Use of e-Assessment in Mathematics Courses for Engineering Students

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Abstract

Assessment methods in education have evolved over the years and currently, the use of technology must be part of these processes. This paper describes the use of the digitization of educational assessment in two engineering courses at our university: one via the Zoom platform and the other an in-person course, where besides evaluating students' knowledge, the objective was to help them develop specific competencies.

The second-semester "Statistical Analysis" engineering course provides the basic concepts of regression analysis and time series. In particular, one class experiences a flexible, digital ELITE modality, which leverages synchronous web conferences via the Zoom platform and extensive interaction through the Canvas Learning Management System (LMS). About 100 enrolled students from several of the university's campuses take the course, which is led by a renowned professor of the institution who is supported by a team of distinguished tutor professors on various university campuses.

On the other hand, "Process Modeling Using Linear Algebra", is a third-semester engineering course covering the concepts of vector space, eigenvalues, orthogonality and linear transformations. The digitization of assessment utilizes Canvas LMS as well, and the WebAssign platform, which is specially designed for STEM courses.

Both courses utilize digital assessments to provide continuous and real-time feedback, enhance accessibility for students, track students performance over time and reduce administrative burdens on professors. In addition, with the use of technology, students can have multiple submissions of the activities and can correct their errors in real time, which helps them gain better understanding of the topics and improve the teaching-learning process.

Keywords: *E-assessment, skills, digitization of assessment, educational innovation, higher education*

1. Introduction

In contemporary higher education, assessment has increasingly evolved from a purely evaluative mechanism into a strategic component for regulating learning processes, supporting competency development, and informing instructional decision-making [1, 2]. In this context, the digitization of assessment has gained relevance not merely as a technological enhancement, but as a structural response to scalability, feedback timeliness, and evidence-based teaching in diverse instructional modalities [3].

The "Statistical Analysis" course is a fundamental second-semester subject for the majority of engineering students at the university, spanning 20 hours over five weeks, in two-hour sessions. The main topics are regression analysis and elementary time series analysis. The ELITE flexible digital version of the course, is offered annually in the spring semester, enabling students to engage with renowned professors and industry experts while fostering collaboration among peers from multiple campuses [4].

The growing adoption of e-assessment has introduced new methodological challenges related to validity, reliability, feedback effectiveness, and academic integrity, particularly in engineering education, where assessment must capture not only procedural knowledge but also higher-order competencies such as modeling, interpretation, and systemic reasoning. While prior research has documented the operational advantages of digital assessment environments, empirical evidence comparing their educational impact across contrasting instructional contexts remains limited [5,6].

This study addresses this gap by examining digitally mediated assessment practices in two undergraduate engineering mathematics courses delivered under markedly different instructional

conditions. The first corresponds to a large-scale, synchronous online course in *Statistical Analysis*, offered through a flexible digital modality and enrolling approximately 100 students from multiple campuses. The second is a small-scale, in-person course in *Process Modeling Using Linear Algebra*, with fewer than 30 students, allowing for closer interaction and monitoring.

These contrasting settings provide an opportunity to explore how e-assessment functions across enrollment scales, delivery modes, and competency frameworks, while maintaining comparable curricular structure and instructional duration. In both courses, digital assessment was implemented through the combined use of Canvas LMS [7], Respondus Lockdown Browser [8], and WebAssign [9], enabling formative and summative evaluation, individualized assessment instances, and systematic collection of performance data.

Accordingly, this study addresses the following research questions:

RQ1. To what extent does digitally mediated assessment align formative and summative performance in engineering mathematics courses?

RQ2. Are there observable differences in the effectiveness of e-assessment between large-scale online and small-scale in-person instructional modalities?

RQ3. How does digital assessment support competency-oriented evaluation in early-stage engineering education?

By providing a comparative, competency-oriented analysis grounded in authentic instructional contexts, this work contributes empirical evidence on the role of e-assessment as a regulatory mechanism for learning and performance consolidation in engineering education.

2. Literature Review

The term "e-assessment" refers to any assessment process that involves technology in its creation, delivery, marking, or feedback, and is also described in the literature as "online assessment", "computer-based testing", or "assessment digitization". In e-assessment, technology supports the end-to-end management of assessment processes, enabling systematic judgments about students' knowledge, skills, and competencies. Fundamentally, e-assessment follows the same principles as traditional assessment but differs in its digital implementation. From a methodological perspective, its validity depends not on the technology itself, but on the alignment between assessment design, learning objectives, and the constructs being measured. E-assessment offers advantages such as enhanced accessibility, improved feedback opportunities, and reduced academic dishonesty through randomization and secure environments, although it requires continuous evaluation to ensure fairness and effectiveness [10–12].

E-assessment incorporates digital tools such as LMS platforms, clickers, and video conferencing systems, enabling dynamic media integration, flexible submission formats, automated feedback, diverse task types, and more efficient evaluation processes [13]. These affordances are particularly relevant in STEM education, where assessment often involves iterative problem-solving, numerical precision, and mathematical modeling. The rapid expansion of e-assessment, accelerated by technological advances and the COVID-19 pandemic, has highlighted both its formative and summative potential, as well as challenges related to infrastructure, security, and reliability. Consequently, current research emphasizes the need to approach e-assessment not merely as an operational solution, but as a pedagogical practice requiring systematic design and refinement [14].

Empirical studies have examined the effectiveness of digital assessment across educational contexts. For example, [15] reported that the use of iPads to support formative assessment in secondary mathematics influenced instructional practices and enhanced student learning. Similarly, the systematic review presented in [16] analyzed e-assessment in computer science assignments, highlighting its growing adoption while underscoring the need to address academic integrity and feedback quality. From a student perspective, [17] identified key dimensions of effective e-assessment in undergraduate mathematics courses, including transparency, meaningful feedback, and pedagogical alignment. Despite these contributions, existing evidence remains context-dependent, reinforcing the importance of examining e-assessment practices within specific disciplinary settings and instructional modalities.

3. Methodology

This research examined two courses in different modalities with different subjects, so naturally, the application assessment digitization differed in the courses. The study followed a descriptive and

comparative educational research approach, focusing on the systematic documentation of assessment practices implemented under distinct instructional conditions.

The ELITE flexible digital version of the "Statistical Analysis" course, enables students from various cities to actively participate in the class via de Zoom platform, interacting not only with their peers but also with a distinguished panel of professors, including the head professor and mentor professors. Another advantage of this course is that all sessions are recorded and uploaded to the platform, allowing students to access the material at their convenience for better understanding or in case they miss a session. This modality supports synchronous and asynchronous learning processes, which impose specific requirements on assessment design, feedback timing, and academic integrity mechanisms. The Canvas LMS platform functioned as the primary hub for the course, supporting the application of a Collaborative Learning strategy aimed at promoting both teamwork and self-directed learning among students. The ten-session course content was carefully arranged on the platform in a weekly format, with two sessions scheduled each week. This structured digital organization ensured alignment between instructional content, assessment activities, and learning outcomes across the duration of the course. The integration of Canvas LMS as a collaborative learning environment was empirically associated with enhanced structuring of communication processes, optimized dissemination of instructional resources, and systematic tracking of learner performance. These affordances were observed to contribute to the development of a more enriched, adaptive, and evidence-informed learning experience.

The distance learning modality necessitated that all assignments, activities and exams be delivered digitally. Although the class included various assessment moments (in-class exercises, questions to students, etc.), most of the assessments were digitalized, utilizing question pools, platform-modified values to create personalized assignments and evaluations for each students. This parameterization strategy aimed to reduce academic dishonesty while preserving equivalence in content coverage and cognitive demand across assessment instances.The instructors parameterized this to indicate a specific range for these values, allowing a great variety of exams in such a way that all evaluations were different, with the same type and number of questions, the same topics, and feedback provided to students. Additionally, some exams used the Respondus Lockdown Browser, which locks down the testing environment within a learning management system like Canvas LMS. The use of secure testing environments contributed to strengthening the reliability of summative assessment results.

To consolidate learning and facilitate self-assessment after class sessions, students were assigned some activities such as practice exams and individual homework assignments, which were self-gradable through the Canvas platform. These activities were designed to function primarily as formative assessments, enabling iterative practice and immediate feedback. With these personalized tasks, it was possible to check pupils' progress, reinforce key concepts, and improve their understanding of the topics. As with all the activities in the course, there was a specified duration and number of allowed submissions. Figure 1, provides an example of a homework assignment, illustrating the instructions and the first question, which is of a numerical answer type.

In the university's educational model of the university, one of the primary objectives is to develop competencies. In the specific case of this statistics course, these skills are Systemic Thinking, Interpretation of Variables, and Scenario Development. These competencies were operationalized through assessment tasks requiring data analysis, interpretation of quantitative relationships, and contextualized decision-making.

Systemic Thinking refers to approaching problems holistically, recognizing the interconnectedness of systems. Interpreting variables means examining the relationships between key variables, applying scientific concepts, mathematical methods, and technological tools. The skill of Scenario Development involves students creating actionable scenarios to support decision-making, grounded in analyzing patterns within a data set.

The assessment of these competencies is performed through the digitization of two argumentative exams, which are applied via the Canvas platform with the support of the Lockdown Browser. The exams are asynchronous with the majority being self-gradable. This assessment design combines automated scoring with instructor-evaluated components, allowing both efficiency and qualitative judgment.These exams include multiple-choice, fill-in-the-blank, numerical answer and true-or-false as well as short answer questions, which are the ones the tutor professors grade. The argumentative exams provide evidence of the competencies to be developed and are carefully designed to evaluate not only mathematical knowledge but also skills development. Figure 2 illustrates an example of a response to a multiple-choice question on an argumentative exam, where the students select the right answer and the platform responds with the message "Well done!".

The "Process Modeling Using Linear Algebra" course is a third-semester in-person course for engineering students. The Canvas LMS platform was utilized along with the WebAssign platform, which promotes self-assessment and self-learning among students. This is a ten-session course along five weeks and with groups of about 28 students. The in-person modality enabled complementary non-digital interactions while maintaining consistency in digitally mediated assessment practices.The course assessment digitization consisted specifically of the homework assignments and quizzes.

Fig. 1 The instructions and the first question of a homework assignment in Canvas.

The homework assignments occurred weekly, with the objective of assessing the material covered during the corresponding instructional period. Figure 3 illustrates an example of such an assignment, showing the due date, the number of exercises, the points per question, and the option to practice additional problems. These activities were 100% self-gradable, allowing students to consult the textbook if difficulties arose.This design emphasizes mastery-oriented learning through repeated attempts and feedback. To assess any activity, the platform offers various templates that allow specification of several features, including the number of submissions allowed, randomization of values, question display configuration, feedback, numerical tolerance, and significant figures. Figure 4 shows an example of an assignment template.

Fig. 2 An example of a multiple-choice question in an argumentative exam.

Additionally, the two quizzes applied, were both outside the classroom. The first through WebAssign and the second through Canvas LMS. These quizzes served as low-stakes summative assessments, reinforcing content consolidation without excessive testing pressure. Regarding the first test, some students commented "After doing the homework assignment, the quiz was easy", indicating that the platform genuinely helped them experience significant learning.

Again, a critical component of the university's educational model is the development of competencies. In the case of the "Process Modeling Using Linear Algebra" course, the skills to be fostered were Determination of Patterns and Variable Interpretation.

Fig. 3 An example of a homework assignment in the WebAssign platform.

The determination of pattern skill is evidenced when students identify significant regularities within a data set by applying principles from the natural sciences, mathematics, and computational fundamentals. Similarly, variable interpretation ability is demonstrated when students analyze the interactions among relevant variables within a problem context through the application of scientific concepts, mathematical techniques, and information technologies. These competencies are

developed progressively throughout the course and are assessed through an argumentative exam at the end of the instructional period, providing summative evidence of skill development aligned with the established instructional objetives.
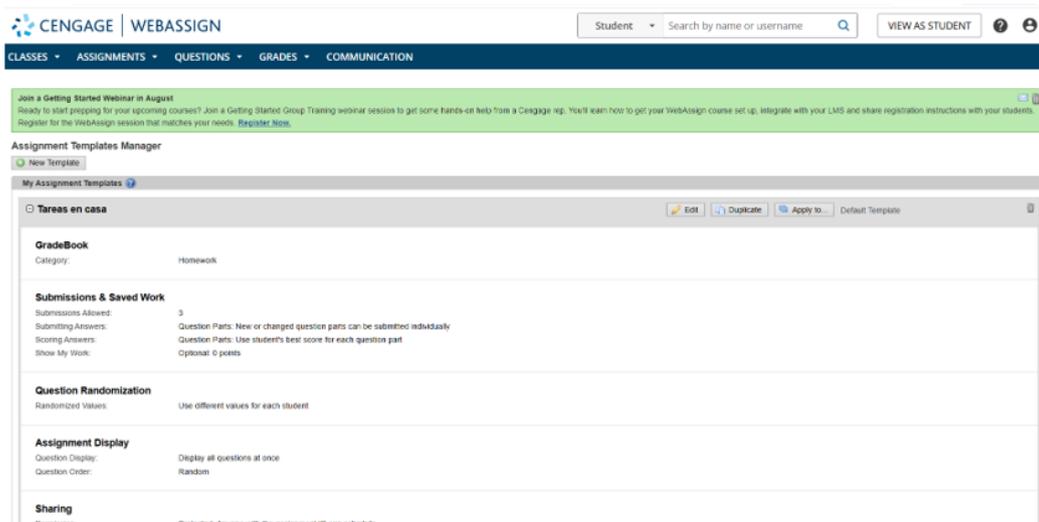

Fig. 4 An example of an assignment template in the WebAssign platform.

4. Results

The digitization of assessment was successfully performed in both courses. In the Statistics course, all homework assignments, quizzes and exams were administered digitally. Of course, there were other assessment moments during the class that, despite not been graded, significantly contributed to the student's leaning process and helped the team of professors track class advancement and provide continuous feedback. These non-graded interactions functioned as informal formative assessment instances, supporting real-time instructional adjustments without influencing summative outcomes.

The homework assignment average was 80 with about 6% of students not submitting at least one activity. Regarding the two argumentative exams, which represent the summative assessment, less than 10% failed, and the average was 88, meaning that the grades improved above the homework activities. The Wilcoxon signed-rank test was applied to validate these results because the data did not satisfy the assumption of normality, [18].

- H0: $\mu D = 0$ (the mean of the differences is zero, indicating no improvement),
- Ha: $\mu D < 0$ (the argumentative exams mean is greater than the homework assignments mean), where μD represents the mean of the differences between argumentative exams and homework scores.

The analysis yielded a p-value less than 0.01, which at a 5% significance level, clearly allowed rejecting the null hypothesis (H0), confirming that the exam's mean was significantly higher than the assignment's mean. This result provides statistical evidence supporting the consistency between formative digital activities and improved performance in summative assessments, without implying causal effects beyond the study design.

In the Linear Algebra class, an in-person course, besides the digital activities, it was feasible to have some non-digital tasks, which allowed the professor to monitor the class progress and make adjustments when necessary. Figure 5 shows the question performance for a homework assignment. The darkest color represents the proportion of students who answered correctly on the first attempt, the next color represents the proportion who answered correctly on the second attempt and the most to the right color represents those who never attempted the question. As seen, most students generally answered the question correctly on the first try. This result provides statistical evidence supporting the consistency between formative digital activities and improved performance in summative assessments, without implying causal effects beyond the study design.

However, a flagged question can be observed, indicating that many students (about 50%) answered the exercise incorrectly in the first attempt, which could prompt the professor to create additional exercises on that specific topic or to explain it differently. Such item-level analytics illustrate the diagnostic value of digital assessment for evidence-informed instructional decision-making.

Finally, the Wilcoxon test was applied to compare the means of the scores of the assignments and the quizzes. The mean of the assignments was 89, and the mean of the quizzes was 91. Even though the

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average of the quizzes was slightly higher, the obtained p-value of 0.42 at a 5% significance level means that statistically, there was no significant difference between the means of these two types of assessment. This finding suggests that both assessment formats yielded comparable performance outcomes, supporting their functional equivalence within the instructional design of the course.
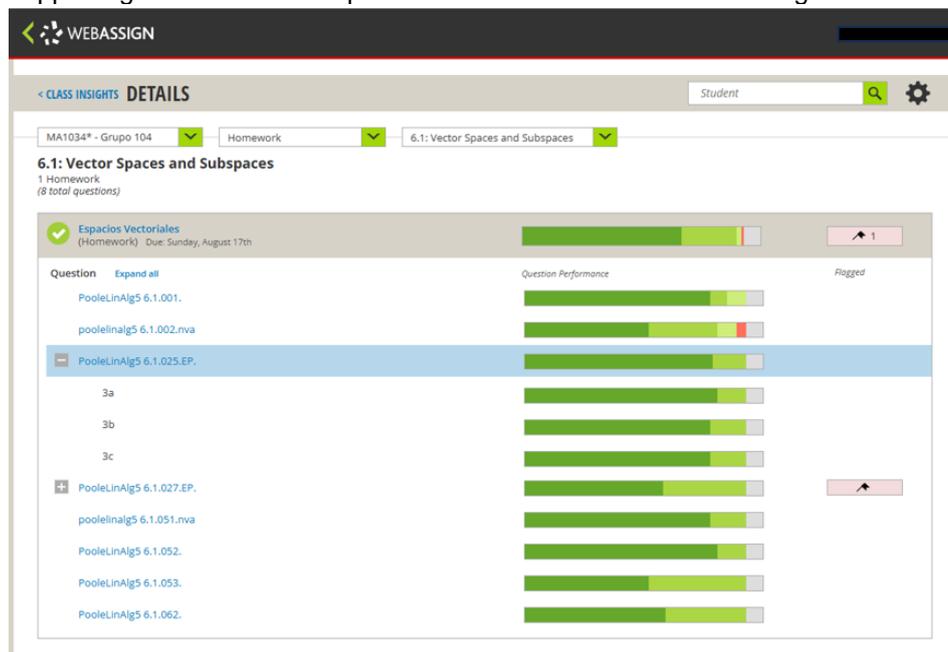

Fig. 5 An example of the question performance by attempt.

5. Discussion

The results of this study provide empirical evidence on the role of digitally mediated assessment as a regulatory component of learning in undergraduate engineering mathematics courses delivered under contrasting instructional modalities. In relation to RQ1, the statistically significant improvement observed between formative digital activities and summative argumentative exams in the large-scale online *Statistical Analysis* course suggests that e-assessment can support performance consolidation when formative feedback is systematically embedded within the instructional design. In this context, digital assessment appears to function not merely as preparatory practice, but as a mechanism that stabilizes learning outcomes prior to summative evaluation.

This finding is particularly relevant in large-enrollment online settings, where direct instructor feedback is inherently limited. The structured use of automated and semi-automated formative assessments may partially compensate for reduced instructor-student interaction by providing continuous performance cues that support self-regulation and iterative improvement. These results align with previous research highlighting the potential of e-assessment to enhance feedback timeliness and learner autonomy in scalable educational environments.

In contrast, the absence of statistically significant differences between assignment and quiz performance in the small-scale, in-person *Process Modeling Using Linear Algebra* course addresses RQ2 by suggesting that, under conditions of close instructor supervision and frequent informal feedback, digital assessment primarily fulfills a diagnostic and monitoring function rather than producing measurable performance differentials. The observed item-level analytics, particularly the identification of flagged questions with high initial error rates, illustrate how e-assessment can inform targeted instructional interventions, reinforcing its value for evidence-informed teaching.

Regarding RQ3, the competency-oriented design of assessment tasks in both courses supports the use of e-assessment for evaluating higher-order skills such as systemic thinking, variable interpretation, and pattern recognition. When assessment activities are intentionally aligned with competency frameworks, digital platforms can effectively capture analytical reasoning and contextualized decision-making beyond procedural knowledge. Overall, these findings indicate that the educational impact of e-assessment is contingent upon instructional scale, modality, and interaction patterns, underscoring the importance of evaluating digital assessment practices within their broader pedagogical context.

6. Conclusions

This study examined the implementation of digitally mediated assessment practices in undergraduate engineering mathematics courses delivered under two contrasting instructional modalities. The results demonstrate the feasibility of integrating e-assessment strategies across both large-scale online and small-scale in-person contexts, supporting consistent evaluation processes while accommodating different levels of instructor–student interaction.

In the large-enrollment online Statistical Analysis course, digitally mediated formative assessment was associated with improved alignment between formative and summative performance, highlighting the potential of e-assessment to support performance consolidation and scalable instructional regulation. In contrast, in the small-scale Process Modeling Using Linear Algebra course, digital assessment primarily functioned as a diagnostic and formative mechanism, enabling continuous monitoring of student progress and timely instructional adjustments.

Taken together, these findings reinforce the view of e-assessment as a pedagogical component that extends beyond grading efficiency, contributing to competency-oriented evaluation and evidence-informed teaching practices in engineering education. The effectiveness of digitally mediated assessment, however, is shown to be contingent upon instructional scale, modality, and interaction patterns.

Future work may explore the integration of emerging digital tools within assessment frameworks, provided that their adoption remains aligned with assessment validity, pedagogical coherence, and academic integrity. Emphasizing ethical assessment practices continues to be essential to ensure fairness and reliability in digitally mediated evaluation environments.

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