

Article

Beyond Quiz Scores: LMS Behavioral Metrics and Their Association with Summative Performance in Higher Education

Marko Radovan 

University of Ljubljana, Faculty of Arts, Aškerčeva 2, 1000 Ljubljana, Slovenia; marko.radovan@ff.uni-lj.si

Abstract

This study investigates how ongoing low-stakes quizzes and other learning management system (LMS)-based activities relate to performance on a summative course quiz in higher education. We analyzed course data from 37 first-year undergraduate students. Data were extracted from Moodle and covered weekly quiz scores across ten quizzes, number of attempts, attempt duration, latency between quiz release and first attempt, and student engagement with course materials. Descriptive statistics, Pearson correlations, and partial correlations were used to examine these relationships. The findings consistently point in the same direction: when and how often students engaged with quizzes mattered far more than how well they scored on them. Longer latency—that is, delaying the first quiz attempt after release—was strongly negatively associated with final quiz performance, while students who attempted quizzes more frequently and completed them more quickly tended to perform better. Among course materials, viewing the core lecture handouts showed the strongest positive association with final scores, while additional reading, Moodle lesson completion, and Padlet participation showed weaker but statistically significant positive associations. Topic materials were not significantly associated with final quiz performance. Partial correlation analyses confirmed that latency, number of attempts, and handout views each remained independently associated with final performance after controlling for average quiz score, suggesting these behavioral indicators capture something that raw accuracy alone does not. These results align with testing-effect and self-regulated learning research and point to a clear practical implication: course designs that encourage early, repeated engagement with structured core materials are likely to support better student outcomes than those that rely primarily on quiz scores as a proxy for learning.

Keywords: formative assessment; low-stakes quizzing; Moodle; learner engagement; self-regulated learning; testing effect; higher education; academic performance



Academic Editors: Sokratis Tselegkaridis and Sapounidis Theodosios

Received: 23 April 2026

Revised: 9 May 2026

Accepted: 11 May 2026

Published: 13 May 2026

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1. Introduction

Over the past two decades, higher education institutions worldwide have increasingly adopted digital learning environments, commonly referred to as learning management systems (LMSs), as key platforms for organizing asynchronous teaching and learning. Systems such as Moodle, Blackboard, and Canvas support distance, hybrid, and face-to-face instruction through a range of digital tools (Bozkurt et al., 2020). LMSs function not only as technical infrastructure but also as environments that enable new pedagogical practices, including independent learning, collaborative learning, and digitally supported knowledge assessment. An important advantage of these systems is their capacity to capture and analyze student activity data, often described as learning analytics, which creates new opportunities for examining learning processes and predicting academic success

(Ifenthaler & Yau, 2020). Within this context, ongoing assessment through quizzes and other automated tools is especially relevant. Previous research has shown that regular quizzes are not only a means of assessment but also an effective instructional tool that can actively support learning (Roediger & Butler, 2011). In the present study, we examine how the use of different teaching materials, with particular attention to ongoing quizzes, relates to performance on the final quiz, which also formed part of the course assessment. This perspective is informed by the testing effect, which suggests that active retrieval contributes more strongly to memory than passive review of learning materials (Roediger & Karpicke, 2006).

Purpose of the Study

This study examines how ongoing quiz performance, quiz-taking behavior, and engagement with LMS course materials are associated with performance on a summative final quiz. In higher education, ongoing quizzes may serve several functions: they provide students with opportunities for self-evaluation and feedback, help instructors identify content that students find challenging, and generate behavioral data that can be used to examine learning processes. In Moodle and similar LMS environments, quizzes automatically record scores, completion times, number of attempts, latency between quiz release and first attempt, and other activity indicators. These data make it possible to examine not only how well students perform on quizzes, but also how and when they engage with learning tasks.

This study addresses the following research questions:

1. How are ongoing quiz performance and quiz-related behavioral indicators associated with success on the final quiz?
2. How is engagement with LMS course materials associated with final quiz performance?
3. Which LMS behavioral and activity indicators are most strongly associated with success on the final quiz, beyond average quiz performance?

2. Literature Review

2.1. LMS Engagement as a Predictor of Academic Performance

Research suggests that student success is not predicted by LMS access alone, but by the quality and type of engagement within the LMS. General indicators such as login frequency or total number of sessions provide only a crude measure of behavioral engagement (Pardo et al., 2017). More specific content-related actions, such as accessing lecture notes, assignments, quizzes, and course files, tend to show stronger associations with academic performance. Ahmadi et al. (2023), for example, found that variables such as files viewed, quiz attempts, and content-related interactions were more informative than total login counts. This distinction is important because meaningful engagement with learning materials provides a more direct indication of students' study behavior than simple access to the platform.

2.2. Timing, Distributed Practice, and Procrastination

In addition to frequency, the temporal distribution of engagement is also highly informative. Students who engage consistently throughout the week in the LMS, rather than in concentrated sessions of cramming immediately before exam deadlines, tend to be significantly more successful. This pattern, known as distributed practice, is an established and effective learning strategy. Research conducted by You (2016) showed that access frequency, measured by the number of days a student was active in the LMS per week, is a reliable predictor of success and often surpasses the total number of accesses. The timing of participation relative to course deadlines is another important indicator. Early and sustained reading or use of new materials is a strong positive predictor. Conversely, delayed engagement with course tasks is a strong negative predictor of performance. In

LMS-based research, this pattern can be operationalized through latency, that is, the time elapsed between the release of a task and a student's first attempt or access. Numerous meta-analyses and empirical studies demonstrate a strong negative correlation between procrastination and academic performance. Students who procrastinate—for example, by delaying access to instructions or submitting assignments late—tend to achieve lower grades and poorer academic outcomes (Kim & Seo, 2015; Martinie et al., 2023; Steel et al., 2001). This association is evident across different populations and educational contexts, although its strength may vary depending on how procrastination is measured and on individual demographic factors. Overall, this points to the negative impact of poor time management and weak self-regulation on academic performance (Hailikari et al., 2021; Martinie et al., 2023). More sophisticated analyses distinguish between passive and active engagement. Simply viewing content is less predictive than contributing to discussion forums, completing quizzes that are not part of the exam grade, or interacting with collaboration tools. Gašević et al. (2016), for example, emphasized that while viewing resources has some predictive power, contributing to forums was a much stronger indicator of deep learning and final course grades, as it reflects cognitive engagement and knowledge construction.

2.3. Self-Regulated Learning and Behavioral Indicators

Research in the field of self-regulated learning (Zimmerman, 2002) shows that a key factor in learning success is the student's ability to plan, monitor, and regulate their own learning. An important dimension of self-regulation is the timely completion of learning tasks. Students who complete assignments and quizzes on time demonstrate a higher level of self-regulation, which is often reflected in better grades on final exams (Broadbent & Poon, 2015). Conversely, procrastination is considered one of the most common forms of unsuccessful self-regulation. In his meta-analysis, Steel (2007) found that procrastination is associated with lower academic achievement, greater stress, and poorer overall well-being. In the context of online quizzes, procrastination may be reflected in greater latency, defined in this study as the time lag between quiz release and the student's first attempt. We also examined this in our study. In addition to timeliness, the duration of engagement is also important. Although a longer quiz completion time may indicate thorough work, it may also indicate comprehension difficulties or a slower pace of work (Krause et al., 2009). On the other hand, a very short completion time may indicate high competence, but it may also suggest superficial engagement. Therefore, duration should be considered as a variable that, in combination with results and timeliness, provides insight into students' learning strategies.

2.4. Ongoing Quizzes as Learning and Analytics Tools

Empirical research shows that ongoing assessment has a positive effect on performance in final exams (Bangert-Drowns et al., 1991; McDaniel et al., 2007). This connection is not only the result of increased practice, but also of changes in learning strategies, as quizzes encourage students to actively recall information. At the same time, ongoing quizzes in digital learning environments can be a rich source of data for researching learning habits. By linking data on results, time lags, and attempt duration, we can gain a comprehensive insight into how different strategies affect final success, which is also the central research problem of this chapter.

3. Materials and Methods

3.1. Sample

The study included 37 first-year undergraduate students enrolled in an undergraduate program at the University of Ljubljana. The sample comprised 34 female and 3 male students. Throughout the semester, students attended weekly in-person lectures and seminars. In addi-

tion to these face-to-face sessions, they had access to a Moodle (version 5.0) course site where the instructor uploaded additional materials after each lecture.

3.2. Instruments

3.2.1. Ongoing Quizzes

Ten weekly quizzes were administered through the Moodle learning management system. Each quiz corresponded to one weekly lecture topic and was designed as a low-stakes retrieval-practice activity. The quizzes assessed students' conceptual understanding of the core course content rather than factual recall alone. The topics covered in the quizzes followed the sequence of the course and included key concepts, theoretical distinctions, and practical applications discussed during lectures and seminars. Each quiz consisted of 10–12 multiple-choice questions, was untimed, and could be attempted multiple times; only the highest score contributed to the final grade. Question order was randomized for each attempt to minimize item-order effects. The quizzes were designed to support examination preparation by encouraging repeated engagement with the weekly material and by providing students with opportunities to monitor their understanding before the final quiz. The item format primarily required students to identify correct concepts, distinguish between related theoretical terms, or apply course concepts to short educational examples. For example, students were asked to select the most appropriate definition of a key concept, identify the correct interpretation of a learning scenario, or recognize the pedagogical implication of a specific instructional principle. For each attempt, Moodle automatically recorded the quiz opening time, the student's start time, attempt duration, and the score achieved. Examples of weekly quiz items are provided in Appendix A.

3.2.2. Final Quiz

Students completed a summative final quiz that accounted for 30% of the overall course grade. The final quiz assessed the same broad course content as the weekly quizzes, but it was designed as a cumulative assessment of students' understanding across the semester. It consisted of 20 randomly selected questions drawn from a shared item pool, including multiple-choice, true/false, and fill-in-the-blank items, with a maximum possible score of 20 points. The items covered key concepts, theoretical distinctions, and applied examples from the course. The quiz was administered through Moodle under the same technical conditions as the weekly quizzes. In contrast to the weekly quizzes, the final quiz functioned as a summative assessment and contributed directly to the final course grade.

3.2.3. LMS Activity Logs

In addition to quiz data, Moodle activity logs were used to capture student engagement with course materials. LMS activity logs were grouped into five categories: presentation handout views, topic materials, additional reading, Moodle lesson activities, and Padlet posts. Presentation handouts referred to the core lecture slides and structured materials prepared by the instructor. Topic materials referred to additional resources directly connected to weekly topics. Additional reading referred to independent reading materials made available to students for broader study. Moodle lesson activities referred to interactive learning activities within Moodle, while Padlet posts captured participation in collaborative online tasks.

3.3. Procedure

We conducted a retrospective quantitative study using data exported from Moodle at the end of the academic term. The analysis involved three steps: (1) integrating data from all 10 quizzes, learning material access logs, and other Moodle activities into a single

dataset; (2) linking these data to final quiz results; and (3) analyzing key variables including quiz performance, submission timing, attempt duration, and material access frequency.

The online course was organized into ten thematic modules corresponding to weekly lecture topics. Following each lecture, the relevant module was released and included lecture slides, additional readings, and a short quiz covering the lecture content. These resources allowed students to review key concepts independently between sessions. Variables derived from quiz logs included average quiz score, number of attempts, attempt duration, and latency. Latency was defined as the time elapsed between the release of a weekly quiz and the student's first attempt. Higher values therefore indicated a longer delay before initial quiz engagement. In this study, latency was treated as an LMS-based behavioral indicator of delayed engagement rather than as a direct psychological measure of procrastination.

3.4. Statistical Analysis

Data were analyzed in jamovi 2.6 ([The jamovi Project, 2024](#)) within the R statistical environment ([R Core Team, 2024](#)). The analysis proceeded in three stages. First, descriptive statistics were calculated for all variables, including mean, standard deviation, minimum, and maximum values, to characterize the distribution of quiz performance and LMS engagement metrics. Second, Pearson correlation analysis was used to examine bivariate relationships between quiz-derived variables, LMS activity metrics, and final quiz performance. Third, partial correlations were calculated to assess whether selected behavioral and engagement indicators (average latency, total number of attempts, and presentation handout views) were associated with final quiz performance beyond average quiz accuracy. This was done by controlling for average quiz score, allowing us to isolate the independent contribution of each behavioral indicator. For Pearson and partial correlations, 95% confidence intervals were calculated to indicate the precision of the estimates. Missing data occurred because not all students completed every weekly quiz. Descriptive statistics were calculated using all available valid cases for each variable. Pearson correlations were computed using pairwise deletion, so the number of valid cases could vary across correlations depending on the variables included. Partial correlations were calculated using cases with complete data on the variables included in each specific analysis. No imputation of missing quiz data was performed.

3.5. Ethical Considerations

The study fully complied with applicable data protection requirements under Slovenian law. Informed consent was obtained from all participants before data collection, authorizing the use of their activity data for research purposes. Data were stored securely and used exclusively for the stated research objectives. After the study was completed, all data were de-identified by removing any information linking individual records to specific participants.

3.6. Data Availability

The data have been deposited in the Zenodo repository ([Radovan, 2026](#)).

3.7. Use of Generative AI

During the preparation of this manuscript, I used ChatGPT (model GPT-5.4) to assist with translation and language editing. All AI-assisted content was reviewed, verified, and revised by me as the sole author, and I take full responsibility for the accuracy and integrity of the published work.

4. Results

The following section presents the findings in relation to the three research questions guiding this study. The first concerns how quiz-taking behavior and weekly quiz performance were associated with success on the final quiz. The second examines how engagement with different types of course materials in the LMS relates to final quiz scores. The third asks whether selected behavioral indicators, specifically latency, number of attempts, and handout views, were associated with final performance beyond average quiz accuracy, as assessed through partial correlation analysis.

4.1. Relationship Between Weekly Quiz Completion and Final Exam Performance

Table 1 summarizes the descriptive statistics for student performance across all ten weekly quizzes, the semester average, and the final quiz, illustrating the variation in scores from week to week.

Table 1. Descriptive Statistics for Weekly and Final Quiz Scores.

Variable	N	M	SD	Min	Max
Quiz 1	37	8.43	2.08	2	10
Quiz 2	29	9.55	3.38	0	12
Quiz 3	27	7.67	2.15	0	10
Quiz 4	34	9.64	2.69	2.55	12
Quiz 5	33	7.33	2.86	0.88	12
Quiz 6	36	8.4	3.76	1.43	12
Quiz 7	37	10.39	3.07	1.82	12
Quiz 8	36	8.94	3.29	1.43	12
Quiz 9	37	8.9	2.74	1.82	12
Quiz 10	30	10.46	2.75	0.7	12
Average Result (Q1–10)	37	8.7	2.19	3.2	11
Final Quiz Score	37	18.76	1.12	15	20

Table 1 shows substantial variation in performance across individual weekly quizzes, with mean scores ranging from 7.3 to 10.5. The relatively large standard deviations indicate considerable between-student variability. Quizzes 5 and 6 had lower mean scores and greater dispersion, suggesting either greater task difficulty or lower student preparedness during those weeks. In contrast, Quizzes 7 and 10 had higher mean scores, which may reflect better mastery of the material or lower item difficulty.

The overall mean quiz score ($M = 8.77$, $SD = 2.19$) suggests generally stable performance across the semester, although minimum scores close to zero on several quizzes indicate that some students performed substantially worse. The mean number of attempts ($M = 13.58$) suggests that some students used repeated attempts as a practice strategy. Attempt duration also varied considerably ($M = 6.31$ min, $SD = 6.71$), indicating that some students completed quizzes quickly, whereas others required substantially more time, possibly reflecting either more careful work or greater difficulty with the content. Final exam performance was high overall ($M = 18.76$ out of 20) and showed less variability than performance on the weekly quizzes. This pattern may suggest that the weekly quizzes supported preparation for the final exam by promoting practice and knowledge consolidation. However, alternative explanations should also be considered, including differences in assessment format, item difficulty, motivation, or short-term exam preparation. This restricted range should be considered when interpreting the correlations with final quiz performance, as a possible ceiling effect may have attenuated some associations.

To examine which quiz-related variables were most closely associated with final performance, Pearson correlations were calculated for individual weekly quiz scores,

summary performance measures, and behavioral indicators; the results are presented in Table 2.

Table 2. Correlations of Weekly Quiz Scores and Behavioral Indicators With Final Quiz Scores.

Variable	Final Quiz Score	95% CI
Quiz 1	0.38 *	[0.067, 0.629]
Quiz 2	0.29	[−0.087, 0.593]
Quiz 3	0.13	[−0.259, 0.489]
Quiz 4	0.06	[−0.288, 0.387]
Quiz 5	−0.04	[−0.380, 0.305]
Quiz 6	−0.02	[−0.344, 0.313]
Quiz 7	0.08	[−0.253, 0.392]
Quiz 8	−0.11	[−0.423, 0.227]
Quiz 9	0.05	[−0.279, 0.367]
Quiz 10	0.14	[−0.228, 0.479]
Highest score	0.21	[−0.184, 0.547]
Average quiz result	0.08	[−0.249, 0.396]
Time taken to complete	−0.50 **	[−0.710, −0.212]
Average latency	−0.70 ***	[−0.836, −0.490]
Number of attempts	0.48 **	[0.112, 0.730]

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The correlation analysis showed that scores on individual weekly quizzes were generally weakly and non-significantly associated with final quiz performance, except for Quiz 1, $r = 0.38$, 95% CI [0.07, 0.63], $p < 0.05$. This finding suggests that early quiz performance may have been associated with later achievement. However, the confidence interval was relatively wide, indicating that the strength of this association should be interpreted cautiously. By contrast, the average score across all weekly quizzes was not significantly associated with final quiz performance, $r = 0.08$, 95% CI [−0.25, 0.40], indicating that overall quiz performance during the semester was not, by itself, a strong indicator of final quiz success. Stronger associations were observed for quiz-taking behavior. Mean quiz completion time was negatively associated with final quiz performance, $r = -0.50$, 95% CI [−0.71, −0.21], $p < 0.01$, indicating that students who completed quizzes more quickly tended to achieve higher final scores. An even stronger negative association was found for latency, $r = -0.70$, 95% CI [−0.84, −0.49], $p < 0.001$. Since latency was defined as the time elapsed between quiz release and the student's first attempt, this result indicates that students who delayed their first quiz attempt tended to achieve lower final quiz scores. In other words, earlier engagement with weekly quizzes was associated with better final performance. The number of attempts was positively associated with final quiz performance, $r = 0.48$, 95% CI [0.11, 0.73], $p < 0.05$, suggesting that students who attempted quizzes more frequently tended to perform better on the final quiz.

These findings suggest that final quiz performance was more strongly associated with when and how often students engaged with the quizzes than with their scores on individual quizzes alone. At the same time, the confidence intervals, particularly for some of the moderate associations, indicate limited precision of the estimates due to the small sample size. These results should therefore be interpreted as exploratory and context-specific.

4.2. Correlation Between Use of Learning Materials and Final Exam Performance

Table 3 presents the correlations between different learning activities in the online environment and final exam performance, providing insight into which types of engagement were most strongly associated with student success.

Table 3. Correlations Between Learning Activities and Final Exam Score.

	FQ	H	TM	AR	ML
Final Quiz Score (FQ)	—				
Handout (H)	0.61 *** [0.36, 0.78]	—			
Topic Materials (TM)	0.12 [−0.21, 0.43]	0.06 [−0.27, 0.38]	—		
Additional Reading (AR)	0.35 * [0.03, 0.61]	0.23 [−0.10, 0.51]	0.16 [−0.18, 0.46]	—	
Moodle Lesson (ML)	0.34 * [0.02, 0.60]	0.25 [−0.08, 0.53]	−0.26 [−0.54, 0.07]	−0.03 [−0.35, 0.30]	—
Padlet (P)	0.40 * [0.09, 0.64]	0.03 [−0.30, 0.35]	0.07 [−0.26, 0.38]	0.22 [−0.12, 0.51]	0.41 * [0.10, 0.65]

Note. Values are Pearson correlation coefficients with 95% confidence intervals in brackets. FQ = Final Quiz Score; H = viewing the presentation handout; TM = viewing topic materials; AR = additional reading; ML = Moodle lesson completion; P = Padlet participation. * $p < 0.05$, *** $p < 0.001$.

The results indicate that final quiz performance was primarily associated with structured and selected interactive activities in the online learning environment. The strongest positive association was observed for viewing the presentation handout, $r = 0.61$, 95% CI [0.36, 0.78], $p < 0.001$, suggesting that engagement with core instructional materials was particularly relevant for final quiz performance. Significant positive associations were also found for Padlet participation, $r = 0.40$, 95% CI [0.09, 0.64], $p < 0.05$, additional reading, $r = 0.35$, 95% CI [0.03, 0.61], $p < 0.05$, and Moodle lesson completion, $r = 0.34$, 95% CI [0.02, 0.60], $p < 0.05$. By contrast, topic materials were not significantly associated with final quiz scores, $r = 0.12$, 95% CI [−0.21, 0.43]. These findings suggest that engagement with core course materials and selected interactive or independent learning activities was more strongly related to final quiz performance than access to topic materials alone. However, the confidence intervals for the weaker significant associations were relatively wide and close to zero at the lower bound, particularly for additional reading and Moodle lesson completion. These results should therefore be interpreted cautiously and as exploratory evidence that different types of LMS engagement were not equally informative indicators of final quiz performance.

4.3. LMS Behavioral Indicators Beyond Average Quiz Score

To examine whether key LMS behavioral indicators were associated with final quiz performance beyond average quiz accuracy, partial correlations were calculated while controlling for average quiz score. Table 4 presents the associations between final quiz performance and three selected indicators: average latency, total attempts, and presentation handout views. The three indicators included in the partial correlation analysis were selected on theoretical and empirical grounds. Average latency was included as an indicator of the timing of engagement, total number of attempts as an indicator of repeated quiz practice, and presentation handout views as an indicator of engagement with core instructional materials. These variables also represented the strongest and most theoretically relevant associations observed in the preceding bivariate analyses.

Table 4. Partial Correlations Between Final Quiz Performance and Selected LMS Behavioral Indicators, Controlling for Average Quiz Score.

Variables	Control Variable	Partial r	95% CI	p
Final Quiz Result and Average Latency	Average Quiz Result	−0.70	[−0.84, −0.49]	<0.001
Total Attempts	Average Quiz Result	0.40	[0.09, 0.65]	0.045
Presentation Handout Views	Average Quiz Result	0.61	[0.35, 0.78]	<0.001

Note. Partial correlations represent associations between final quiz performance and selected LMS behavioral indicators after statistically controlling for average quiz score.

As shown in Table 4, average latency remained strongly and negatively associated with final quiz performance after controlling for average quiz score, partial $r(34) = -0.70$, 95% CI [−0.84, −0.49], $p < 0.001$. This indicates that students who delayed their first quiz attempts

tended to obtain lower final quiz scores, independently of their average quiz accuracy. Presentation handout views were also strongly and positively associated with final quiz performance, partial $r(34) = 0.61$, 95% CI [0.35, 0.78], $p < 0.001$, indicating that engagement with core instructional materials was related to higher final achievement beyond average quiz score. Total number of quiz attempts showed a smaller positive association with final quiz performance, partial $r(34) = 0.40$, 95% CI [0.09, 0.65], $p = 0.045$, suggesting that repeated quiz engagement was also linked to better outcomes. Together, these findings suggest that timeliness, repeated practice, and use of core course materials were associated with final performance beyond quiz accuracy alone. However, the confidence interval for total attempts was relatively wide and close to zero at the lower bound, indicating that this association should be interpreted more cautiously than the associations observed for latency and handout views.

5. Discussion

The central finding of this study is that the timing and pattern of engagement with weekly quizzes and core course materials, rather than average quiz scores, were most strongly associated with final exam performance. This finding is relevant to educational technology because it shifts attention from how well students perform during the semester to when and how they engage with learning activities. By identifying useful learning analytics indicators within the learning management system (LMS), such as quiz start time, number of attempts, and access to course materials, the study helps connect theory, practice, and course design in higher education (Roediger & Karpicke, 2006; Ifenthaler & Yau, 2020).

5.1. Interpretation of Key Results

With respect to RQ1 (weekly quizzes and achievement), the results indicate that early quiz completion, repeated practice through multiple attempts, and shorter attempt duration were more strongly associated with final exam performance than average quiz accuracy across the semester. This pattern is consistent with the view that retrieval practice is most effective when it is distributed, timely, and repeated, rather than simply accurate at isolated points in time (Roediger & Butler, 2011). The modest contribution of the first quiz likely reflects initial readiness and early adjustment to the course rather than cumulative learning.

With respect to RQ2, viewing core presentation materials showed the strongest association with final quiz success among the LMS activity indicators. Additional reading, Moodle lesson completion, and Padlet participation were also positively associated with final performance, although these associations were weaker than the association observed for handout views. By contrast, topic materials were not significantly associated with final quiz scores. This pattern suggests that students benefited most from structured core materials and from selected active or independent learning activities, whereas not all forms of material access were equally informative as indicators of achievement. The positive associations observed for Moodle lesson completion and Padlet participation are also consistent with principles of active processing, as these activities required students to engage with the course content more actively than through simple access to materials alone (Gašević et al., 2016; Black & Wiliam, 2009). The weak association between average weekly quiz score and final quiz performance is noteworthy. One possible explanation is that the weekly quizzes allowed multiple attempts and counted only the highest score, which may have reduced the extent to which average quiz scores reflected stable individual differences in mastery. Students could improve their quiz scores through repeated attempts, feedback, or familiarity with the item format, making the final recorded score less informative than the behavioral process leading to it. In this context, when students engaged with quizzes and how often they attempted them may have captured more meaningful differences in learning regula-

tion than the average score itself. Another possible explanation is the restricted range of final quiz performance, which may have attenuated the correlation between weekly quiz accuracy and final achievement.

With respect to RQ3 (combined activities), the partial correlation analyses showed that selected LMS behavioral and engagement indicators remained significantly associated with final quiz performance even after controlling for average quiz score. In particular, greater latency was associated with lower final performance, whereas a higher number of quiz attempts and more frequent viewing of presentation handouts were associated with better outcomes. These findings suggest that final achievement is linked not only to how well students perform on ongoing quizzes, but also to how they organize their engagement with learning activities, especially in terms of timeliness, repeated practice, and use of core instructional materials (Ifenthaler & Yau, 2020; Pardo et al., 2017).

The negative association between quiz completion time and final quiz performance should also be interpreted cautiously. Shorter completion time may indicate greater fluency, stronger familiarity with the material, or more efficient retrieval. However, completion time alone does not reveal whether students engaged deeply with the material or completed the quiz superficially. As Tan et al. (2020) note, quiz completion time may reflect different motivational and learning strategies depending on the instructional context. In the present study, completion time should therefore be interpreted together with other indicators, particularly latency, number of attempts, and final quiz performance.

5.2. Comparison with Previous Research

The importance of timeliness is consistent with prior research showing that regular participation predicts success in online courses (You, 2016; Kim & Seo, 2015; Martinie et al., 2023). The negative association between quiz completion latency and final exam performance is also consistent with meta-analytic evidence linking procrastination to poorer academic outcomes and greater stress (Steel, 2007). Similarly, the positive role of multiple attempts aligns with the literature on retrieval practice and test-enhanced learning, which shows that frequent low-stakes practice can strengthen retention and transfer (Bangert-Drowns et al., 1991; McDaniel et al., 2007; Roediger & Butler, 2011).

By contrast, the weak association between average weekly quiz scores and final exam performance differs from studies that have treated formative assessment data as a strong predictor of final achievement (Pardo et al., 2017). At the same time, the strong association with viewing core materials is consistent with findings that purposeful access to relevant resources is more informative than overall participation volume alone (Ahmadi et al., 2023). This also complements earlier work suggesting that passive content viewing is generally a weaker predictor of final learning outcomes than active participation in the online environment (Gašević et al., 2016). Taken together, the present findings extend previous research by identifying which materials and which patterns of behavior—particularly timely starts and repeated practice—were most strongly associated with final exam success.

More broadly, this study extends understanding of the testing effect by situating repeated weekly quiz practice within a self-regulated learning (SRL) framework and linking it to time management in the online classroom. Learning appears to be most effective when students begin practice early, repeat it, and combine it with structured course materials. This interpretation is consistent with the principles of distributed practice and spacing (Roediger & Karpicke, 2006; You, 2016). In this sense, timely engagement may function as a behavioral indicator of planning and regulation within SRL models (Zimmerman, 2002; Steel, 2007).

5.3. Limitations

This study has several limitations. First, it was conducted within a single course at one institution and involved a small sample of 37 students. This limits statistical power and reduces the precision of the estimated correlations, as reflected in the confidence intervals reported in the correlation tables. The findings should therefore be interpreted as exploratory and context-specific rather than as stable population estimates. Second, the sample consisted predominantly of female students, with 34 female and 3 male participants. This distribution reflects the demographic profile of the specific undergraduate program (in the field of education) and course context in which the study was conducted. However, the uneven gender composition limits the extent to which the findings can be generalized to programs, disciplines, or student populations with a more balanced gender distribution. Future studies should therefore examine whether similar LMS engagement patterns are observed in more diverse samples and across different disciplinary contexts. Third, the study design was correlational and does not support causal or statistical prediction claims. Although several LMS indicators were associated with final quiz performance, unmeasured variables such as prior knowledge, motivation, study habits, grade point average, or broader self-regulated learning skills may partly explain these associations. Fourth, final quiz performance was high overall and showed limited variability, suggesting a possible ceiling effect. This restricted range may have attenuated some associations, particularly the relationship between average weekly quiz score and final quiz performance. At the same time, it may also affect the stability of large correlations observed for behavioral indicators such as latency. Future studies should examine similar relationships using outcome measures with greater variability. Finally, missing quiz data were present because not all students completed every weekly quiz. Although available case analyses allowed the use of the existing LMS data, future studies should use larger samples and more systematic missing-data procedures.

6. Conclusions

This study shows that, in blended learning environments, final exam performance is more closely associated with the timing and pattern of students' engagement than with their average scores on weekly quizzes. Early participation, repeated quiz attempts, and consistent use of core course materials emerged as the most robust indicators of academic success. These findings suggest that behavioral traces captured in LMS platforms can provide more informative signals of student preparedness than performance measures alone.

The study therefore has both theoretical and practical implications. Theoretically, it reinforces the value of retrieval practice, timely engagement, and self-regulated learning as key mechanisms underlying academic achievement. Practically, these findings suggest several course-design strategies. Instructors can release weekly quizzes early enough to encourage distributed practice, use automated LMS reminders for students who delay their first attempt, and monitor high-latency quiz behavior as a possible early warning indicator. Courses can also encourage repeated low-stakes attempts by allowing multiple submissions and by providing feedback after each attempt. Instructors should also ensure that core presentation handouts and structured learning materials are clearly aligned with weekly quizzes and final assessment requirements, because engagement with these materials showed the strongest association with final quiz performance.

Future research should test the generalizability of these findings across disciplines, institutions, and course formats, and should examine them using experimental or longitudinal designs. Such work would help clarify causal relationships and determine whether targeted interventions aimed at improving timely engagement can enhance student outcomes. Overall, the present study contributes to the development of evidence-based digital

pedagogy by showing that how and when students engage may matter more than how well they perform at isolated points during the semester.

Funding: The research and APC was funded by The Slovenian Research and Innovation Agency, grant number P5-0174 “Pedagogical-Andragogical Research—Learning and Education for Quality Community Life”.

Institutional Review Board Statement: Under the Regulation (EU) 2016/679 (General Data Protection Regulation), when data has been completely anonymized or pseudo-anonymized so as to make it impossible to link such data to an identifiable natural person in all reasonable circumstances, said data are excluded from the obligations relating to the processing of personal data. As the analyzed data include no identifiers directly linking them to specific persons and will not enable identification of the participating persons obtaining formal approval from an appropriate ethics committee under both applicable EU and Slovenian laws (Zakon o varstvu osebnih podatkov, ZVOP-2, Uradni list RS št. 163/22) is not necessary. Thus, in accordance with the aforementioned, this study represents minimal-risk research and therefore is not required to obtain a formal ethics exemption letter based upon the regulatory framework of both the EU and Slovenia.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original data presented in the study are openly available in Zenodo repository at <https://doi.org/10.5281/zenodo.19707608> (accessed on 22 April 2026).

Acknowledgments: During the preparation of this manuscript, the author used ChatGPT (model GPT-5.4) for translation and editing of the text. The author has reviewed and edited the output and takes full responsibility for the content of this publication.

Conflicts of Interest: The author declares no conflicts of interest.

Appendix A

Three examples of weekly quiz items are provided below. The examples illustrate the type of conceptual and applied knowledge assessed in the ongoing quizzes. They are representative of the item format used in the course but do not reproduce the full item pool.

Example 1.

Which of the following statements best describes the difference between formal and postformal thinking?

- (a) Formal thinking is based on experience, whereas postformal thinking is based on abstract rules.
- (b) Postformal thinking considers context and contradictions, whereas formal thinking seeks one correct solution.
- (c) Formal thinking is characteristic of late adulthood, whereas postformal thinking is characteristic of adolescence.
- (d) Postformal thinking rejects logic, whereas formal thinking fully accepts it.

Correct answer: (b)

Example 2.

According to Cattell’s theory, which type of intelligence is most strongly associated with long-term experience and education?

- (a) Emotional intelligence
- (b) Fluid intelligence
- (c) Crystallized intelligence
- (d) Spatial intelligence

Correct answer: (c)

Example 3.

Why is it important to include adults' prior experiences in adult education?

- (a) Because adults are always right and must be respected.
- (b) Because adults' experiences are the only source of knowledge.
- (c) Because adults connect learning with meaning and practical usefulness.
- (d) Because adults do not have access to theoretical sources.

Correct answer: (c)

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