The Impact of Gamification on Student Engagement and Learning in Science: A Study on Team Jeopardy

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ABSTRACT

Student engagement in a science classroom is challenging and most students perceive science courses as difficult. Gamification is an emerging strategy used by educators across various disciplines to increase student engagement and promote active learning. One known gamification technique is team Jeopardy, however, there is a gap in knowledge about the effectiveness of team Jeopardy in a biology classroom at the community college level. We hypothesized that team Jeopardy would improve student engagement and academic performance when implemented in biology courses. To assess this hypothesis, we used a one-group pretest-posttest study design and quantitative student surveys on 55 Community College of Baltimore County students who were enrolled in 4 different biology courses. Students' academic performance was measured using pre/post quizzes before and after a game of team Jeopardy was implemented. In addition, student perception and engagement were measured using surveys. Using paired t-tests, we found a statistically significant improvement in student quiz scores after team Jeopardy implementation with varying magnitudes of improvement across different biology courses. Quantitative analysis of survey data indicated a positive impact of team Jeopardy on subject matter retention, student engagement, student confidence, and enthusiasm in the classroom. In conclusion, gamification techniques like team Jeopardy have a positive impact on student

engagement and performance. Thus, this study has useful implications for science educators seeking to enhance student success by creating dynamic and stimulating learning environments.

INTRODUCTION

In most science courses, foundational knowledge of the subject must be mastered before moving on to higher-level concepts. Foundational knowledge involves understanding and memorizing basic facts and vocabulary. However, students often find it difficult to grasp, retain, and recall concepts learned in a traditional science lecture (Alaagib et al., 2019). Moreover, students are not always motivated to put effort into memorizing material and may be only marginally engaged in learning from a lecture. Therefore, student engagement in a science classroom is a challenging endeavor for educators (Schmidt et al., 2015). Student engagement represents the mental intersection between motivation and active learning, and teachers can do much to promote motivation and active learning in the classroom (Barkley, 2020). Thus far, student engagement has been achieved through methods designed to promote active learning and incorporation of student motivation techniques in the classroom pedagogy (Martella et al., 2021; Church, 2021). That said, the integration of new technology-based techniques, such as gamification, is becoming increasingly popular in recent years.

Gamification in education is a strategy to enhance student engagement by introducing game elements into non-game environments, such as conventional classrooms (Laura-De La Cruz et al., 2023). The goal of gamification is to generate the level of involvement and enthusiasm associated with a game for learning activities. There is also a large body of literature on the benefits of incorporating gaming in all levels of education. A meta-analysis of academic literature has shown significant positive effects on cognitive, motivational, and behavioral outcomes due to gamification in the classroom (Sailer & Homner, 2019). Another recent meta-analysis of literature had found that science students benefited more from gamification than other disciplines, including business, engineering/computing and social sciences (Li et al., 2023). Further, gamification in education elevates problem-solving, team-working, and communication skills (Zvarych et al., 2019). Several previous studies have shown that gamification can positively impact student engagement and retention of learning (Lutfi et al., 2023; Paľová & Vejačka, 2022; Pozo-Sánchez et al., 2022). In addition, gamification has been shown to reduce

student anxiety and create a supportive, empowering student-centered environment (Gironella, 2023).

Team Jeopardy is a gamification technique that encourages student participation and teamwork (Barkley, 2020). The earliest classroom experiments with Jeopardy include trials for students with mild learning disabilities (Rotter, 2004). In addition, studies have shown a positive impact on student attitudes and perceptions when students find the learning environment enjoyable (Afari et al., 2012; Boctor, 2013). However, many of these studies are based solely on student surveys and observations and very few of them examined student academic performance after the intervention. Therefore, there is a paucity of research on the effectiveness of team Jeopardy on cognitive learning outcomes by quantitatively assessing student knowledge, specifically in a Community College environment. Moreover, there is ambiguity in the results of the limited research conducted. In one of the studies conducted with medical students, Jeopardy significantly increased the students' knowledge of psychopharmacology, although the students exposed to traditional methods also displayed similar gains (Shiroma et al., 2010). Another study conducted with computer science students found little difference in student performance between the group of students exposed to Jeopardy and those not exposed (Simkin, 2013).

While previous studies have concluded minimal variance in academic performance between students exposed to Jeopardy and those not (Shiroma et al., 2010; Simkin, 2013), we hypothesized that team Jeopardy would improve student learning outcomes and student engagement in a Community College biology classroom. In this study, we aimed to quantitatively assess the academic performance and student perception of team Jeopardy as an active engagement technique to improve student learning outcomes.

METHODS

Study Participants

The research participants were Community College of Baltimore County students from sections of 4 different biology courses, Human Biology (BIOL 107), Human Anatomy and Physiology (BIOL 109), Molecules and Cells (BIOL 110), and Microbiology for Mortuary Science (BIOL 245) that ran in spring 2024. The BIOL 107, BIOL 109, and BIOL 245 sections were taught fully in-person. BIOL 110, however, was a hybrid online class, in

which the class only met in person once a week for a laboratory and a recitation session. Information such as age and whether the student was new, returning, or a transfer student was collected. Table 1 summarizes the characteristics and the sample sizes from each course. The research was approved by the Institutional Review Board of the Community College of Baltimore County and informed consent was obtained from all participants.

Table 1. Student Characteristics.

	Sample size (N)	**Number of students in each age category (Years)**	**Student type**
Human Biology (BIOL 107)	7	Below 20: 2 21-30: 4 31-40: 0 41-50: 0 50 & above: 1	New: 3 Returning: 0 Transfer: 4
Human Anatomy & Physiology (BIOL 109)	22	Below 20: 5 21-30: 11 31-40: 5 41-50: 1 50 & above: 0	New: 5 Returning: 15 Transfer: 2
Molecules and Cells (BIOL 110)	10	Below 20: 6 21-30: 4 31-40: 0 41-50: 0 50 & above: 0	New: 4 Returning: 2 Transfer: 4
Microbiology for Mortuary Science (BIOL 245)	16*	Below 20: 1 21-30: 6 31-40: 4 41-50: 2 50 & above: 1	New: 1 Returning: 12 Transfer: 1
All courses combined	55*	Below 20: 14 21-30: 25 31-40: 9 41-50: 3 50 & above: 2	New: 13 Returning: 29 Transfer: 11

Table 1. Student Characteristics.			
	Sample size (N)	**Number of students in each age category (Years)**	**Student type**
*2 students from BIOL 245 did not participate in the survey.			

Study Design

This study used a quasi-experimental design to examine the impact of team Jeopardy on students. A one-group, pretest-posttest design was used which included a pretest measure followed by a treatment and a posttest for a single group (Jhangiani et al., 2019). The team Jeopardy game was designed using a Microsoft PowerPoint template, which looks like the television version of "Jeopardy!". The topics and questions were different based on the course, but each Jeopardy game had at least 24 questions in at least 4 categories related to a specific chapter from the textbook. Questions were organized into point-based categories and varied in difficulty, with more points allocated for challenging questions. Pretest and posttest quizzes were designed to cover 1 specific chapter with 10-15 multiple-choice questions.

Implementation of Team Jeopardy and Data Collection

Instructors administered a proctored pretest quiz immediately after teaching a chapter through a conventional lecture. Students then partnered to play team Jeopardy for 45-60 minutes, followed by a proctored posttest quiz on the same objectives. All activities were completed on the same day, except in BIOL 107. Due to time constraints in BIOL 107, team Jeopardy and the posttest quiz were conducted the following day after the conventional lecture and pretest quiz. In all courses, the pretest quiz was administered promptly after the conventional lecture, and the posttest quiz followed immediately after team Jeopardy.

We adapted the team Jeopardy technique described previously (Barkley, 2020). Teams of students took turns selecting the category and point values of boxes on a grid that corresponded to chapter-based content questions. When the question was revealed, a team was given a minute to answer the question on the screen. Upon each correct answer, the team was awarded the allocated points. If the team failed to answer

correctly, then that same number of points was deducted, and other teams were presented the opportunity to answer the question. If any other team answered correctly, the points were added to their total score. The other team answering would not be penalized for an incorrect answer. After each correct answer, the team who answered was asked to explain their answer to the class. The instructors gave meaningful feedback, affirming correct answers while correcting any misconceptions from incorrect answers.

Student perception was measured through a questionnaire. Questionnaire responses used the 1-5 Likert scale, where 1 was the lowest rating and 5 was the highest rating. Surveys were administered using Microsoft Forms and responses were anonymized as they were collected. Instructors and other researchers involved could track who participated in the study but could not connect student identities to survey responses. As an incentive, students were offered extra credit for completing the surveys.

Furthermore, a retrospective analysis was conducted to examine the impact of team Jeopardy on exam scores across 2 different semesters for BIOL109. The control group consisted of students from the spring 2023 semester, while the intervention group comprised students from the fall 2023 semester. In the intervention group, team Jeopardy was played 2 days before a unit exam was administered. Team Jeopardy covered material from each unit of the course curriculum and similar procedures were followed as those described in the previous section. In the control group, students followed the standard course curriculum without implementation of team Jeopardy before unit exams. Unit exams in both groups had the same questions and were administered the same way. Exam scores from 3 units (Units 1-3) were collected from the control and the intervention groups. Scores from students who withdrew from the class were excluded from the study.

Data Analysis

Data from the pretest and posttest quizzes were analyzed to evaluate the impact of team Jeopardy on quiz scores. Descriptive statistics, such as mean and standard deviation were calculated for pretest and posttest scores. A paired sample t-test was conducted to assess the statistical significance of any difference between the pretest and posttest quizzes. For each survey question, the mean score and standard deviation were computed, and frequency distribution was examined to identify the

percentage of students selecting each option. The unit exam scores from spring 2023 and fall 2023 were compared using independent sample t-tests to assess any statistical significance. All statistical analysis was performed using Python 3.12.0 and statistical significance was determined using a predetermined alpha level of 0.05.

RESULTS

Varied and Significant Positive Effect of Team Jeopardy on Biology Course Outcomes

In this study, we analyzed pretest and posttest quiz data from 55 students in 4 different biology courses (BIOL 107, BIOL 109, BIOL 110, and BIOL 245). The mean pretest and posttest scores and statistical analyses are summarized in Table 2. The mean pre-quiz scores for BIOL 107, BIOL 109, BIOL 110, and BIOL 245 were 67.14%, 61.31%, 48.75%, and 74.16%, respectively. While the comparable mean post-quiz scores were 90.24%. 81.43%, 91.07%, 93.75%, and 91.24%, respectively. Across the 4 biology courses, students demonstrated varying degrees of improvement from their pretest scores to posttest scores after participating in team Jeopardy. The magnitude of improvement differed among courses with a 40.75% improvement in the post-test across all courses combined, as reflected in the changes of scores (Table 2). Among the tested courses, BIOL 110 exhibited the highest improvement of 92.3%. BIOL 107, BIOL 109 and BIOL 245 showed 21.29%, 48.55% and 23.03% improvement in the post-test, respectively.

Table 2. Effect of Team Jeopardy on Quiz Scores.

	Quiz type	Mean score (%)	Standard deviation	t-Statistic (paired)	Improvement (%)	p-value
Human Biology (BIOL 107)	Pre-test	67.14	11.13	-1.759	21.29	p = 0.129
	Post-test	81.43	17.73			
Human Anatomy & Physiology (BIOL 109)	Pre-test	61.31	27.07	-5.963	48.55	p = 7.85E-06*
	Post-test	91.08	12.59			

Table 2. Effect of Team Jeopardy on Quiz Scores.						
	Quiz type	**Mean score (%)**	**Standard deviation**	**t-Statistic (paired)**	**Improvement (%)**	**p-value**
Molecules and Cells (BIOL 110)	Pre-test	48.75	30.44	-4.965	92.3	p = 0.00163*
	Post-test	93.75	7.44			
Microbiology for Mortuary Science (BIOL 245)	Pre-test	74.16	15.19	-4.438	23.03	p = 0.000479*
	Post-test	91.24	10.24			
All courses combined	Pre-test	64.11	23.88	-8.217	40.75	p = 6.67E-11*
	Post-test	90.24	12.28			
*Statistically significant ($p < 0.05$)						

Individual paired t-tests were then performed for each course and the combined dataset included all courses. The tests yielded a t-statistic of -8.217 for the combined data set and t-statistics of -1.759, -5.963, -4.965, and -4.438 for BIOL 107, BIOL 109, BIOL 110, and BIOL 245, respectively. All t-statistics were in a negative direction, indicating a consistent improvement in post-quiz scores compared to pre-quiz scores. It should be noted that BIOL 107 has a uniquely low absolute value t-statistic compared to the other class results. Furthermore, when analyzing the p-values of the datasets, all values except for BIOL 107 were found to be below the significance level of 0.05, indicating strong evidence against the null hypothesis and supporting the conclusion of a statistically significant difference in quiz scores before and after the team Jeopardy activity. The tests yielded a p-value of 6.67e-11 for the combined data set and p-values of 0.129, 7.85e-06, 0.00163, and 0.000479 for BIOL 107, BIOL 109, BIOL 110, and BIOL 245, respectively. The lack of statistical significance of the BIOL 107 results may be due in part to the relatively small sample (N = 7). Regardless, the low p-value of the combined data set indicates that there is strong evidence against the null hypothesis, signaling that there is a statistically significant difference between the means of the 2 paired groups. BIOL 109 also strongly rejects the null

hypothesis with a very low p-value of 7.85e-06. The results for BIOL 110 and BIOL 245 also reject the null hypothesis, but with comparatively higher p-values. It is also important to note that the data set (excluding combined) with the lowest p-value was BIOL 109, which also had the largest sample size (N = 22). Overall, this study demonstrates a statistically significant improvement in student quiz scores after participating in Team Jeopardy, with the degree of improvement varying across different biology courses.

Student Survey Responses Indicated Positive Perceptions and Benefits of Team Jeopardy

A total of 53 students took the survey after participating in team Jeopardy. Quantitative assessment of student responses to survey questions showed a positive impact of team Jeopardy in all 4 biology courses. The frequency distribution of responses for each assessed element in the courses is summarized in Figure 1. The percentage of responses for the highest outcome (5 on the Likert scale) for each element is described below. 74% of students (86% in BIOL 107; 86% in BIOL 109; 70% in BIOL 110; 50% in BIOL 245) reported that team Jeopardy helped them retain subject matter effectively (concepts and vocabulary). 64% of students (86% in BIOL 107; 64% in BIOL 109; 70% in BIOL 110; 50% in BIOL 245) indicated that their understanding of subject matter increased. 57% of students (57% in BIOL 107; 59% in BIOL 109; 70% in BIOL 110; 43% in BIOL 245) agreed that engaging in team Jeopardy increased self-confidence for learning. A significant portion of students (83% in total; 86% in BIOL 107; 91% in BIOL 109; 90% in BIOL 110; 64% in BIOL 245) reported feeling more engaged in the classroom after participating in team Jeopardy. The survey results suggest that engaging in team Jeopardy fosters collaboration and communication in the classroom with 74% of students (86% in BIOL 107; 86% in BIOL 109; 90% in BIOL 110; 57% in BIOL 245) indicating that team Jeopardy helped to build their teamwork skills. Many students acknowledged the positive influence of competition (76% in total; 82% in BIOL 109; 90% in BIOL 110; 57% in BIOL 245), stating that it motivated them to perform better. A notable percentage of students (62% in total; 57% in BIOL 107; 73% in BIOL 109; 70% in BIOL 110; 43% in BIOL 245) reported an increased enthusiasm for the subject after engaging in team Jeopardy. Many students (72% in total; 86% in BIOL 107; 73% in BIOL 109; 80% in BIOL 110; 57% in BIOL 245) expressed a high level of enjoyment during team Jeopardy sessions. 74% of students (82% in BIOL 109; 80% in BIOL 110;

57% in BIOL 245) indicated an increased motivation for learning. Overall, the survey responses demonstrated a positive impact of integrating team Jeopardy into a biology classroom on various aspects of student engagement and learning.

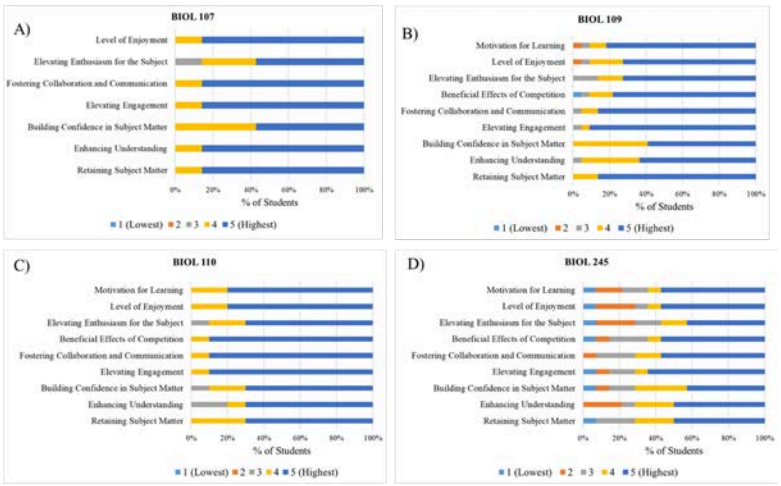

Figure 1. Frequency distribution of responses to student surveys in A) Human Biology (BIOL 107), B) Human Anatomy and Physiology (BIOL 109), C) Molecules and Cells (BIOL 110), and D) Microbiology for Mortuary Science (BIOL 245). How students perceived team Jeopardy was measured using a self-administered survey on 53 students who participated in team Jeopardy. The survey used a 1-5 Likert scale, where one being the lowest and 5 being the highest. The percentage of students selected each numerical value was determined and depicted for each question on the survey.

Engaging in Team Jeopardy May Enhance Exam Performance

Table 3: Effect of Team Jeopardy (Fall 2023) on Exam Scores Compared with the Control (Spring 2023) Group.						
		Number of students	**Mean score (%)**	**Standard deviation**	**Improvement (%)**	**p-value**
Exam 1	Control	16	58.12	19.26	19.22	p = 0.09
	Team Jeopardy	17	69.29	17.49		
Exam 2	Control	16	61.25	17.55	10.73	p = 0.25
	Team Jeopardy	17	67.82	14.63		
Exam 3	Control	16	65.88	19.58	12.26	p = 0.28
	Team Jeopardy	17	59.35	18.25		
Pooled Exams	Control	48	59.35	18.46	12.26	p = 0.28
	Team Jeopardy	51	67.66	16.58		
*Statistically significant ($p < 0.05$)						

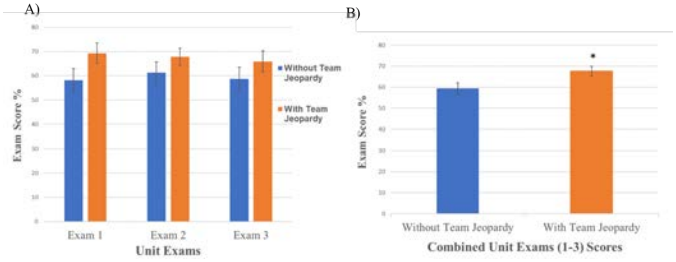

Figure 2. Mean exam scores on the A) individual units 1-3 and B) combined exams. Blue bars represent in the control group (without team Jeopardy, N = 16) and orange bars are the intervention group (with team Jeopardy, N = 17). The range of the standard error of the mean is depicted. An independent t-test analysis was performed to compare the control and intervention groups (*$p < 0.05$).

In an additional analysis, we pooled the exam scores from all 3 exams which allowed for a comprehensive evaluation of overall performance on exams. The pooled mean exam score for the control group was 59.35% whereas the pooled mean score for the intervention group was 67.67% (Table 3 and Figure 2B). Intriguingly, a statistically significant difference between the groups was revealed ($p < 0.05$). This suggests that when considering performance across all 3 exams, the students exposed to team Jeopardy performed significantly better than the control.

DISCUSSION AND CONCLUSION

The findings of this study, stemming from a 1-group, pretest-posttest quasi experimental design, highlight the positive impacts of integrating team Jeopardy into community college biology classes. The statistically significant improvement observed in student academic performance following exposure to team Jeopardy aligns with existing literature on other gamification strategies in the classroom such as Kahoot! and gamified quizzes (Sanchez et al., 2020; Wichadee & Pattanapichet, 2018). Contrary to our findings, when investigating the impact of team Jeopardy on academic performance, Shiroma et al. (2010) and Simkin (2013) did not report statistically significant results. This discrepancy in research findings could be due to differences in study design, participant demographics, or implementation of the team Jeopardy intervention. For instance, variations in the duration of the intervention, the way the game was facilitated, or the specific learning objectives targeted and measured may have contributed to the divergent outcomes observed across different studies. Further research may be warranted to reconcile these discrepancies and elucidate the effect of team Jeopardy on student performance.

Interestingly, we found that the magnitude of improvement in quiz scores varied across different biology courses. This observation may be due to factors such as the complexity of course content, nuances in different learning environments, or variations in student characteristics and cognitive profiles. Our findings suggest that some courses may benefit more from team Jeopardy than the others. For instance, students in Human Anatomy and Physiology (BIOL 109), a class that relies heavily on memorizing facts and vocabulary, displayed the second largest mean score increase, suggesting the applicability of team Jeopardy in increasing student retention of key concepts and vocabulary in BIOL 109 students. The largest gain was observed in Molecules and Cells, BIOL

110, which was a hybrid online course with face-to-face classes once a week. This suggests that the learning environment may play a role in the effectiveness of team Jeopardy in enhancing student performance. Differences in student academic backgrounds, learning styles, and prior experiences of students enrolled in various biology courses can influence their receptiveness to instructional methods or pedagogical approaches and consequently, their learning outcomes. Supporting this assertion, a previous study has shown that the effectiveness of gamification strategies partially relies on students' individual characteristics (Smiderle et al., 2020).

Quantitative analysis of student survey responses provides valuable insights into the perceived impact of the team Jeopardy intervention across several dimensions of the learning experience. Our findings are in agreement with prior research on student perceptions of various gamification techniques, including team Jeopardy (Afari et al., 2012; Boctor, 2013; Asniza et al., 2021). Most respondents reported positive effects in terms of retaining subject matter, enhancing understanding, building confidence, elevating engagement, fostering collaboration, and increasing enjoyment. Notably, these effects varied across the different biology courses. Microbiology for Mortuary Science, BIOL 245, showed marginally lower frequencies of positive responses compared to other courses. This may be because BIOL 245 covers topics that are less conducive to the interactive format of team Jeopardy. The BIOL 245 students' individual characteristics such as motivation and prior knowledge may also influence their experience with team Jeopardy.

Our findings support numerous benefits to team Jeopardy and hold significant implications for educators and curriculum designers seeking to enhance student engagement and academic achievement in a community college biology classroom. It is evident that gamification techniques such as team Jeopardy have a positive impact on student engagement and performance by creating a dynamic and stimulating learning environment. Furthermore, positive student survey feedback indicates the importance of generating student-centered, collaborative, and interactive pedagogies. This is especially crucial for complex subjects that are typically difficult for students, such as biology.

However, it is important to acknowledge certain limitations of this study. The 1-group, pretest-posttest design lacks a control group, which diminishes its ability to establish a causal relationship between the

intervention and the outcome. Additionally, the quasi-experimental design introduces selection bias, and a lack of randomization limits the generalizability of the findings. However, the 1-group pretest-posttest design controls individual differences among participants because each participant serves as their own control. This helps to reduce the influence of confounding variables that may be present in 2-group study designs. Although the 1-group pretest-posttest design has its limitations, it is still incredibly useful because of its simplicity and efficiency when an experimental control is challenging to achieve.

Another limitation in the study was the use of self-reported student surveys subject to response bias. Participants may provide socially desirable responses or recall their experiences inaccurately. Additionally, interpretation of survey questions may vary among respondents. To overcome some of the limitations, future research should be designed more rigorously using randomized, controlled trials with larger samples to validate these findings. Moreover, further studies are needed to identify the factors that affect the observed variability in student achievement and perception across different biology courses.

In conclusion, our study provides valuable insight into the positive impact of team Jeopardy on academic performance and the overall learning experience in biology courses. By gaining a deeper understanding of the course-specific factors that affect the effectiveness of team Jeopardy, educators can refine their educational strategies and optimize the implementation of team Jeopardy to match the specific needs of the course.

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