

# Enhancing Learning and Engagement through Gamification of Student Response Systems

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### Abstract

Structuring classroom activities around games has been shown to increase student motivation and enjoyment. Less work has been done evaluating whether gamification benefits students in the particular context of a student response system (SRS). This evidence-based practice paper compares two SRSs, SurveyMonkey and Kahoot, to quantify the added value of gamification in enhancing student engagement during in-class problem sessions in a numerical methods course for biomedical engineering undergraduates. Students reported that both the traditional and gamified systems encouraged collaboration and made them more likely to complete the problems and to achieve the correct answer than if there had been no SRS. The gamified response system, however, resulted in significantly higher student motivation, enjoyment, and encouragement to collaborate than the non-gamified version. Students also indicated that gamification helped increase learning during the problem session, although it did not make them significantly more likely to complete the problems and achieve the correct answers. Our results suggest that by enhancing aesthetics and letting students compete as teams, gamification can boost the appeal and efficacy of SRSs.

#### Introduction

Student response systems (SRSs) are powerful tools for transforming classroom dynamics. Although using a response system does not automatically improve learning, studies have shown that when carefully implemented, they can increase participation, help sustain student attention, and allow instructors to better gauge levels of understanding [1], [2]. Previous systems required students to purchase dedicated equipment, but access and affordability has dramatically increased now that students can submit answers through their own laptops or mobile devices [3]. Recently, a new generation of SRSs has focused on boosting their appeal and effectiveness through gamification [4], defined as the incorporation of game design elements such as avatars, points, competition, teams, and time limits into a non-game context [5]. Gamification has been shown to enhance student engagement across a wide variety of educational activities [6].

Previous studies have reported favorable student responses to using gamified SRSs [7], [8], but less work has been done directly quantifying the difference between traditional and gamified systems. In this study, we compared two student response systems to assess the impact of gamification in the context of in-class problem sessions. Our results demonstrate significant gains in motivation, enjoyment, and collaboration with the gamified SRS compared to the non-gamified SRS. We also elucidate several contributing factors to the appeal of gamified response systems, such as attractive graphics, the ability to form teams, and a competitive scoring system. Finally, we discuss potential drawbacks that may need to be considered when introducing a game-based SRS.

#### Methods

We tested the two response systems in Computational Biomedical Engineering, a required sophomore-level numerical methods course in which 104 biomedical engineering students were enrolled. The course was taught with a hybrid format in which lecturing was interspersed with in-class problem solving sessions during each class period. After the instructor explained a new numerical method, students would work in groups of 2–3 to solve an example problem using the method while the instructor and teaching assistants walked about the classroom answering questions. Once most of students indicated they had reached an answer, the instructor would open the SRS for the students to complete. Afterward, the instructor would review the steps for achieving the correct answer and answer any remaining questions. In order to reduce stress and help students focus on mastering the concepts rather than simply rushing to determine the answer, full credit was given for the SRS based on participation.

Throughout the length of the course, we employed Kahoot, a team-based, game-show-style immediate feedback platform, as our SRS. Since only one section of the course was offered, it was not possible to teach the same class for two parallel groups of students in a single semester. Thus, to permit direct comparison between a gamified and a non-gamified SRS, we tested them on two consecutive class periods taught by the same instructor and involving comparable in-class problems and SRS questions. We use SurveyMonkey as our non-gamified SRS because, like Kahoot, it is accessible from mobile devices, can be used without charge, supports multiple choice format with anonymized participation. However, SurveyMonkey lacks music, animations, the ability to form teams with custom names, and reporting of top-scoring teams. To assess students' views of the two response systems (Table 1; Appendix 1) several days after they were tested. Survey results were anonymized, but students were given extra credit on the following homework assignment if they indicated that they completed the survey.

Metric	Question (5-point Likert scale, asked for each response system)
Motivation	The response system helps motivate me to complete the in-class problems.
Collaboration	The response system encourages me to collaborate with my classmates on in- class problems.
Enjoyment	I enjoy using the response system with the in-class problems.
Learning	Using the response system with the in-class problems helps increase student learning.
Problem completion	When there was a quiz, I was more likely to complete the in-class problems than if there had been no quiz.
Correct answer	When there was a quiz, I was more likely to reach the correct answer to in- class problems than if there had been no quiz.

Table 1. Questions used to evaluate student response systems.

The paired-sample two-sided Wilcoxon signed-rank test was used for each metric to assess the null hypothesis that differences between matched survey results for the two response systems came from distributions with zero median. The same test was also used for each question to assess the null hypothesis that survey results came from a distribution with median equal to neutral on the Likert scale.

To evaluate whether students were achieving desired course outcomes in our gamified classroom, we used pre- and post-tests designed to assess interest, expectations, and mastery of course content. Both tests used identical questions (Appendix 2) and were graded for participation only. The paired-sample two-sided t-test was used to assess the null hypothesis that differences between matched scores came from a normal distribution with zero mean. The paired-sample two-sided Wilcoxon signed-rank test was used to assess matched Likert scale responses reporting confidence for each numerical method. All statistical analysis was performed in MATLAB.

#### Results

A total of 64 students who had participated in both class sessions completed the survey evaluating the two student response systems (Figure 1). In general, the results indicated that most students perceived both versions favorably. Students agreed that use of both systems encouraged



Figure 1. Student perceptions of whether use of SurveyMonkey (SM) or Kahoot (K) increased motivation, collaboration, enjoyment, learning, problem completion, or achieving correct answers (see Table 1 for full wording). \*\*p < 0.01. \*p < 0.05. N.S. = not significant.

them to collaborate with their classmates on the in-class problems (42% for the non-gamified and 58% for the gamified SRS). An even larger group of students agreed that during the in-class active learning sessions, using a response system made them more likely to complete the problems than if there had been no response system (52% for the non-gamified and 64% for the gamified SRS). "Both worked well enough," commented one student, "and achieve the goal of increased class participation." Additionally, students concurred that they were more likely to reach the correct answer to the problems they were working on when an SRS was used (41% for the non-gamified and 48% for the gamified SRS).

Although both systems scored generally well across most metrics, the gamified SRS outperformed the non-gamified one in several key areas. A significantly higher proportion of students (66% vs. 34%) agreed that the gamified response system helped motivate them to complete the in-class problems. "The gamification and the competition liven the classroom and encourage participation," remarked one student. Likewise, significantly more students reported that the gamified version encouraged collaboration between classmates on the in-class problems, with one student praising its "team building aspect."

By far the most dramatic difference between the two systems was the level of student enjoyment, with 73% of students stating that they enjoyed using the gamified SRS. One student enthused over the points system and the music Kahoot uses, remarking that they "can really brighten up class." Another reported that the gamified SRS helped enliven the active learning sessions, commenting, "I'm always excited for the Kahoot quizzes when we get to come up with clever nicknames. I look forward to that part of class." In contrast, only 25% of students said they enjoyed using the non-gamified version, with several mentioning the lack of visual and auditory appeal: "It wasn't as aesthetically pleasing, which shouldn't make a difference in participation but is something to note."

The questions asking whether each response system helped increase student learning generated the most controversy. Overall, significantly more students (70% vs. 42%) attributed the gamified SRS with boosting learning. Several mentioned that the quick scoring after each question helped them confirm which answer was right, and claimed that the lack of immediate feedback with the non-gamified version dampened its effectiveness. However, numerous students dissented. Some voiced the opinion that although Kahoot's game-show style was fun, it hampered learning in the long run. "I think that the game-like atmosphere of Kahoot is detrimental to how well the information 'sticks' around," argued one student. Similarly, another preferred SurveyMonkey "because the questions seemed to follow more logical steps and it was less of a game." A separate criticism leveled at Kahoot's impact on learning targeted its fast, competitive pace. "Goes so quickly you don't have time to get anything out of it," complained one student. "Maybe if it wasn't so competition-heavy with the scoreboard," observed another, "I would feel less pressure to get it right and [could] focus on the concepts."

No significant difference was detected between the two systems regarding their effectiveness at improving the likelihood of completing the in-class problems and achieving the correct answer. Likewise, the average student scores were almost identical (60% correct for the non-

gamified and 59% correct for the gamified). Nonetheless, several students did report that the gamified SRS helped enhance their performance. "The Kahoot system that keeps track of points and a ranking system is much more motivating to solve problems and get the right answer," stated one. Another commented, "During a 9:30 class when many of us are tired, sometimes the best way to get me to focus is by using Kahoot, something that is fun and enjoyable, but still gets me to do the problems."

Our pre- and post-tests for the course indicated that students were successfully meeting course objectives in the gamified classroom, though obviously these improvements across the semester cannot be attributed solely to the gamified SRS. Average scores on identical sets of multiple-choice questions with 4 options rose from 28% correct during the first week of class (barely higher than random) to 89% correct by the last week (Figure 2). Moreover, confidence in implementing numerical methods rose significantly across a wide range of techniques and algorithms (Figure 3).



Figure 2. Improvement in course content mastery between the first and last weeks of class as assessed by 7 multiple-choice questions (n = 103 students). The difference between pre- and post-tests was significant at p < 0.01.

#### Discussion

This study indicated several benefits of response system gamification, including higher levels of motivation and enjoyment, as well as increased collaboration and greater improvements in student learning. Our results generally agree with previous studies that have reported positive student reception to game-based SRSs [7]–[9]. The numerous comments praising Kahoot's aesthetic appeal emphasize the powerful effect of music on classroom dynamics [10]. Likewise, enthusiasm for the points-based system and the ability to form team names comports with past observations of the wide appeal of games in the classroom, even for students without a gaming background [11].

The conflicting perspectives observed in this study regarding how gamification affected learning emphasize the diverse attitudes students hold toward game-like systems [12], [13]. Given that some students perceive an inherent tension between cultivating a fun versus a scholarly atmosphere, instructors may wish to explain the measured benefits of gamification to learning so that it is not merely perceived as an unwelcome distraction [14], [15]. In addition, despite the ability for competition to increase student engagement [16], caution may need to be exercised to ensure the competitive dynamic does not result in students feeling disempowered





[17], [18]. The fact that students in this study viewed the gamified SRS as increasing collaboration suggests that encouraging students to work in teams may help mitigate negative aspects of competition.

One limitation of our study was that it was restricted to a single type of active learning activity, implementation of numerical methods. It would be intriguing to determine whether the advantages of gamification depend on the genre of course material, and to study how student enthusiasm varies across grade levels. A drawback to using SurveyMonkey as the non-gamified SRS was its lack of immediate feedback. Since many non-gamified systems do provide instant feedback, such as Quiz Socket, Poll Everywhere, and Mentimeter [3], comparing a gamified system to one of these would help eliminate this confounding factor. Yet another limitation was the potential for instructor preferences to influence student perceptions of the two systems. Finally, given differing opinions about whether benefits of gamification are enduring [19], [20], it would be helpful to track independent groups of students to look for long-term differences in knowledge retention and course enjoyment. More work is needed to assess the potential for gamification of response systems to produce long-term benefits to student learning.

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Appendix 1: Google Forms survey questions used to evaluate response systems. All questions used a 5-point Likert scale from Disagree to Agree unless otherwise noted.

- For which of the last two class sessions were you present? (*Both, Tuesday, Thursday, neither*)
- The SurveyMonkey response system helps motivate me to complete the in-class problems.
- The Kahoot response system helps motivate me to complete the in-class problems.
- The SurveyMonkey response system encourages me to collaborate with my classmates on in-class problems.
- The Kahoot response system encourages me to collaborate with my classmates on inclass problems.
- I enjoy using the SurveyMonkey response system with the in-class problems.
- I enjoy using the Kahoot response system with the in-class problems.
- Using the SurveyMonkey response system with the in-class problems helps increase student learning.
- Using the Kahoot response system with the in-class problems helps increase student learning.
- When there was a SurveyMonkey quiz, I was more likely to complete the in-class problems than if there had been no quiz.
- When there was a Kahoot quiz, I was more likely to complete the in-class problems than if there had been no quiz.
- When there was a SurveyMonkey quiz, I was more likely to reach the correct answer to in-class problems than if there had been no quiz.
- When there was a Kahoot quiz, I was more likely to reach the correct answer to in-class problems than if there had been no quiz.
- Please add any additional comments you have regarding the SurveyMonkey response system: (*long-answer free response*)
- Please add any additional comments you have regarding the Kahoot response system: (*long-answer free response*)

Appendix 2: Pre- and post-test questions used to evaluate learning outcomes.

Self assessment of preparation

- On a scale of 1-5 (5 being highly confident), how confident are you in your knowledge and skills in the following topics?
  - Programming control structures (if/then, for/while loops)
  - Programming functions
  - Taylor series
  - Binary numbers
  - Numerical integration and differentiation
  - Matrix multiplication
  - Gaussian elimination
  - Computational methods for solving ODEs
- With which of the following programming languages do you have experience? (*MATLAB, Python, Java, C++, other*)

Course content questions

- What type of error causes unexpected results when you type 1 3\*(4/3 1) in MATLAB? (*Truncation error; Roundoff error; Approximate error; True error*)
- Which of the following methods can be applied to data points, without an explicit equation (e.g. for f(x) or f'(x))? (*Adaptive Euler's method; Quadratic interpolation; Finite difference method for PDEs; Newton–Raphson method*)
- Which of the following methods is considered a bracketing or closed method? (*Forward-divided difference method; Euler's method; Simpson's 1/3 rule; Bisection method*)
- What is the goal of nonlinear regression on a function f(t,p) with parameter p? (*To* maximize f(t,p); *To* minimize f(t,p); *To* find a value of p that is a root of the sum of squares error; *To* find a value of p that maximizes the sum of squares error; *To* find a value of p that maximizes the sum of squares error; *To* find a value of p that maximizes the sum of squares error; *To* find a value of p that maximizes the sum of squares error; *To* find a value of p that maximizes the sum of squares error; *To* find a value of p that maximizes the sum of squares error; *To* find a value of p that maximizes the sum of squares error.
- Which of the following approximation methods is NOT derived from a Taylor Series expansion? (*Newton's method; Gaussian elimination; Interpolation; Simpson's 1/3 rule*)
- In the vicinity of a function's maximum, which optimization method converges the fastest? (*Golden section; Steepest ascent; Newton's method; Newton-Raphson method*)
- Which method can be used to find the maximum of a function when you cannot take its derivative? (*Newton–Raphson; Newton's method; Steepest ascent; Golden-section search; Secant method*)