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RESEARCH ARTICLE

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Gamified learning: Assessing the influence of leaderboards on online formative quizzes in a computer programming course

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Abstract

This quasi-experimental study investigates the impact of gamification on learning outcomes and course engagement in the computer programming course, a mandatory course in the Electronics and Communication Technology and Mechatronics Technology departments. The experimental group (EG) ($N = 48$) utilized leaderboards for gamified weekly online formative exams, while the control group ($N = 48$) used nongamified exams. Our hypothesis was that the EG would exhibit higher quiz completion rates and improved learning. However, the findings indicate no significant difference between gamified and nongamified approaches in terms of learning and course engagement. Although the EG completed more quizzes, it did not result in a substantial difference. Correlations reveal a positive relationship between theoretical exam scores and the number of completed quizzes, suggesting that gamification may not directly enhance learning. Notably, the overall impact of quiz completion on learning is more pronounced when considering all participants. Furthermore, the decline in quiz completion rates after the third week in both groups suggests that gamification may yield an innovative effect but lacks long-term sustainability. These results suggest that gamification may be suitable for short-term activities, such as 2–3 weeks, and may not sufficiently engage all students in the lesson.

KEYWORDS

achievement, computer programming course, engagement, engineering education, gamification

1 | INTRODUCTION

In the field of engineering education, the use of technology for teaching activities has become increasingly prevalent, offering numerous benefits. For this reason, engineering educators organize technology-supported interactive teaching activities [12] to improve students' learning. However, the successful implementation of technology-supported interactive teaching activities, especially in the context of online learning environments, requires careful consideration and preparation. One crucial aspect is the effective engagement of students in the learning process, particularly during assessments.

Traditionally, assessment systems have undergone significant changes due to technological advancements, with a shift toward online formative assessments (FAs) [25]. However, it can be challenging to motivate students to actively participate and remain engaged in online courses outside the traditional classroom setting. Therefore, it is essential to explore methods that can make online teaching as engaging and enjoyable as possible [49].

Gamification, a popular approach fueled by technological advancements, has gained attention in education [20, 27]. The use of gamified elements, such as leaderboards, in teaching activities has shown promise in improving learning outcomes, student motivation, and engagement [14, 19, 43, 47]. However, the specific effects of gamification elements, such as leaderboards, on student participation and academic achievement in engineering education require further exploration.

1.1 | Gamification, leaderboards, and online quizzes

The use of interactive multimedia in online activities has been shown to increase students' attention, curiosity, interest, and excitement while improving their perseverance, knowledge construction, and critical thinking skills [50]. As a result, game-based teaching approaches have gained popularity as effective tools for improving learning outcomes [40, 45]. Gamification, as an instructional design strategy, allows for the integration of game elements at both macro- and microlevels, ranging from subtle incorporation to full game-like experiences [41].

The effectiveness of gamification in education has been supported by an increasing number of experimental studies [3]. It has been recognized that a game-based teaching approach can improve learning outcomes, motivate students, and enhance engagement [14, 19, 43, 47].

Sanchez et al. [45] implemented gamification in an online exam module within a learning management system and found that the inclusion of gamification elements led to increased student participation in preparatory exams [35]. Ibáñez et al. [29] evaluated the learning effectiveness and classroom participation of a gamified learning exercise in a course on the C programming language. The results showed that students' participation in gamified learning activities positively influenced their engagement and led to moderate improvements in learning outcomes.

However, research on the impact of gamification on student performance and motivation in educational activities has yielded conflicting results [10, 19]. While some experimental studies have demonstrated the effectiveness of gamification in various ways [7, 22, 33], others have reported mixed findings [17, 20, 27].

In the realm of online gamified activities, leaderboards have emerged as one of the most commonly used game design elements [3, 26, 33] due to their utility and ease of implementation [26]. Several studies have highlighted the advantages of incorporating leaderboards in gamified educational environments.

The leaderboard is a visual element that ranks players based on their achievements. In an educational context, it provides students with comparative feedback on their performance within a gamified environment, allowing them to see how they compare to other students in the same course [14, 15]. Leaderboards can also display group averages if students are grouped together.

Research studies in gamified courses have shown that leaderboards can have positive effects on students' performance [4, 33, 34], course participation [5, 46], and the amount of activity students engage in related to the course [20, 28, 36, 38, 49]. Leaderboards can also motivate users to replay and increase their engagement [4, 35] and can serve as external incentives to improve students' academic performance [38].

However, there are some caveats to consider. Interactions with leaderboards may only have a short-term impact [3, 31, 32], and if students focus solely on climbing the leaderboards, it may not necessarily lead to meaningful learning or high-quality work [20, 28, 42, 49]. Additionally, while the competitive nature of leaderboards can be beneficial for students who enjoy high competition, it can have a negative impact on underperforming students [3, 11, 49]. It is important to note that short-term performance gains from extrinsic rewards provided by leaderboards can potentially reduce students' intrinsic motivation [27, 42].

To better understand the effects of gamification, it is essential to examine individual game elements separately rather than in combination [18]. Studying the effects of specific game elements, such as leaderboards, on outcomes like learning performance, motivation, and engagement can provide a clearer understanding of their impact in a given context [38]. This knowledge can guide educators in making informed decisions about the implementation of gamification, including the use of leaderboards.

Despite the growing popularity of gamification in both educational and industrial settings [27], there are some concerns regarding its educational benefits, particularly in engineering education. While gamification may be perceived positively by users in many studies, the actual effects on learning outcomes are not always reported [27]. Additionally, most studies on gamification are short-term and typically do not exceed a duration of 3 weeks [10, 48]. Gamification studies have often focused on evaluating the outcomes without in-depth examination.

Online quizzes are among the most common items that are gamified. Additionally, online formative quizzes have emerged as a significant feature that can be gamified [23, 30]. These quizzes offer opportunities for continuous assessment and immediate feedback, thereby supporting student progress and performance tracking [1, 9]. However, there remains a need to determine the comparative effectiveness of gamified online formative quizzes, specifically those incorporating leaderboards, in terms of their impact on learning outcomes.

Assessment in education can be categorized into two types: summative assessment (SA) and FA. SA is typically conducted at the end of the teaching process to inform decisions about student learning, while FA is integrated into the educational process to provide feedback for both students and teachers, with the aim of improving learning outcomes [6, 8, 44] Well-designed FA, including online quizzes, can enhance learning outcomes and the quality of teaching [25].

The use of online quizzes for FA has gained popularity, offering students unlimited trial opportunities and multimedia features [25]. Online quizzes are easily accessible outside the classroom and are considered effective tools for FA [2]. They provide students with instant feedback, allowing them to gauge their understanding of each topic [23, 30]. Furthermore, online application of weekly quizzes enables instructors to track students' progress and performance more efficiently [1, 9].

The advancement of learning management system (LMS) technology has facilitated the design, implementation, and grading of various assessment tools, including quizzes, in a faster and more streamlined manner compared to traditional paper-based tests. Additionally, LMS technology has increased instructor–student interaction [25].

1.2 | Aim

The aim of this study is to investigate the impact of gamification, specifically the use of leaderboards and online quizzes, on student performance and motivation in engineering education. By examining the effects of these gamification elements individually, we seek to gain a more precise understanding of their influence in a specific educational context.

While gamification has gained attention as an effective instructional approach across various domains, its specific applications and benefits in engineering education have not been extensively explored. Engineering education faces unique challenges, including the need to engage students in complex problem-solving tasks and foster their motivation to learn and excel in technical subjects.

The rationale for this study stems from the growing interest in gamification as an instructional approach and the need for empirical evidence regarding its effectiveness in engineering education. While gamification has shown promising results in enhancing learning outcomes and student engagement in various fields, there is a lack of research specifically targeting engineering education. By focusing on leaderboards and online quizzes, which are commonly used gamification elements, we aim to contribute to the understanding of how these elements impact student performance and motivation in the engineering domain.

Furthermore, the investigation of these gamification elements individually allows for a more nuanced analysis of their effects, which can inform educators on the appropriate implementation of gamification strategies. This research will provide valuable insights into the potential benefits and limitations of gamification in engineering education, ultimately guiding educators in designing effective and engaging learning experiences for engineering students.

Therefore, this study aims to address the research gaps in engineering education by examining the effects of gamified weekly formative quizzes, with a focus on leaderboards, on student success and engagement. The context of the study will be the Computer Programming Language (CPL) course, which is compulsory in the Electronics and Communication Technologies (ECT) and Mechatronics Technology (MT) departments.

The research questions guiding this study are as follows:

RQ1: *Is there a significant difference between the group using gamified online formative quizzes and the group using nongamified online formative quizzes in terms of academic achievement?*

RQ2: *Is there a significant difference between the group using gamified online formative quizzes and the group using nongamified online formative quizzes in terms of course engagement?*

RQ3: *Is there a significant difference between the group using gamified online formative quizzes and the group using nongamified online formative* *quizzes in terms of the number of completed quizzes and time spent on task?*

RQ4: *Is there a correlation between students' quiz attempts, time spent, achievement, and course engagement?*

In summary, this study aims to contribute to the existing literature by examining the effects of gamified online formative quizzes, incorporating leaderboards, on student success and class participation in the CPL course. By filling the identified research gap, we aim to provide valuable insights for educators and contribute to the enhancement of teaching practices in engineering education.

2 | METHOD

In our study, we employed a matching pretest and posttest control group (CG) design, commonly used in quasi-experimental studies, as random assignment of students into experimental and CGs was not feasible. This design allows researchers to investigate the impact of a manipulated independent variable (online formative quiz) on various dependent variables (achievement, engagement, quiz attempts, time spent on task) [16, 21, 24]. Both the CG and experimental group (EG) participated in weekly online quizzes for the CPL course. However, the EG differed in that it utilized leaderboards, created based on the results of online quizzes, for gamification purposes.

2.1 | Participants

This research was conducted during the fall semester of 2022–2023 in the Algorithm unit of the CPL course, which is a compulsory course offered by a Turkish state university in the Departments of ECT and MT. The study included 96 sophomores who were enrolled in the CPL course, which was taught by two instructors with 4 years of teaching experience in the CPL course. The participants were not randomly assigned to conditions as the groups (classes) were already established and the instructors had no control over the group composition. To determine if there were any significant pre-existing differences between the groups, the students' CPL knowledge was assessed using one-way analysis of variance (ANOVA) at the beginning of the study ($F(3, 92) = 0.335$, $p = .800$). Based on the ANOVA results and to account for the variable of the department in which the students were enrolled, one class from the ECT department (EG: 1, $N = 23$), one class from the MT department (EG: 2, $N = 25$), and one class from each department ($N = 48$) were included in the CG.

2.2 | Context and data collection procedure

The CPL course is offered to second-year students in the ECT and MT departments, totaling 3 h per week. The course consists of theoretical and practical components, with 1 h conducted by an instructor and the remaining 2 h conducted by two instructors for hands-on practice. It is divided into two units: "Algorithm and Flow Diagrams" and "Visual Programming." Each unit concludes with both a practical and theoretical exam, with the practical exam carrying a weight of 60% and the theoretical exam carrying a weight of 40%.

The Algorithm unit, which incorporates online formative quizzes, focuses on topics such as algorithms, algorithm logic, and flow diagrams. The aim is to equip students with problem-solving skills by breaking down problems into steps, analyzing them in smaller parts, gaining diverse perspectives, and effectively resolving them.

To support face-to-face teaching, an LMS page was created for the CPL course (see Figure 1). The page includes lecture notes, practice questions, and weekly online quizzes designed by the instructors. While presentations and PDF files are accessible to everyone, the online quizzes are restricted to registered students. Notably, Activity Results, a Moodle plugin, is utilized to generate leaderboards displayed on the right side of the screen (Figure 1).

Upon completing the online quizzes, EG participants are ranked on the leaderboard based on their scores. Additionally, the LMS generates class rankings by calculating the average scores of students within each class. The leaderboard displays the top three highest-scoring students and the bottom three lowest-scoring students from the EG who completed the online quiz. Furthermore, another leaderboard showcases the rankings of the EG classes based on their average scores. An illustrative screenshot of the leaderboard is provided in Figure 2.

Figure 3 presents a sample screenshot of the weekly online quizzes. These quizzes, created by the researchers, consist of 10 multiple-choice questions for each week of the unit. Students in both the EG and CG are allotted 10 min to complete the exams.

Once the students began the quiz, their progress is automatically tracked on the LMS. The instructor had access to information such as the time spent by each student on the exam and their performance on individual

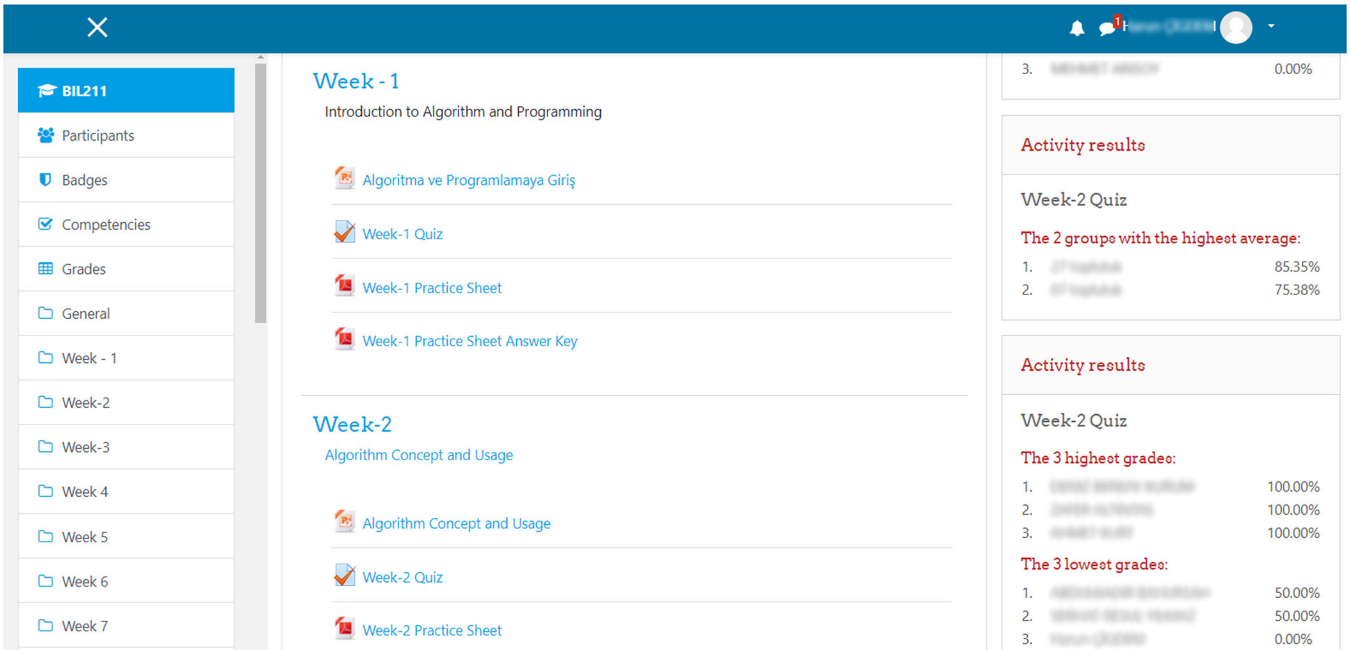

FIGURE 1 Learning management page of computer programming course.

questions. Figure 4 displays a sample screenshot of the page where quiz results can be viewed.

Data for this study were collected through six online activities, including a pretest, formative quizzes, and a midterm exam, which encompassed both theoretical and practical components of the CPL course. Additionally, the Perceived Academic Engagement Scale (PAES), developed by Öncü, [39] was employed to assess students' engagement during the implementation. For the EG group, two leaderboards were generated weekly specifically for the online quizzes, allowing students to attempt them as many times as desired.

The PAES utilized a 7-point Likert scale ranging from 1 (never) to 7 (always). It consisted of two dimensions, active learning (AL) and paying attention (PA), each comprising four items. The original study reported satisfactory internal consistency reliability values, with Cronbach's α coefficients of .85 for AL and .77 for PA. In this study, the internal consistency coefficients were calculated as .84 for AL and .72 for PA.

2.3 | Data analysis

Assumptions for *t* tests and ANOVA were assessed to ensure the validity of the analyses. The data obtained exhibited normal distribution for both groups and all measurements. ANOVA was conducted to examine significant differences in pretest results across classes. Additionally, *t* tests were utilized to determine significant differences in exam scores, engagement levels, number of quiz completions, and time spent on quizzes between the groups.

Pearson correlation analysis was performed to assess the relationships between the number of quizzes completed, time spent on quizzes, scores from theoretical and practical exams, midterm exam results, and PAES scores.

3 | RESULTS

3.1 | Difference between EG and CG in terms of academic achievement

The distribution of EG and CG's exam scores is presented in Table 1.

No significant differences were found between the EG and CG in terms of the theoretical exam ($t(94) = -0.375$, $p = .708$), practice exam ($t(94) = -0.553$, $p = .581$), and midterm exam ($t(94) = -0.666$, $p = .507$) results, according to the results of the *t* tests conducted (Table 2).

3.2 | Difference between EG and CG in terms of course engagement

The PAES results presented in Table 3 strongly indicate that students are almost completely engaged in course activities using online formative quizzes. In other words,

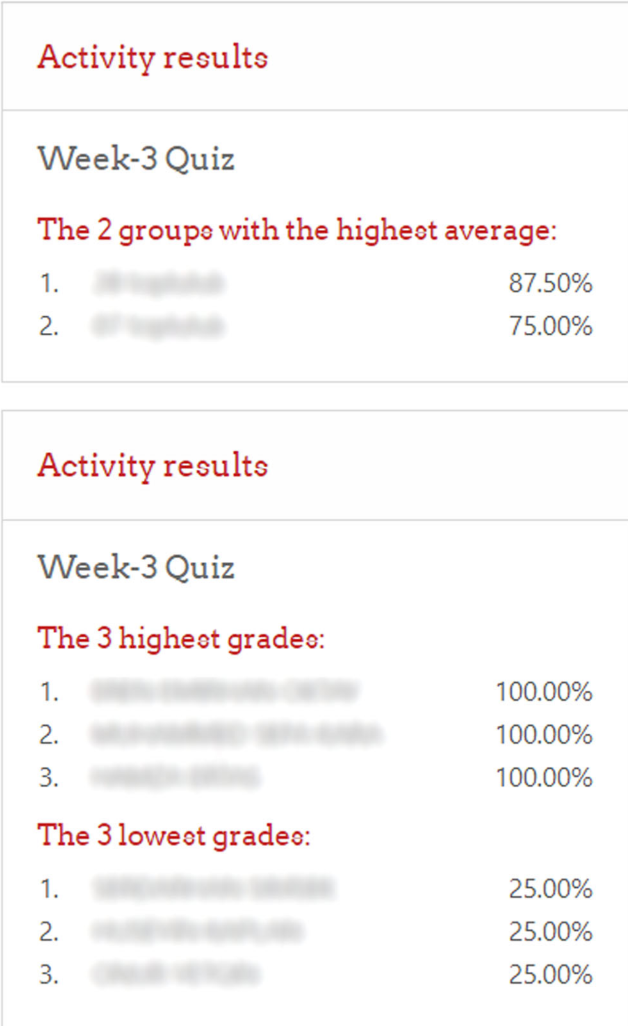

FIGURE 2 A sample screenshot of leaderboard.

their academic commitment was high throughout the experiment.

The results of the *t* tests conducted to examine the differences in the results of PAES and its subdimensions between the EG and CG showed no significant differences. These findings are presented in Table 4.

3.3 | Difference between EG and CG in terms of number of completed quizzes and time spent on task?

Table 5 displays the results of the online formative quizzes administered in the CPL course. The table includes information on the number of students who completed each quiz, the total number of quizzes completed, the average number of quizzes completed, and the time taken by students to complete the quizzes in seconds. The data is presented separately for EG and CG.

The number of students who completed the weekly online quizzes showed a decrease in both the CG and EG, particularly after the third quiz (Table 5). However, the decrease was more pronounced in the CG. Interestingly, in the quiz conducted 1 week before the exam, the number of students who completed the exam was higher in the CG compared to the EG.

The results of the independent samples *t* test comparing the EG and CG for the total time spent on weekly quizzes and the total number of quiz attempts are presented in Table 6. No significant differences were found in completion rates and time spent on all other quizzes, including the overall number of completions.

3.4 | Correlation between number of students' quiz attempts, time spent, exam results, and course engagement

To explore potential relationships between the number of completed quizzes, time spent on quizzes, theoretical exam results, practice exam results, posttest results, and PAES scores (including subdimensions), Pearson correlation coefficients were calculated (Table 7). The analysis revealed a correlation between PAES scores and posttest grades, indicating a relationship between students' perceived academic engagement and their performance on the posttest.

Table 7 shows that there were no significant correlations observed between student engagement (PAES, AL, and PA) and exam results, as well as the number of completed weekly online quizzes and time spent. This suggests that students' engagement with the course was not necessarily linked to their exam performance.

Interestingly, when examining the relationship between exam results, number of completed quizzes, and time spent, it was found that both midterm exam and theoretical exam results were positively correlated with the number of quizzes completed and the time spent. This finding aligns with the nature of theoretical exams in computer-related courses, where students' ability to express their knowledge of paper is highly valued. In contrast, practice exams often involve trial-and-error methods. Consequently, the emphasis on theoretical knowledge in the weekly online quizzes may have contributed to this correlation.

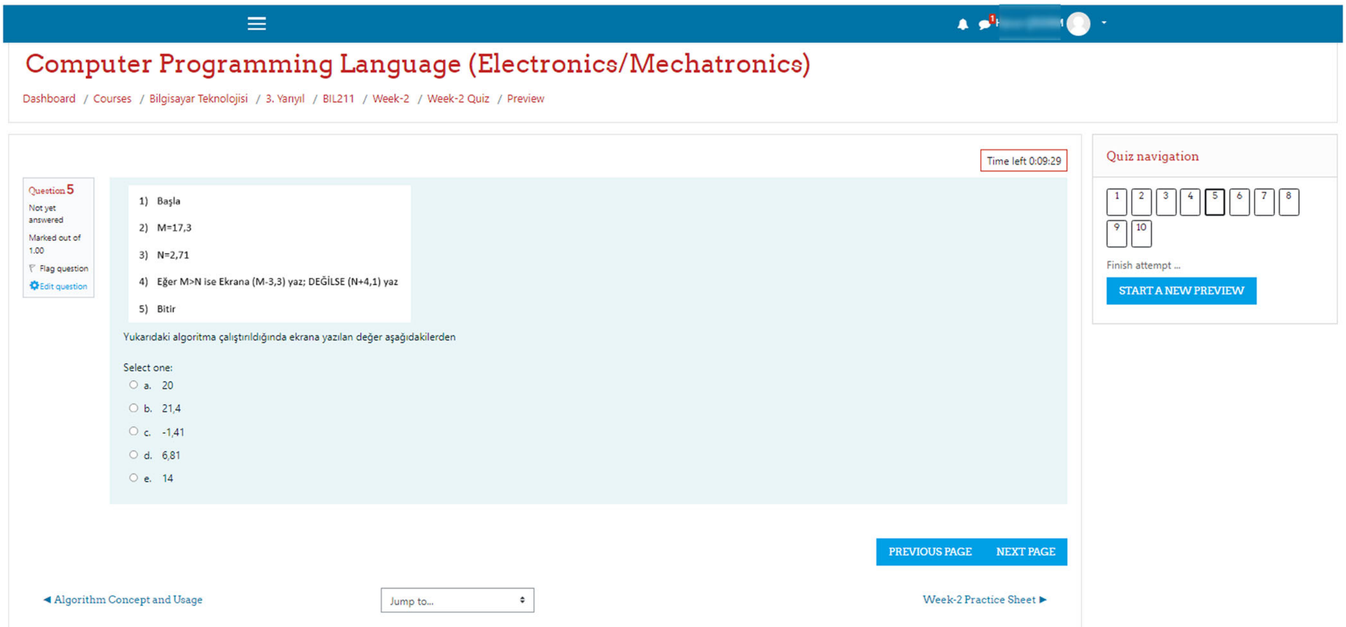

FIGURE 3 A sample screenshot of the weekly online quizzes.

First name / Surname	Email address	State	Started on	Completed	Time taken	Grade/100.00	Q. 1 /10.00	Q. 2 /10.00	Q. 3 /10.00	Q. 4 /10.00	Q. 5 /10.00	Q. 6 /10.00	Q. 7 /10.00	Q. 8 /10.00	Q. 9 /10.00	Q. 10 /10.00
[illegible]	[illegible]	Finished	25 October 2022 10:56 AM	25 October 2022 11:02 AM	5 mins 9 secs	80.00	0.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	10.00	10.00
[illegible]	[illegible]	Finished	25 October 2022 10:58 AM	25 October 2022 11:04 AM	6 mins 30 secs	40.00	10.00	0.00	10.00	0.00	0.00	0.00	10.00	10.00	0.00	0.00
[illegible]	[illegible]	Finished	25 October 2022 10:58 AM	25 October 2022 11:04 AM	5 mins 51 secs	70.00	0.00	10.00	10.00	10.00	10.00	0.00	10.00	10.00	10.00	0.00
[illegible]	[illegible]	Finished	25 October 2022 10:58 AM	25 October 2022 11:05 AM	6 mins 33 secs	60.00	0.00	10.00	10.00	10.00	10.00	0.00	10.00	0.00	10.00	0.00
[illegible]	[illegible]	Finished	25 October 2022 10:58 AM	25 October 2022 11:01 AM	3 mins 14 secs	70.00	10.00	10.00	10.00	10.00	10.00	0.00	10.00	0.00	0.00	10.00

FIGURE 4 The sample screenshot of the quiz results.

4 | DISCUSSION

In this study, the impact of gamified online formative quizzes, specifically using leaderboards, on learning outcomes and course participation was examined in the Algorithm unit of the CPL course. The course is compulsory for students in the ECT and MT departments. Both the experimental and CGs engaged in weekly online quizzes, with the EG incorporating leaderboards for gamification purposes. The findings indicate a positive relationship between solving weekly online quizzes, regardless of gamification, and students' learning outcomes, particularly in theoretical exams.

4.1 | Difference between EG and CG in terms of academic achievement

The findings of this study reveal that gamifying the online quiz activity did not yield a significant effect on

TABLE 1 Means and standard deviations of exams.

Group/Class	n	Pretest M	Pretest SD	Theoretical exam M	Theoretical exam SD	Practice exam M	Practice exam SD	Midterm exam M	Midterm exam SD
Experimental	48	40.00	14.03	64.97	12.00	89.68	12.50	79.80	9.28
EG1	23	41.82	14.49	69.08	11.21	91.56	12.96	82.57	9.13
EG2	25	38.32	13.67	61.20	11.65	87.96	12.05	77.25	8.85
Control	48	38.60	13.85	64.02	12.99	88.16	14.37	78.50	9.78
CG1	23	38.91	14.70	69.78	10.62	88.13	13.65	80.79	8.11
CG2	25	38.32	13.32	58.72	12.89	88.20	15.28	76.40	10.83

TABLE 2 Differences in theoretical, practice, and midterm exams by groups.

Exam	t test	Groups	Descriptives M	SD	Max	Min	N
Theoretical	$t(94) = -0.375$, $p = .708$	EG	64.97	12.00	88.00	49.00	48
		CG	64.02	12.99	88.00	22.00	48
Practice	$t(94) = -0.553$, $p = .581$	EG	89.68	12.50	100	60.00	48
		CG	88.16	14.37	100	47.00	48
Midterm	$t(94) = -0.666$, $p = .507$	EG	79.80	9.28	94.00	58.60	48
		CG	78.50	9.78	94.40	52.00	48

Abbreviations: CG, control group; EG, experimental group; SD, standard deviation.

TABLE 3 Descriptive statistics for the Perceived Academic Engagement Scale (PAES).

Scale dimensions/Items	Min	Max	M	SD	Cronbach's α
Active learning (AL. four items)	3.50	7.00	6.13	1.00	.841
I participated in class discussions	1.00	7.00	6.06	1.28	
I tried to answer the questions of the teacher during discussions	3.00	7.00	6.16	1.08	
I approached the teacher when I had to clarify something	2.00	7.00	6.36	1.09	
Asked questions and contributed to discussions in class	1.00	7.00	5.94	1.39	
Paying attention (PA. four items)	3.00	7.00	6.29	0.80	.717
I concentrated in class	4.00	7.00	6.43	0.88	
I went to classes	3.00	7.00	6.65	0.79	
I listened intensively to lectures	2.00	7.00	6.18	1.08	
I helped my classmates who did not understand the lesson	1.00	7.00	5.89	1.46	
Overall mean score (PAES all eight items)	3.25	7.00	6.21	0.84	.876

Abbreviations: *M*, mean; SD, standard deviation of the mean.
Source: Öncü (2015).

learning. The inclusion of leaderboards as a gamification element did not demonstrate a noticeable impact on student achievement, as all other activities remained the same for both groups. This aligns with the mixed results reported in the literature regarding the relationship between gamification and academic performance. While studies by Mekler et al. [37] and Sanchez et al. [45] have shown significant improvements in performance through

TABLE 4 Differences in PAES and its subdimensions by groups.

Subscale	t test	Groups	Descriptives *M*	SD	*Max*	*Min*	*N*
Active learning	$t(94) = 0.505$, $p = .614$	EG	6.08	1.02	7.00	3.50	48
		CG	6.19	0.99	7.00	3.50	48
Paying attention	$t(94) = 1.181$, $p = .241$	EG	6.20	0.88	7.00	3.00	48
		CG	6.39	0.71	7.00	4.25	48
PAES	$t(94) = 0.857$, $p = .394$	EG	6.14	0.90	7.00	3.25	48
		CG	6.29	0.79	7.00	3.88	48

Abbreviations: CG, control group; EG, experimental group; *M*, mean; PAES, Perceived Academic Engagement Scale; SD, standard deviation of the mean.

TABLE 5 Number of students, completed quizzes (CQ), and average time-spent for groups' weekly online quizzes.

Quiz	Experimental group Mean of CQ	Total of CQ	No. of students	M of time spent in seconds	Control group Mean of CQ	Total of CQ	No. of students	*M* of time spent in seconds
1	3.16	152	48	459.50	2.67	123	46	405.50
2	3.51	165	47	610.65	1.59	70	44	261.38
3	7.42	312	42	911.00	6.69	261	39	891.28
4	7.93	230	29	1065.65	6.82	157	23	982.52
5	10.04	66	24	1390.29	8.50	86	18	1101.55
6	2.27	241	29	632.17	2.00	153	43	536.84
Total	24.29	1168	48	3575.47	17.70	851	48	2739.02

TABLE 6 Differences in total time spent on weekly quizzes and the total number of quiz attempts by groups.

Dimension	t test	Groups	Descriptives *M*	SD	*Max*	*Min*	*N*
total time spent on weekly quizzes	$t(94) = -1.686$, $p = .095$	EG	3575.47	2668.90	12375.00	241.00	48
		CG	2739.02	1951.51	8636.00	578.00	48
total number of quiz attempts	$t(94) = -1.753$, $p = .083$	EG	24.29	22.23	107.00	2.00	48
		CG	17.71	15.43	64.00	2.00	48

Abbreviations: CG, control group; EG, experimental group.

gamification, our findings contradict those results. Moreover, studies [4, 29, 33, 34, 38] have reported the direct or indirect enhancement of student performance through the use of leaderboards, which contrasts with our findings. Conversely, the findings of Hanus and Fox [27] and de-Marcos et al. [17] support our study, as they found lower test scores among learners in a gamified environment.

4.2 | Difference between EG and CG in terms of course engagement

All students in the study demonstrated high levels of course engagement. In other words, there is no significant difference in engagement due to gamification, and contrary to these research findings, some studies have found an increase in student engagement [5, 13, 19, 46].

TABLE 7 Correlations (Pearson's *r* values) between course grades (midterm, theoretical, and practice exams), online quiz logs (QA, TS), and PAES scores, and ($n = 96$).

	ME	TE	PE	QA	TS
Midterm exam (ME)	1.000				
Theoretical exam (TE)	0.532[a]	1.000			
Practice exam (PE)	0.852[a]	0.009	1.000		
Number of quiz attempts (QA)	0.338[a]	0.323[a]	0.200	1.000	
Time spent on solving quiz (TS)	0.288[a]	0.277[a]	0.168	0.932[a]	1.000
Active learning	0.086	0.011	0.095	0.055	0.070
Paying attention	0.187	0.036	0.198	0.158	0.125
Overall PAES	0.139	0.023	0.150	0.107	0.101

Abbreviation: PAES, Perceived Academic Engagement Scale.

[a]Correlation is significant at the 0.01 level (two-tailed).

4.3 | Difference between EG and CG in terms of number of completed quizzes and time spent on task

No significant differences were observed in the total time spent on weekly quizzes, the total number of quizzes completed, the time spent on weekly quizzes, and the number of quizzes completed, except for the second week. The significant difference in the second week can be attributed to the novelty effect of the leaderboards, motivating students to complete more quizzes to secure a higher ranking. However, this effect was not sustained over time.

Examining the data in Table 5 for subsequent weeks reveals a significant decrease in the number of students completing the quizzes, particularly after the third week, in both the experimental and CGs. This suggests that the impact of the new method introduced in the course, whether gamified or not, diminishes within a span of 3–4 weeks.

These findings highlight the need for ongoing innovation and varied instructional strategies to sustain student engagement beyond the initial stages of implementation.

The findings of this study align with existing literature regarding the positive impact of gamification on student engagement. The high number of students who participated in the quizzes, completed quizzes, and the total time spent are consistent with previous studies [20, 28, 36, 38, 49]. The inclusion of leaderboards likely motivated students to repeat quizzes, leading to increased task time, as supported by prior research [4, 35]. However, the decrease in the number of students completing the quizzes after the third test, observed in both groups as shown in Table 5, may reflect the transient nature of students' interaction with leaderboards, as mentioned in the literature [3, 31, 32]. This highlights the importance of considering sustained engagement strategies to maintain student involvement throughout the course.

4.4 | Correlation between number of students' quiz attempts, time spent, exam results, and course engagement

The students' engagement, irrespective of the group they were in, positively correlated with their midterm exam results. This suggests that the implementation of weekly online quizzes in the course increased students' engagement and, consequently, their success.

The positive correlation observed between the number of quizzes completed by students and their performance in the theoretical exam, among the various components of the midterm exam, can be attributed to the testing effect. The more quizzes students completed, the more successful they tended to be in the theoretical exam. This finding supports previous studies [45] that have demonstrated the positive effects of the testing effect on student learning in online systems.

Although the gamified approach did not significantly impact the number of quizzes completed and time spent by students, it can be interpreted that the significant difference in midterm exam results was actually driven by the increased number of students taking the test and completing quizzes due to the gamified method. This aligns with previous research [33, 35] highlighting the influence of completed quizzes on exam performance.

4.5 | Limitations and future research

4.5.1 | Limited focus on leaderboards

This study only examined the effect of leaderboards among various gamification elements. Other gamification elements, such as badges or levels, were not explored separately. Future research could investigate the impact of different gamification elements individually to gain a comprehensive understanding of their effects.

4.5.2 | Reliance on quantitative measures

This study relied on quantitative measures, including the PAES scale, exam grades, and LMS logs of completed quizzes. Incorporating qualitative data, such as interviews or surveys, could provide valuable insights into students' experiences and perceptions of gamified online learning. Future studies may consider collecting qualitative data to complement the quantitative findings.

4.5.3 | Lack of significant difference in achievement

Although this study did not find a significant difference in the effectiveness of gamified online formative quizzes compared to nongamified quizzes, it is important to note that the literature indicates a need for further research on gamification elements. Thus, this study supports the call for additional investigation into the effects of gamified learning.

In conclusion, while this study contributes to understanding the impact of leaderboards in gamified online formative quizzes, future research should explore other gamification elements, incorporate qualitative data, and continue investigating the effects of gamified learning to provide a more comprehensive understanding of its potential benefits.

4.6 | Practical implications

Practical implications can be drawn from this study, particularly for teachers in the field of engineering. The findings highlight the benefits of implementing weekly online quizzes, particularly when gamified using leaderboards, in improving student engagement and completion rates. Teachers can leverage online formative quizzes as a valuable tool to enhance student learning.

The use of leaderboards in the online learning environment offers a practical and easily adaptable method to gamify other activities. By incorporating leaderboards, teachers can effectively capture students' attention and enhance their engagement with course materials. This approach can be extended to various online learning activities, encouraging active participation and promoting a deeper understanding of the subject matter.

Moreover, considering the positive correlation between the number of completed online quizzes and students' self-learning, teachers can consider diversifying the quiz formats. Incorporating different question types, such as open-ended or short-answer questions, can enhance students' preparation for practice exams and facilitate a comprehensive understanding of the course material.

However, it is crucial to acknowledge the short-lived nature of student interest and participation, as observed in previous studies [31, 45]. Teachers should consider designing and implementing gamified activities that account for the individual characteristics and preferences of learners. By tailoring gamification approaches to meet students' needs, more students can benefit from the activities and maintain their engagement over time.

Overall, the practical implications of this study suggest that the strategic implementation of gamified online quizzes, particularly through leaderboards, can enhance student engagement, completion rates, and self-directed learning. Teachers can leverage these insights to design effective gamified activities and foster an engaging online learning environment.

5 | CONCLUSION

The conclusions of this study indicate that the implementation of weekly online quizzes, regardless of gamification, can positively influence student learning outcomes. The significant factor contributing to this improvement appears to be the number of quizzes completed by students, suggesting the influence of the testing effect. The findings highlight the importance of regular practice and assessment in reinforcing knowledge and enhancing academic performance.

Furthermore, the study suggests that the impact of gamification on student engagement and learning may diminish after approximately 3 weeks. This finding emphasizes the need for sustained innovation and variation in gamified activities to maintain students' interest and motivation throughout the course. Future research should explore the specific elements of gamification that can contribute to prolonged engagement and sustained learning outcomes.

In conclusion, this study underscores the value of integrating online quizzes as a pedagogical tool for enhancing student learning. While gamification shows potential benefits in terms of initial engagement and completion rates, it is essential to carefully consider the design and implementation of gamified elements to ensure their long-term effectiveness. Continued investigation into the specific gamification elements and their impact on learning outcomes will further contribute to the field of educational technology and inform instructional practices.

CONFLICT OF INTEREST STATEMENT
The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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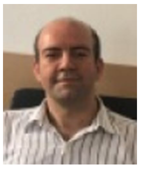

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