

PAPER

Analyzing Student Engagement and Learning Outcomes in a Gamified Blended Cybersecurity Course Using LMS-Based Behavioral Data

Wen-Shin Hsu^{1,2}  ¹Chung Shan Medical University, Taichung, Taiwan²Chung Shan Medical University Hospital, Taichung, Taiwanwshsu@csmu.edu.tw**ABSTRACT**

This study investigates how gamified and blended instructional design affects student engagement and learning outcomes in an undergraduate cybersecurity course. The course was implemented across two academic years using consistent content and delivery, providing a natural context for cohort-based comparison. Participants included third-year ($n = 47$) and second-year ($n = 52$) students enrolled in the same course, enabling analysis of academic-level differences in cognitive, behavioral, and motivational outcomes. A mixed-methods approach was used, combining pre/post-test results, learning management systems (LMS)-based behavioral data (e.g., login frequency, task completion, forum activity), and a student perception survey. Both cohorts showed significant learning gains, but behavioral engagement differed. Second-year students exhibited higher LMS activity and stronger motivational responses to gamification, while third-year students completed tasks more efficiently. Forum participation was positively correlated with learning gains, suggesting that interactive engagement is a key factor in performance. The study provides practical insights into how gamified blended learning, supported by digital learning analytics, can be scaled across diverse student profiles. It contributes to emerging technologies in higher education by demonstrating the role of behavioral data in refining instructional design.

KEYWORDS

gamification, blended learning, cybersecurity education, student engagement, learning analytics, Cohort-based comparison

1 INTRODUCTION

With rapid advancements in digital technologies, higher education institutions have increasingly integrated emerging technologies such as gamified platforms, blended learning systems, and learning analytics tools to enhance student engagement and learning outcomes. This integration is particularly crucial in technically

Hsu, W.-S. (2025). Analyzing Student Engagement and Learning Outcomes in a Gamified Blended Cybersecurity Course Using LMS-Based Behavioral Data. *International Journal of Engineering Pedagogy (IJEP)*, 15(6), pp. 111–122. <https://doi.org/10.3991/ijep.v15i6.57015>

Article submitted 2025-04-29. Revision uploaded 2025-06-02. Final acceptance 2025-06-05.

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demanding disciplines such as cybersecurity, where traditional instructional methods often struggle to effectively engage students due to the abstract nature of the content and the need for continuous interaction and problem-solving [1], [2].

Gamification, which applies game elements such as points, badges, leaderboards, and interactive scenarios to learning environments, has emerged as a powerful strategy to boost student motivation and engagement [3], [4], [5]. Similarly, blended learning, combining face-to-face instruction with digital content and activities, provides flexible and repeated interactions with course material, supporting deeper understanding and retention [6], [7]. Additionally, learning management systems (LMS) with integrated analytics capabilities enable educators to monitor, analyze, and interpret real-time student behavior and engagement data, thus allowing for targeted instructional interventions and adaptive learning experiences [8]–[10].

Despite these promising strategies, there remains a gap in understanding how different student cohorts, particularly those at varying academic levels and stages of digital fluency, respond to the same gamified blended instructional designs. Existing research suggests that factors such as academic maturity, digital competence, and intrinsic motivation significantly influence student interactions with digital learning tools [11], [12]. However, empirical studies explicitly comparing these engagement patterns across different academic cohorts remain scarce.

To address this gap, the current study investigates how undergraduate computer science students from two different academic cohorts engage with and benefit from a consistently implemented gamified blended cybersecurity course. Utilizing pre- and post-assessments, LMS analytics, and student perception surveys, the study aims to identify differences in cognitive outcomes, behavioral engagement, and motivational responses. Findings from this research will provide valuable insights for educators and instructional designers seeking to leverage emerging digital technologies and data-driven practices to enhance personalized learning experiences in higher education.

2 LITERATURE REVIEW

Integrating gamification, blended learning, and analytics tools in education has received substantial attention in recent years, particularly in the context of cybersecurity training and other technically intensive disciplines. Traditional teaching methods often fall short in effectively engaging students with complex technical content, prompting educators to explore innovative instructional strategies to enhance learning outcomes [13], [14].

Problem-based learning (PBL), characterized by authentic and contextual learning scenarios, has emerged as an effective instructional method, particularly in fields requiring critical thinking and problem-solving capabilities, such as cybersecurity [15], [16]. Studies indicate that PBL significantly enhances learners' engagement, motivation, and cognitive skills by immersing them in real-world challenges and collaborative environments [5], [8].

Gamification, defined as the application of game-design elements in non-game contexts, has been widely implemented to increase student motivation, participation, and persistence. Techniques such as digital badges, leaderboards, interactive competitions, and escape-room simulations have demonstrated positive impacts on student engagement and motivation [3], [9], [10], [17]. Furthermore, gamification is particularly effective in fostering intrinsic motivation and self-regulated

learning behaviors among students, enhancing their overall educational experience [4], [18]–[21].

Blended learning, combining face-to-face instruction with online digital resources and activities, is another approach gaining popularity in higher education. Blended formats provide learners with flexible access to instructional materials, facilitate continuous interactions, and enable repeated exposure to complex concepts, thus significantly improving knowledge retention and learner satisfaction [6], [7], [22]. When combined with gamified elements and analytics tools, blended learning environments allow educators to capture detailed behavioral data, monitor learner engagement, and provide personalized learning experiences [23].

Despite extensive research on these individual strategies, limited attention has been given to how learner characteristics, such as academic maturity, digital literacy, and motivational orientation, mediate the effectiveness of these instructional approaches. Existing literature highlights the potential variability in student responses to gamified blended learning environments, emphasizing the necessity for adaptive instructional designs that consider diverse learner profiles [11], [12], [24].

The present study addresses this critical research gap by comparing learning outcomes, behavioral engagement patterns, and motivational responses among undergraduate computer science students across different academic cohorts exposed to the same gamified blended cybersecurity course. The findings aim to contribute to the development of tailored instructional strategies that leverage gamification, blended learning, and analytics tools to enhance educational practices in technology-intensive domains.

3 RESEARCH OBJECTIVES AND QUESTIONS

The overarching aim of this study was to evaluate the effectiveness and adaptability of a gamified blended learning model in undergraduate cybersecurity education. The course design integrated PBL, game-based instructional elements, and digital delivery via a LMS. Critically, the course was delivered across two academic years with identical structure, content, and assessments—providing a unique opportunity to observe how students at different academic levels responded to the same learning experience.

The study focused on two distinct cohorts: third-year students enrolled in 2023 and second-year students enrolled in 2024. This natural grouping enabled an exploration of whether learner maturity, academic experience, and motivational responsiveness affected how students engaged with the course, both cognitively and behaviorally.

To guide the investigation, the following research questions were posed:

- RQ1: To what extent did student learning outcomes differ between the two cohorts following identical instruction?
- RQ2: How did behavioral engagement with the course platform and activities vary between cohorts?
- RQ3: How did students from each cohort perceive the gamified blended learning experience, and what differences emerged in motivational responses?

These questions were examined through a mixed-methods approach, combining pre- and post-test data, LMS usage analytics, and perception surveys.

4 METHODOLOGY

This study employed a mixed-methods, cohort-based design to investigate how students at different academic levels responded to a gamified blended cybersecurity course. The course was delivered over two consecutive academic years to two cohorts of undergraduate students, using identical content, instructional strategies, and learning activities. The primary aim was to examine differences in learning outcomes, behavioral engagement, and student perceptions resulting from consistent course delivery across distinct learner groups.

The participants were 99 undergraduate computer science students at a university in Taiwan. Cohort A consisted of 47 third-year students who completed the course in 2023, and Cohort B included 52 second-year students who completed it in 2024. The grouping was based on enrollment year and academic level, with no prior exposure to cybersecurity content for either group. All students participated voluntarily and provided informed consent for the use of anonymized learning data.

The course spanned 18 weeks and integrated three instructional phases: (1) foundational lectures on cybersecurity concepts; (2) PBL using case scenarios and interactive activities; and (3) a capstone project involving the design of a gamified escape-room-style board game. The learning experience was enhanced by digital tools such as a LMS, ClassPoint, and Kahoot! for formative feedback, and a card-based game system to reinforce gamified learning during collaborative sessions.

Data were collected at three key stages: 1) pre-test (Weeks 1–2) mid-course engagement tracking (Weeks 8–9), and 3) post-course assessments (Weeks 16–18). Three types of data were gathered:

1. Knowledge assessments: Pre- and post-tests containing multiple-choice items assessing core cybersecurity knowledge.
2. Behavioral engagement metrics: LMS data including login frequency, task completion rates, time spent on platform activities, and discussion forum participation.
3. Perception survey: A Likert-scale questionnaire measured students' motivation, satisfaction with gamified elements, and attitudes toward the blended PBL format. Open-ended responses provided additional qualitative insights.

Quantitative data were analyzed using SPSS. Paired-sample t-tests assessed within-group learning gains; independent-sample t-tests and Mann–Whitney U tests were used for between-group comparisons. Pearson correlation analysis was conducted to explore the relationship between engagement metrics and post-test performance. Qualitative responses from the survey were thematically coded to support and interpret the quantitative findings.

5 RESULTS

This section presents the results of the study in relation to the three research questions, integrating descriptive and inferential statistical analyses. Figures and tables are provided to support key comparisons between the two academic cohorts.

- RQ1: Learning outcomes across cohorts
- RQ2: Behavioral engagement patterns
- Student Perceptions of the instructional model

5.1 Learning outcomes across cohorts

Both cohorts demonstrated statistically significant learning gains after completing the gamified blended course. As presented in Table 1 and visualized in Figure 1, Cohort A (third-year students) improved from a pre-test mean of 54.1 (SD = 9.8) to 79.0 (SD = 7.9), $t(46) = 16.08$, $p < .001$, Cohen's $d = 2.34$. Cohort B (second-year students) increased from 52.3 (SD = 10.5) to 76.8 (SD = 8.7), $t(51) = 15.12$, $p < .001$, Cohen's $d = 2.10$.

Between-group comparison of gain scores revealed no statistically significant difference, $t(97) = 0.21$, $p = .836$, suggesting that the instructional model was equally effective for students at different academic levels. These results indicate that the gamified blended design supported substantial knowledge gains regardless of cohort.

Table 1. Pre- and post-test scores by cohort

Cohort	Pre-Test Mean (SD)	Post-Test Mean (SD)	t-Value	p-Value	Effect Size (d)
Cohort A (2023)	54.1 (9.8)	79.0 (7.9)	16.08	<.001	2.34
Cohort B (2024)	52.3 (10.5)	76.8 (8.7)	15.12	<.001	2.10

Note: Post-test scores were significantly higher for both cohorts. No significant difference in learning gains was found between cohorts.

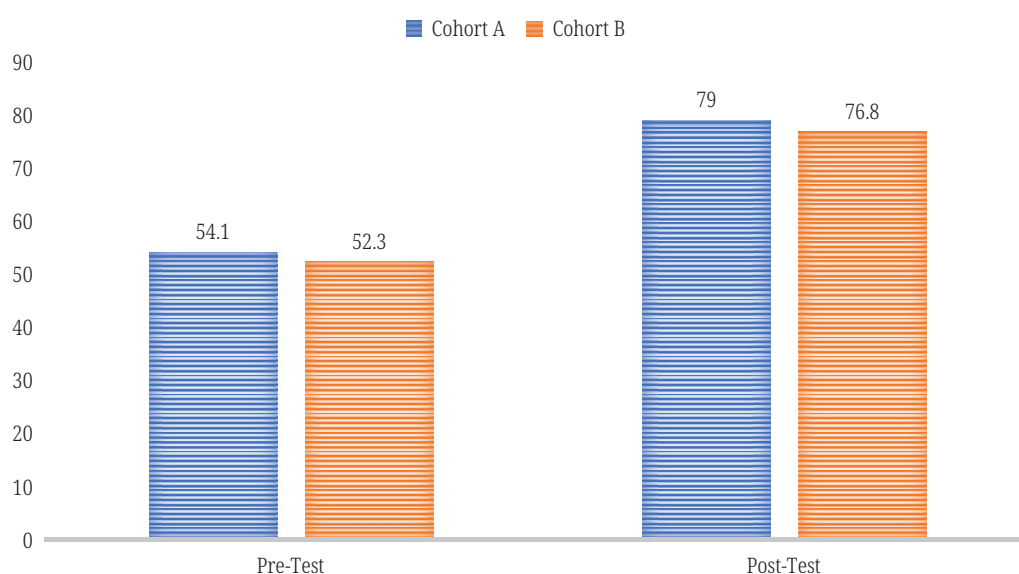


Fig. 1. Pre- and post-test scores by cohort

5.2 Behavioral engagement patterns

Analysis of LMS usage data revealed both similarities and differences in engagement behaviors. As summarized in Table 2 and shown in Figure 2, second-year students (Cohort B) demonstrated higher login frequency ($M = 48.2$), time on task ($M = 132.5$ minutes), and forum posts ($M = 5.2$), while third-year students (Cohort A) had a higher task completion rate (91.1%). Among these, only the difference in forum activity reached statistical significance, $t(97) = 2.19$, $p = .030$.

Table 2. Analysis of LMS usage data by cohort

Metric	Cohort A (2023)	Cohort B (2024)	t/U	p-Value
Login Frequency	41.7	48.2	1.85	.074
Time on Task (min)	118.7	132.5	1.43	.158
Forum Posts	4.0	5.2	2.19	.030*
Task Completion Rate (%)	91.1	86.3	U = 1074	.091

Note: *p < .05 indicates statistical significance.

Further analysis explored the relationship between forum participation and learning outcomes. As shown in Figure 3, forum posting was positively correlated with post-test performance ($r = .29, p < .05$). To clarify this relationship, students were divided into high-gain and low-gain subgroups. Figure 4 demonstrates that high-gain students posted more frequently ($M = 5.6$) than low-gain students ($M = 3.8$), $t(97) = 2.42, p = .017$.

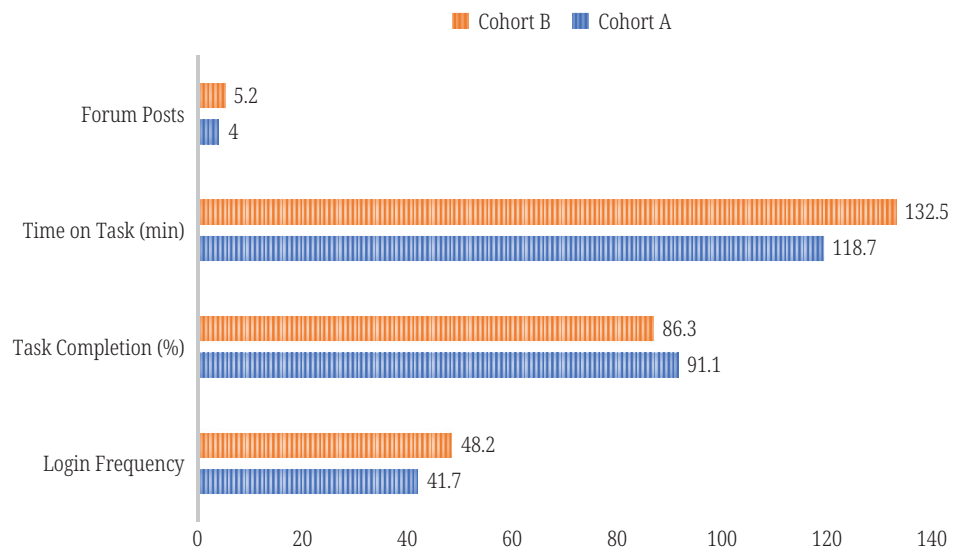


Fig. 2. LMS behavioral metrics by cohort

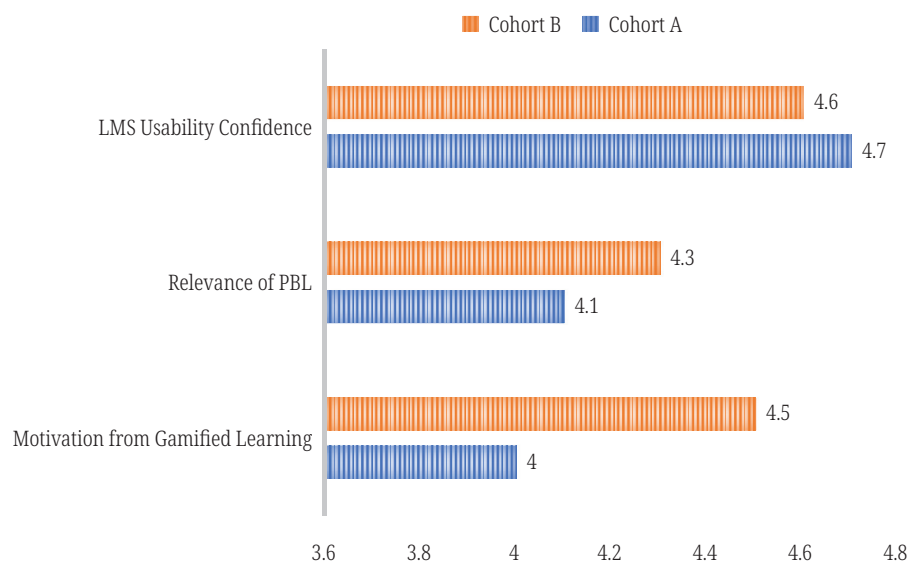


Fig. 3. Forum participation and post-test performance

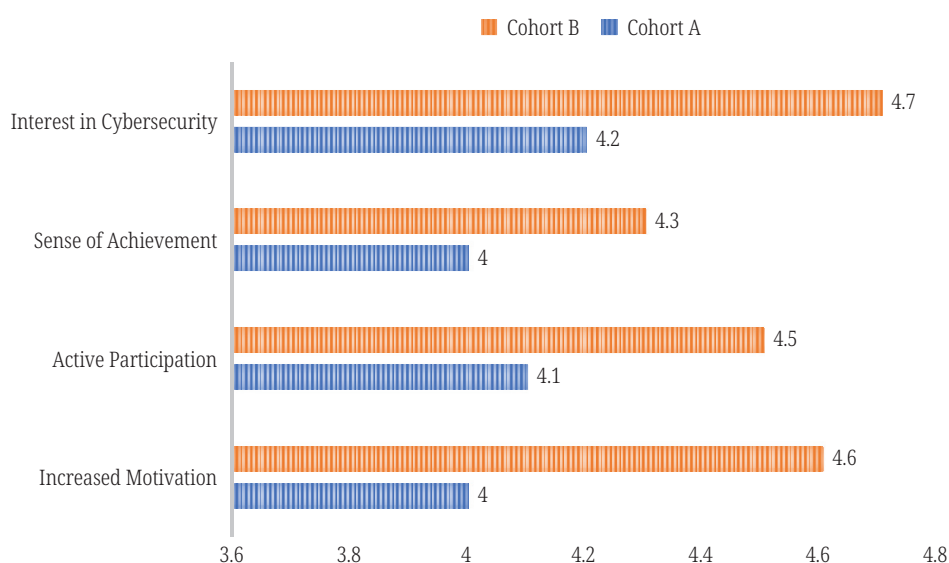


Fig. 4. Forum participation by learning gain group

These results suggest that while not all behavioral metrics predicted learning success, collaborative engagement through forum activity was significantly associated with improved performance. This highlights the pedagogical importance of interactive learning components in blended formats.

5.3 Student perceptions of the instructional model

Students’ perceptions of the course were generally positive, with notable cohort-based differences in motivational responses. As shown in Figure 5, both groups valued the blended PBL format, but second-year students reported higher motivation derived from gamification elements ($M = 4.5$ vs. 4.0), $t(97) = 3.22$, $p = .002$.

A detailed item-level analysis in Figure 6 showed that Cohort B rated every gamification item significantly higher, including enjoyment, motivation, and learning impact (all $p < .05$). This indicates that younger students may be more receptive to gamified instructional strategies.

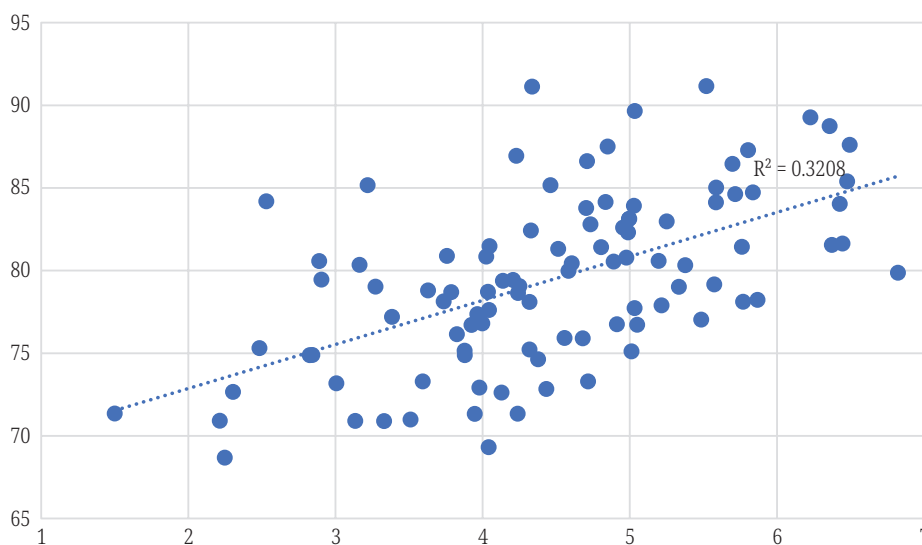


Fig. 5. Course perception ratings by cohort

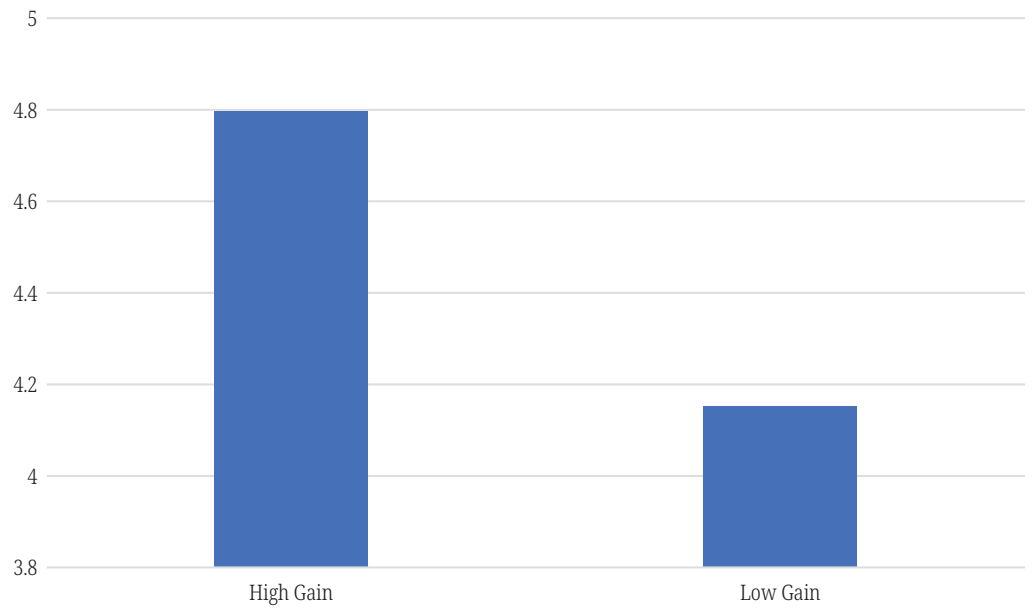


Fig. 6. Item-level analysis of gamified motivation

To examine whether motivation translated into engagement, students were grouped by their self-reported motivation scores. As depicted in Figure 7, highly motivated students logged in more frequently ($M = 52.1$), completed more tasks (94.2%), and posted more often (5.9) than those with lower motivation levels. All differences were statistically significant ($p < .05$), confirming that affective response to gamification influenced behavioral engagement.

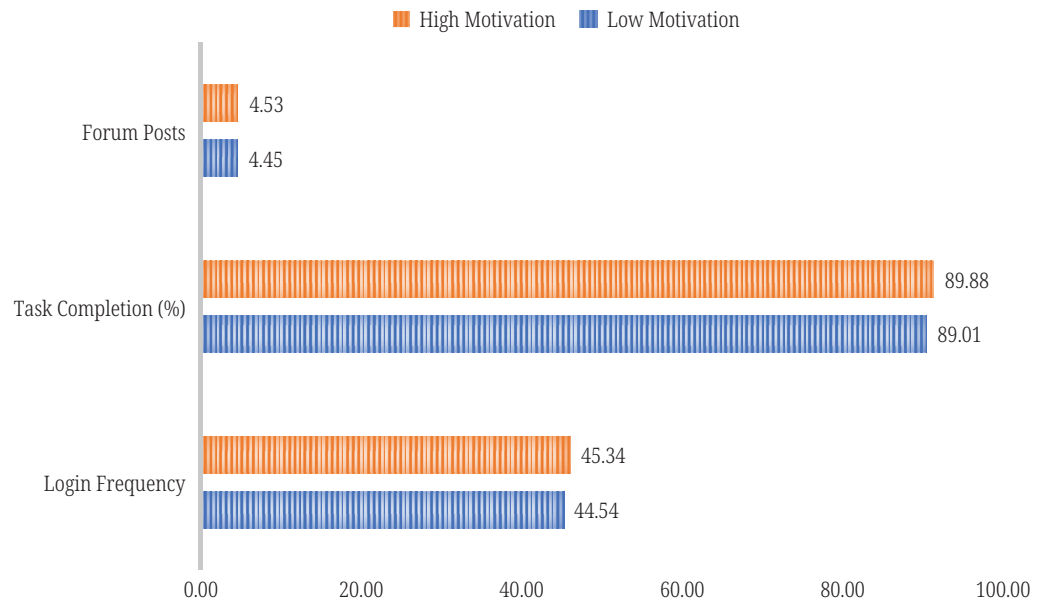


Fig. 7. LMS engagement by gamification motivation group

In summary, while both cohorts benefited cognitively from the gamified blended course, meaningful differences emerged in behavioral patterns and motivational responses. Forum participation was a consistent predictor of learning success, and students with stronger motivation toward gamification engaged more actively

across all LMS metrics. These findings suggest that student maturity and motivational orientation modulate how learners interact with consistent course design, and that targeted adjustments to engagement strategies may optimize instructional impact.

6 DISCUSSION

The findings of this study highlight the effectiveness of integrating gamification, blended learning, and learning analytics in enhancing student engagement and learning outcomes in cybersecurity education. Consistent with prior research [5], [16], our results demonstrate that a structured, interactive instructional design significantly enhances cognitive performance across different student cohorts. Importantly, the study also reveals nuanced differences in engagement patterns and motivational responses between second-year and third-year undergraduate students, underscoring the need to consider learner characteristics in instructional design.

Second-year students demonstrated notably higher levels of platform interaction, task engagement, and motivational responses toward gamification elements, indicating a strong alignment between gamification strategies and their learning preferences. These findings align with existing literature suggesting younger or less experienced students are often more responsive to external motivational cues provided by gamification, benefiting greatly from structured interactive tasks [12], [25], [26]. Conversely, third-year students, while engaging less frequently with platform activities, displayed more efficient task management, potentially reflecting higher self-regulation and goal-directed learning strategies.

Notably, active participation in discussion forums emerged as a strong predictor of learning outcomes, reinforcing the significance of collaborative interaction and active engagement in digital learning environments [6]. Unlike passive metrics such as login frequency or time spent, forum participation directly correlated with improved cognitive gains. This distinction underscores the importance of interactive, collaborative components in blended and gamified learning contexts.

From a practical perspective, this research provides valuable insights for educators and instructional designers aiming to leverage emerging digital technologies effectively. While maintaining consistent instructional frameworks for scalability, designers should incorporate adaptive mechanisms based on learner profiles. For early-stage learners, incorporating structured gamified incentives and collaborative tasks may enhance motivation and participation. More advanced learners might benefit from increased autonomy, challenging problem-solving tasks, and self-directed learning experiences.

Moreover, the integration of learning analytics into instructional design offers significant potential for personalized education. LMS analytics provide educators with timely, actionable insights into student engagement behaviors, enabling targeted interventions and informed instructional adjustments to support diverse learner needs.

Despite the valuable contributions, the current study acknowledges limitations, including the single-institutional context and reliance on behavioral analytics from a single LMS platform. Future research should extend to multi-institutional studies, longitudinal tracking, and multimodal data analysis to deepen the understanding of how learner characteristics interact with instructional design elements in emerging educational technologies.

7 CONCLUSION

This study examined the implementation of a gamified, problem-based, and blended instructional model in an undergraduate cybersecurity course, delivered across two academic cohorts. By maintaining identical content and delivery while comparing student outcomes and engagement across two academic levels, the research provided insights into how learner characteristics shape instructional effectiveness.

The results confirm that a consistent course design can produce substantial and comparable learning gains regardless of academic standing. However, differences in behavioral engagement and motivational responses suggest that student profiles influence how they interact with and benefit from instructional elements. Specifically, forum participation was linked to better learning outcomes, and students with stronger motivation toward gamified components engaged more frequently with course activities. These findings emphasize the importance of considering both cognitive and affective dimensions when evaluating instructional impact.

For educators and instructional designers, the study offers practical implications: while a unified structure ensures consistency and scalability, integrating adaptable gamification strategies and interaction models may enhance engagement and learning experiences for diverse student groups. Educational technologies such as LMS analytics can support this differentiation by providing timely feedback on learner behaviors.

The study is limited by its single-institution context and the reliance on platform-based behavioral metrics. Future research may involve multi-institutional samples, longitudinal tracking, and richer forms of learning analytics—such as semantic analysis of student dialogue—to deepen understanding of how instructional design interacts with learner diversity in applied STEM education.

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