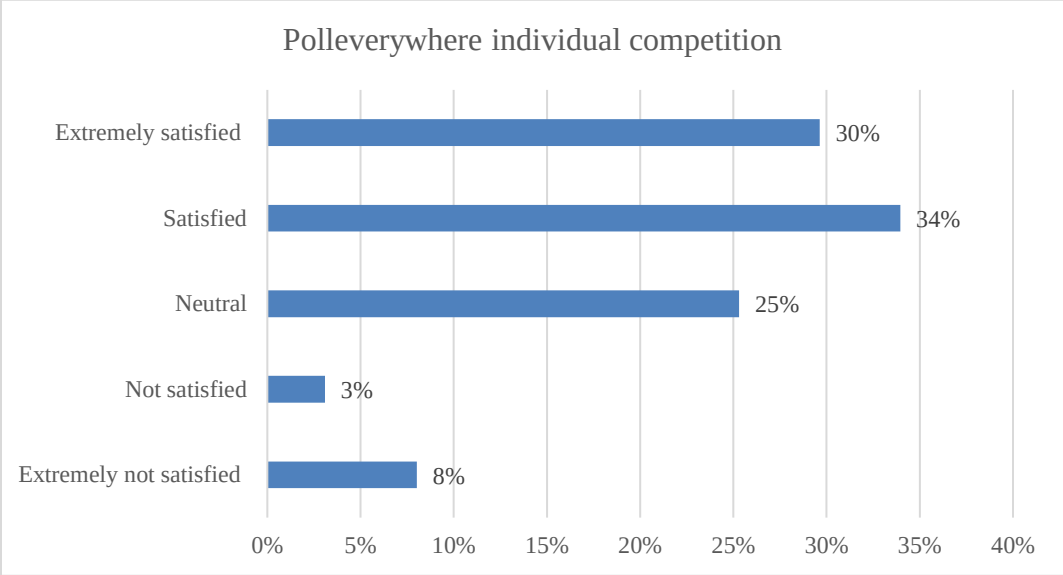

Figure 4. Students’ perception of polleverywhere individual competition

Figure 5 shows the students’ perception of the leaderboard. This one became the least popular one comparing to all the other gamification activities. Even though some students commented, “Everything else was great! Definitely felt motivated to work hard to make it unto the leader board.”, and “I think the gamification design encouraged students to be more engaged in learning and made it a competition to know more than our peers. When you see the leader board you want to try to earn more points to try to win.”, some student indicated that, “I did not like the leader board, it tended to feed peoples ego's making it not fun and making it so I was less motivated to try and win.” Toda et al [16] did an overview of negative effects of gamification in education and pointed out that leaderboards are strongly associated to the loss of performance, which is considered as one of the four negative effects in the gamified learning design.

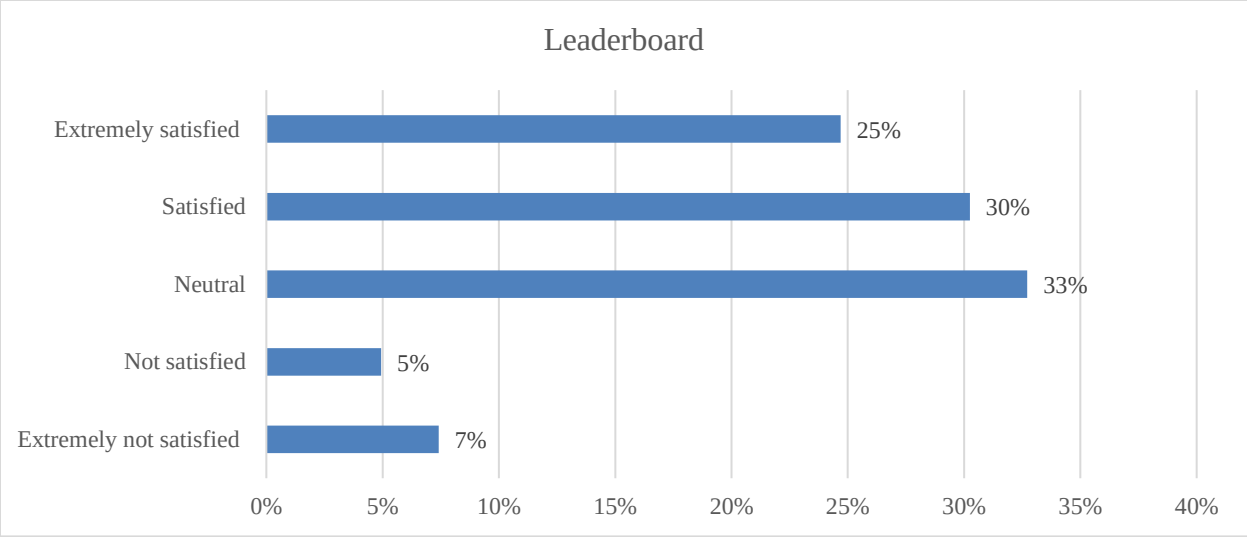

Figure 5. Students' perception of the leaderboard

Figure 6 shows students' perception of gamification points. This one could be considered the most popular gamification activity. Who did not like free points which could help improve the final grades? Especially there were so many different ways to earn points. There was no penalty at all if they got the wrong answer. The only thing they were asked to do was to give it a try. One student said that "I liked the gamification points for answering questions right in class it gave me a reason to raise my hand and made me feel accomplished when i got something right.". The other students mentioned that "Giving gamification points for the interactive online quizzes encouraged me to take advantage of them and go through them.".

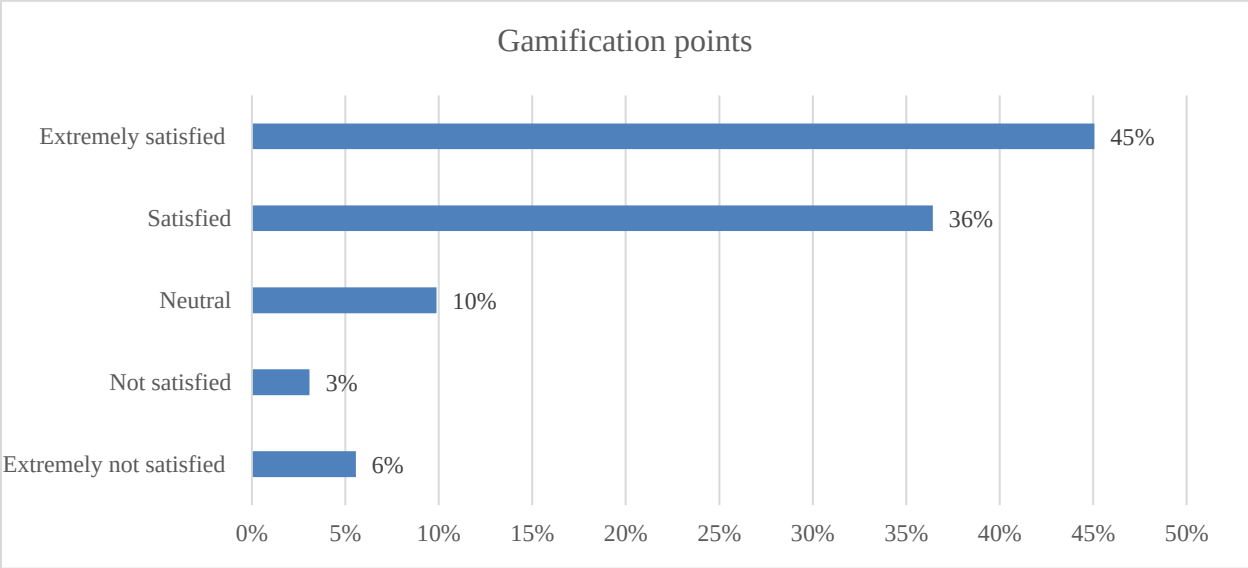

Figure 6. Students' perception of gamification points

Overall students showed their enthusiasm for gamification activities. Some additional comments are included below.

Positive comments

- "I enjoyed all of the gamification activities, I believe it made learning the material easier. My favorite is the teamwork because it is nice to learn in a group, in order to understand others perspectives."
- "I thought the gratification was approached rather well. I would do more of the polleverywhere thing."
- "I think the polleverywhere is one of the most engaging activities and can be used for both individual and teamwork gamification in conjunction with what was learned from the interactive materials with the embedded quiz."
- "Giving gamification points for the interactive online quizzes encouraged me to take advantage of them and go through them. However I felt the leader board was unnecessary, it is not a bad thing just not necessary."
- "I think the gamification design encouraged students to be more engaged in learning and made it a competition to know more than our peers. When you see the leader board you want to try to earn more points to try to win. The addition of extra credit points further gave more incentive to try to learn more because they help our grade. The online materials with embedded quiz helped us practice the new skills and helped understand the material. Overall I think the gamification design is a great idea, though I don't think there is anything else to add to it due to a limited amount of time to work on material for each class in a given day."
- "I think that the gamification system works very well and helps students that are looking for extra credit. Although I did not need extra credit, I enjoyed having the opportunity to gain points"
- "I really like it. It makes the learning process more competitive to compete against my peers. That competition makes me want to learn more and master my stuff."
- "I liked the gamification design because it included an element of fun for the course. My favorite was the polleverywhere competition because I am very competitive and it helped me remember the material. Overall, it was very successful and I enjoyed the course very much. It also motivated me to earn extra credit in case I did not do well on a particular assignment. For additional activities, there could be a kahoot on previous knowledge, or a large polleverywhere competition regarding the material learned over the entire semester."

Negative comment

- "I really do not like hearing about how good other students are doing when I am not doing so great. It makes me upset, and start to resent the class."

Conclusions and Recommendations

This paper described how to use gamification to engage Gen Zers in learning of engineering graphics course. Different gamification activities were applied to nine sections in three semesters. From the online interactive study, online quizzes, classroom teamwork to polleverywhere.com individual competition, students can earn and accumulate gamification points, which could be used to determine top game gurus on the monthly leaderboard, and help improve their final grades. A survey was implemented at the end of each semester to understand the student's perceptions. From the survey results, we learned that students highly rated gamification activities. Students believed that overall gamification could engage their learning and helped create a positive learning environment. However, game elements are associated with effects. Some game elements such as leaderboard and badges could generate negative effects. Instructors must carefully design the education context to avoid some game elements and corresponding negative effects.

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