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Enhancing methods engineering education with a digital platform: usability and educational impact on industrial engineering students

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Introduction: Work study aims to comprehend the potential of human work by assessing the duration of tasks and identifying methods for reducing them to enhance productivity and efficiency. On the other hand, methods engineering analyzes job processes to determine the most efficient and cost-effective techniques, resulting in improved operations. These areas are essential in the field of industrial engineering. Traditionally, they are taught using printed manuals and classroom-based instruction. Nevertheless, these conventional strategies frequently encounter difficulties engaging students and generating solid comprehension of the topics.

Methods: This study involved the development of a digital platform to improve methods engineering education. The platform adapts the curriculum of the methods engineering course offered at Universidad Panamericana. Each laboratory's practice includes detailed instructions and tasks for students to complete. Upon finishing, students submit their reports, which the professor then assesses. If the report meets the required standards, it is approved; otherwise, students must repeat the activities. An *experience* system serves as a tracker for course completion and keeps track of the student's progress.

Results: An experimental group of 26 students who responded to Doll and Torkzadeh's end-user computer satisfaction survey tested the platform. Participants responded positively, particularly regarding the platform's accuracy (73.08% high satisfaction), ease of use (majority rated 5 for user-friendliness), and timeliness (majority satisfied with up-to-date information). However, the format dimension received mixed ratings, indicating areas for improvement. Additionally, participants appreciated the platform's ability to track progress and motivate the completion of laboratories, with 61.54% finding the content relevant and valuable for learning methods engineering concepts.

Discussion: The results suggest that integrating digital platforms into educational settings could significantly enhance educational settings, particularly in engineering courses where conventional approaches struggle to maintain student interest and engagement. Participants' positive responses support digital platforms' potential to complement and improve teaching methods. Future research will focus on integrating adaptive learning and generating micro-credentials to certify student expertise.

KEYWORDS

work study, methods engineering, digital platforms, future skills, educational innovation, higher education

1 Introduction

Work study is the field that focuses on maximizing human work efficiency by analyzing the time it takes to complete tasks and finding new ways to minimize it (Alarcón Jiménez et al., 2013). It aims to optimize productivity and efficiency, thereby enhancing overall organizational performance. Methods engineering, closely associated with work study, involves assessing job processes to identify the most efficient and cost-effective strategies (García Criollo, 2005). In industrial engineering education, both areas contribute to improving operations and achieving substantial cost reductions by improving job procedures. They prepare students for the demands of the modern workforce.

Teaching methods usually rely on conventional educational resources, such as printed books and manuals. However, these traditional methods may not sufficiently prepare students for the practical challenges they will encounter in a rapidly evolving technological society (Luckin et al., 2012; Yarychev and Mentsiev, 2020). In recent years, there has been an increase in interest in using digital platforms to improve educational outcomes and provide students with engaging learning experiences directly related to industry requirements (European Commission, 2015). Current technologies are transforming educational resources and approaches, making them learning aids that are dynamic and interactive.

Education must address developing future skills to succeed in a technology-based labor market (Stewart et al., 2016; Escobar-Castillejos et al., 2024). According to Kirchherr et al. (2018), digital literacy, the ability to interact with digital tools, and the capacity for digital learning are becoming essential. In addition, the industry is placing greater importance on competencies that promote personal development, reflection, self-management, self-efficacy, motivation, and autonomy (Ehlers and Kellermann, 2019). These abilities empower students to assume control over their academic and professional development, encouraging continuous learning and flexibility (Chou, 2012).

Acquiring these skills is essential for aligning with Sustainable Development Goal 4, which seeks to guarantee high-quality education (UNESCO, 2023). Education systems should adapt and progress to provide students with the necessary skills and knowledge to navigate these emerging paradigms. Within this context, digital technologies are transforming educational settings by enabling students to interact with educational content, comprehend concepts differently, and actively engage in activities (Khan et al., 2017). This strategy could ensure that students have the technical proficiency required by the industry and the abilities necessary for resilient and sustainable innovation and leadership (Dondi et al., 2021).

This study presents the design and development of a novel digital platform for improving methods engineering education. The platform lets students view, carry out, upload, and monitor the advancement of their practical homework. This study aims to assess the platform's usability and educational efficacy in motivating students to complete their activities and receive recognition for their achievements. To address them, the following research questions were formulated:

1. How does the digital platform impact students' ability to follow and perform their assignments?
2. What is the usability of the digital platform for tracking the progress of students' activities?
3. How does the digital platform influence students' motivation to complete activities and earn recognition for their expertise?

This study addresses the need for modern, interactive learning tools in engineering education, and it offers insights into the potential of digital platforms to complement traditional teaching methods. Therefore, this work consists of five main sections: Section 2 addresses the current educational obstacles and the challenges of incorporating digital platforms in educational environments. Section 3 describes the materials and methods used in developing and implementing the digital platform. Section 4 presents the study results. Section 5 highlights the findings related to the platform's usability and educational value and suggests future work directions. Section 6 concludes the study by summarizing the key insights.

2 Background

To promote the use of digital technologies in learning, addressing and overcoming several challenges is imperative. An obstacle to students' education is the inflexibility of the established curriculum, which leads to the acquisition of obsolete or inconsequential knowledge (Anna Hurlimann and Robins, 2013). Educational institutions suggest frameworks to encourage the development of innovative teaching methods (Ryan and Tilbury, 2013). These techniques aim to optimize learning and increase its adaptability to technology. Miranda et al. (2021) conducted a study to demonstrate the advantages of using innovative educational resources. The authors implemented technological tools to enhance students' visual analysis in solving a transportation problem in Mexico City. The results show that the students improved their capacity to analyze and apply academic knowledge in real-world scenarios. These approaches suggest that incorporating digital technologies into education could give students the necessary skills and knowledge for their future careers.

Another potential obstacle to integrating technology in educational settings is pedagogical adaptation. Authors have emphasized the importance of employing digital resources in higher education, stating that digital technologies facilitate self-directed learning by following constructivist principles, emphasizing student-centered learning and collaboration (Benavides et al., 2020; Qureshi et al., 2021). However, traditional teaching methods may encounter challenges when transitioning to digital environments (Asgari et al., 2021). A transition from passive to active learning is needed to solve this challenge. Educators should identify strategies that engage students and facilitate participation in digital environments. According to Laursen and Ryberg (2024), using pedagogical methodologies like structured freedom, flipped engagement, hybridity, and transparency can significantly improve active learning. These principles promote student autonomy in learning, participation in collaborative and adaptable learning settings, and the use of both digital and physical resources.

In addition, Koretsky and Magana (2019) conducted a study to identify the influence of computer technology on engineering education. The authors highlight the value of computer technology in learning to improve educational outcomes and boost student engagement. They emphasize the significance of designing educational resources that align with curriculum objectives and meet the needs of students. It is essential to regularly revise the curriculum to integrate the latest necessities in the industry and guarantee continuous student involvement. They also indicate the role of technology in building flexible and adaptable learning environments, as they can change how students, content, and teachers interact. This approach could enhance problem-solving skills, increase motivation, and provide more meaningful learning experiences (Coşkun et al., 2019).

Furthermore, Alhammad and Moreno (2018) argue that it is necessary to use tracking technologies in engineering education to monitor and analyze the relationship between the completion of activities and the achievement of learning outcomes. Integrating game components, like progress trackers, can offer comprehensive data on students' interactions with digital environments. For example, Mora et al. (2016) employed exercise stages to supervise tasks, allowing educators to obtain accurate information about student performance and task completion rates. In the same area, Fuchs and Wolff (2016) applied incentives to allow participants to check their progress throughout activities and encourage them to finish their tasks. The representation of progression through these elements can let students become aware of their level of engagement, measure their retention of knowledge, and improve their skills. Adopting these strategies in college and university curricula could create captivating and inspiring learning environments that support students' academic and professional development.

Lastly, it is essential for professional development to cultivate a culture that values constant improvement of skills and the acquisition of new knowledge (National Research Council et al., 1985). According to Zea Restrepo et al. (2013), integrating projects into classroom planning allows educators to introduce new materials and types of interactions to transform educational practices. The authors suggest that projects strengthen learning, involve teachers and students to participate in collaborative research, and discern new concepts and ideas. Rampazzo and Beghi (2018) also support this approach through their research on developing practical continuing education courses. The authors mention that students enrolled in a course of this type achieve high ratings on activities and exercises. Additionally, the authors listed strategies and guidelines for designing and modeling these types of courses. Collectively, these studies highlight the importance of emphasizing and improving lifelong learning programs in educational systems to meet the requirements of modern industry.

Consequently, to improve the level and competitiveness of future professionals, it is essential to prioritize continuous education and knowledge acquisition in emerging technological setups (Mourtzis et al., 2018). Colleges and universities function as centers of culture and technology, supporting the expansion and dissemination of worldwide knowledge. They provide students with the tools and knowledge to succeed and are specialists in creating new and improved education methods. Finally, these institutions promote economic growth by incorporating the advancement of knowledge into society, thereby fostering both personal and professional progress and development (United Nations, 2023).

3 Methods

Methods engineering and work study are the areas that analyze and seek to improve work processes to increase efficiency and productivity. These courses are often offered during the second year of an industrial engineering program. When introduced to these courses, students are intrigued by the practical application of their knowledge and how they can apply it. An effective strategy for methods engineering or work study courses is to incorporate project-based activities or laboratory exercises. This approach allows students to use the principles learned in practical scenarios (Zea Restrepo et al., 2013). Consequently, professors need to pay meticulous attention when designing these educational resources, as they have to be meaningful and aligned with the learning objectives of the courses. This section outlines the methodology used to evaluate the digital platform with a cohort of engineering students. A mixed-methods approach was employed, combining quantitative and qualitative data collection techniques. This approach was used to understand the platform's practical use and educational benefits and to measure whether the learning process was more captivating. This section describes the design and implementation of the digital platform developed for this study.

3.1 Design of the practical laboratories

The laboratory exercises manual for methods engineering at Universidad Panamericana was designed to offer students hands-on training by applying the course's theoretical concepts to practical scenarios. The laboratories cover essential topics such as process analysis, workstation design, task design, time studies, and productivity assessment. The structure of each laboratory session was designed to facilitate the gradual development of student's abilities and knowledge. The printed guidebook, which served as the basis for the digital platform, was created by Claudia Yohana

Arias Portelas. The guidebook contains the following laboratory practices:

1. Introduction to Methods Engineering Laboratory: This practice focuses on designing or redesigning workstations by applying methods engineering principles, considering standardization, and analyzing productive environment variables.
2. Productivity and Process Indicators: Efficacy, Efficiency, and Effectiveness: This laboratory focuses on diagnosing processes using productivity and process indicators to address production issues and achieve the most cost-effective and highest production output, adhering to economies of scale principles.
3. Operation Process Chart or Synoptic Chart: This practice focuses on applying the operation process chart to identify the effectiveness of a process and generate a solution to improve it, ensuring an orderly and efficient process from project selection to implementation.
4. Process Flow Diagram and Travel Chart: This laboratory focuses on employing process flow diagrams and travel charts to substantially improve production processes, analyzing cross and major movement between workstations and proposing optimal layouts.
5. Human-Machine Diagram: This practice focuses on understanding human-machine diagrams to study, analyze, and improve a workstation by examining the relationship between human work and machine operation cycles and balancing idle time.
6. Operation Process Chart or Bimanual Chart: This laboratory focuses on applying bimanual charts to inspect hand movement synchronization and detect efficient and inefficient movements, generating substantial activity improvements.
7. Line Balancing: This practice focuses on using line balancing techniques to determine processes that should be combined or eliminated to minimize imbalance between machines and personnel and meet required production rates.
8. Time Studies: Observed, Normal, and Standard Times: This laboratory allows the students to practice continuous timing methods to evaluate operator performance and analyze data to determine standard times.
9. Predetermined Time Systems: This practice presents to the students the use of the Methods-Time Measurement (MTM) system to calculate theoretical times for manual operations based on micro-movements, accounting for fatigue and delays and optimizing workstation design.
10. Predetermined Time Systems - MOST: This laboratory teaches students the Maynard Operation Sequence Technique (MOST) to analyze manual operations and equipment operations by identifying the three types of movement sequences and applying human factor care competencies.
11. Work Sampling: This practice enables students to determine representative observations and times in a production process using traditional statistical methods to determine the optimal number of samples and analyze the technique's reliability.
12. Workstation Design - Anthropometry: This laboratory lets students employ anthropometric data to design workstations that accommodate human body dimensions, weights, shapes, strengths, and work capacities, ensuring a comprehensive and globally informed approach to ergonomics.
13. Learning Curves: This practice permits students to understand the learning curve concept by applying the logarithmic method to plan man-hours for a disassembly project, recognizing its importance and how the industry could develop strategic improvements.
14. Physical Risk (Lighting, Noise, and Temperature) - Safety and Hygiene: This laboratory grants students the knowledge to understand physical risk factors in the work environment that can impact worker health and performance, comparing ideal and imbalanced conditions and verifying exposure limits according to national and international standards.
15. Industrial Safety - Personal Protective Equipment: This final practice allows the students to comprehend industrial safety and how using personal protective equipment (PPE) can control and mitigate risks in the workplace. This practice also lets students learn about different types of PPE for various body parts and hazards.

The laboratories in this course were carefully designed after conducting a comprehensive examination of relevant literature (Meyers, 2013; Kanawaty, 2014; Niebel and Freivalds, 2014; ACGIH, 2022). This approach guarantees that the procedures and techniques employed in the manual are based on established theories and practices, offering students an adequate and complete educational experience.

3.2 Development of the digital platform

The digital learning platform was designed to match and support the structure of the laboratories presented in the hands-on manual. The platform uses modern technologies, development frameworks, and principles of user interface (UI) and user experience (UX). The platform is responsive and functions on both web and mobile devices (Figure 1). It was built using Vite, a local JavaScript development server for React and TypeScript projects, and Tailwind, a CSS framework. Its key components include:

- Login Module: It provides secure access, allowing users to authorize and manage their data.
- Laboratory Instructions: It presents detailed instructions, objectives, and related content for each laboratory activity, ensuring students have a clear understanding of the tasks they need to perform.
- Homework Upload Module: It enables students to submit their laboratory reports for grading. This ensures that submissions are securely stored and accessible for grading.
- Experience Tracking and Badge System: The platform updates students' progress by adding experience points. Once all laboratories are completed with satisfactory grades, students receive a completion badge, which serves as a recognition of their achievement.

The incorporation of these modules in the platform provides several benefits. Through digitization, the laboratory manual becomes accessible to students on any device, allowing them to access and review the laboratories conveniently. The login module guarantees the secure management of user data. The upload module simplifies submitting and grading laboratory reports and makes it more efficient for students and professors. Lastly, the experience points and badge system motivate students to complete their laboratory exercises, fostering a sense of achievement and encouraging them to complete the laboratories.

3.2.1 Platform interface and modules

To guarantee security and safeguard user data, the login module incorporates Google Sign-In, which prompts users to authorize access to their name, email, language preference, and profile image (Figure 2). Users can manage and withdraw these rights anytime, granting them control over their data. In addition, Firebase, Google's backend cloud computing service, was used to host the platform's database, enabling real-time database administration and authentication services.

Regarding the experience tracking system, users are presented with an initial dashboard when they access the platform. This dashboard enables students to monitor their progress by providing information on the number of pending laboratories, laboratories that are being reviewed, laboratories with assigned scores, and the student's experience tracker (Figure 3). Furthermore, the dashboard displays announcements from the professor, which serve to remind students about upcoming laboratory deadlines or to provide general comments.

Moreover, the platform's sidebar provides quick access to the list of laboratories (Figure 4). Once the professor has graded the laboratory, any completed laboratory will appear with a checkmark and be highlighted in gold. This provides an additional tracking measurement of progress.

When the user accesses a laboratory instruction via the platform's menu, he can read its introduction and objectives and follow the instructions to perform the laboratory (Figure 5). Once the student has finished the practice, he has to perform a report that can be uploaded using the platform's upload module (Figure 6). After the reports are submitted, professors assess and assign grades to them. Once a report passes the specified criteria, the laboratory is designated as completed, and the student is granted experience points. Conversely, If the report is incorrect, the professor provides feedback through the announcements module, and the student must revise and resubmit the laboratory report.

Once the student has finished all the laboratories, thanks to the badge system, he receives a completion badge as a form of recognition. The student can see it once he accesses the "My Badges" section. This badge is gray if the course is incomplete or displayed in color once all the laboratories have been finished with satisfactory grades (Figure 7).

3.3 Student's perception questionnaire

To evaluate the digital learning platform, the experimental group answered Doll and Torkzadeh (1988)'s survey on end-user computer satisfaction. This instrument combines ease of use and information product features to assess the satisfaction of users directly engaging with the computer applications. The survey comprises the questions presented in Table 1, and each question is evaluated using a five-point Likert scale, where a score of five represents the highest level of satisfaction and a score of one indicates the lowest rate.

Each item in Doll and Torkzadeh's survey assesses important dimensions related to computer applications:

1. Content: This dimension refers to the relevance and completeness of the system's information.
2. Accuracy: This dimension evaluates the correctness and reliability of the system's information.
3. Format: This dimension assesses the presentation and layout of the information.
4. Ease of Use: This dimension evaluates how user-friendly the system is.
5. Timeliness: This dimension measures the promptness of the system's information.

3.4 Participants

In the academic semester of January to May 2024, an experimental group of 26 engineering students from Universidad Panamericana participated in the study. Participation was voluntary, and informed consent was obtained from all students. The students were from the 2nd to 8th semesters and had different experience levels with the topics. The students tested the platform and performed the laboratory work over two weeks. As mentioned in Section 1, the sessions were conducted to assess the platform's usefulness and gather students' perspectives on the learning experience provided by the digital resource.

The students were assigned a classmate as their partner to carry out the laboratory experiments. Due to space restrictions, some participants conducted their activities in the iOS Development Lab, as the development team was on-site to assist with any issues and debug the platform if necessary. However, some students took advantage of the platform's portability and performed the activities at home. Consequently, if they experienced any problem, they communicated via the institutional messaging system.

After the testing period ended, the end-user computing satisfaction survey was applied to the students. Additionally, two additional open questions were added: (1) What suggestions do you have to improve the digital learning platform to support you better in the laboratories? and (2) General comments. These questions allowed students to reflect on their experience with the platform and suggest any further comments they believe could enhance it.

4 Results

Figures 8–12 present the end-user computing satisfaction survey results. Moreover, as mentioned before, the additional two questions were open questions in which the students could freely comment on their perception, and in Table 2, a summary of the representative comments is presented. These results were analyzed to identify trends and patterns in student responses.

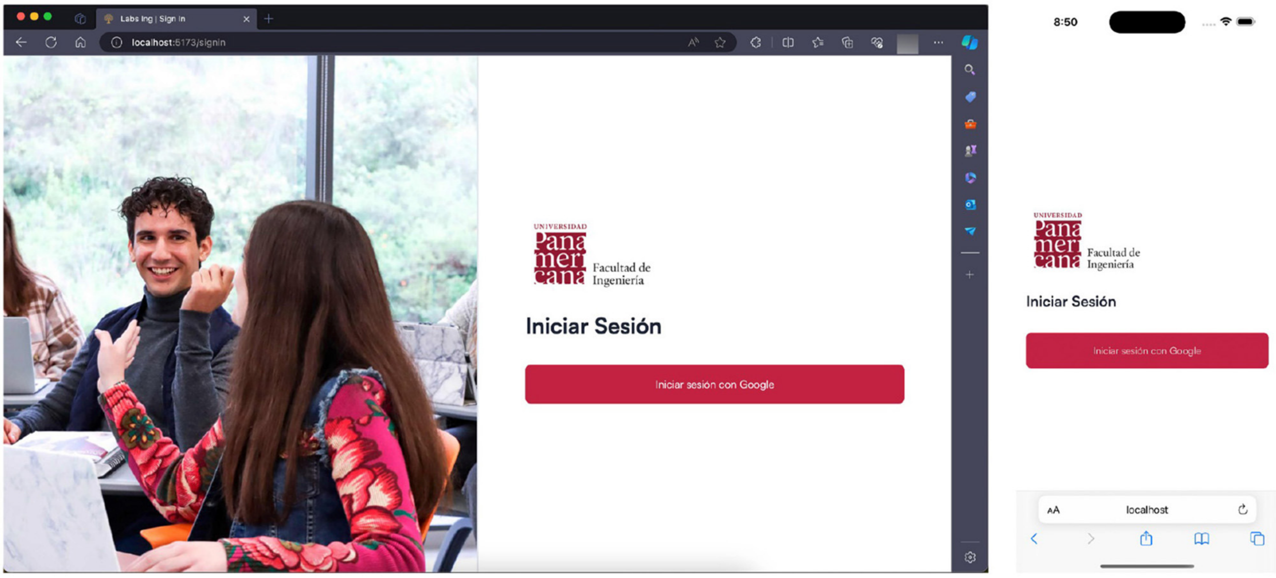

FIGURE 1
User platform views: **(left)** desktop interface and **(right)** mobile interface.

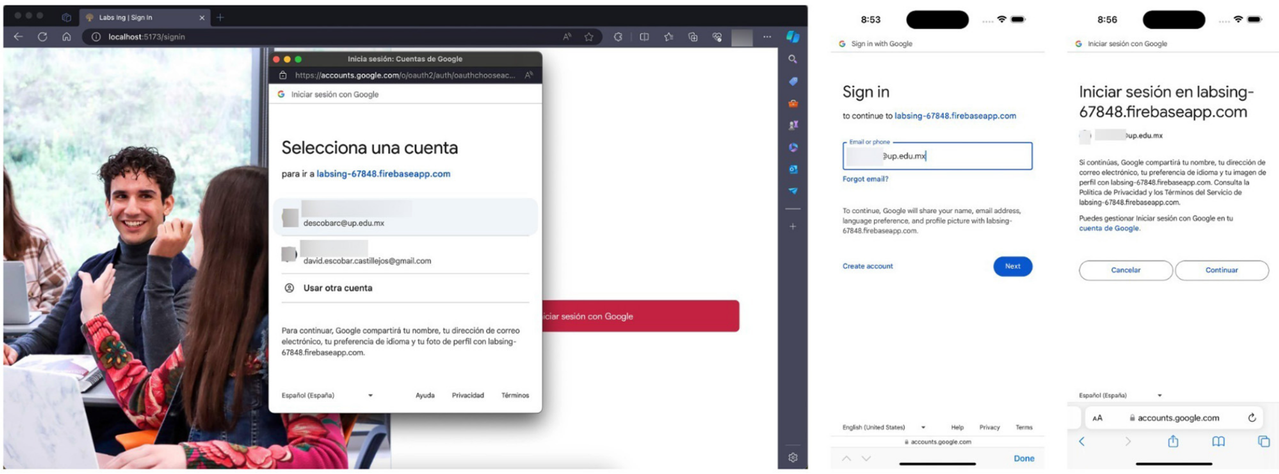

FIGURE 2
Login platform views: **(left)** selection of Google user account, **(middle)** input form prompted if no Google session is found on the device, and **(right)** Google's permission granting view to access user data.

Figure 8 shows the results for the content dimension. For Content-1, most students find the information provided by the platform to be precise, with 61.54% of the participants giving it a high rating. This indicates that the system meets students' expectations for delivering exact information. However, a minority of students, reflected in the lower ratings, feel that there is potential for improvement in the provided information. Regarding Content-2, responses show that although many students find the content adequate (34.61%), a segment believes the content is inadequate (30.77%). On the other hand, Content-3 demonstrates that the reports generated by the system are appropriate and meet the student's needs, with a rating of 4 given by 53.84% and a rating of 5 given by 26.92%. An opposite tendency is presented in Content-4. The majority of students (69.23%) consider the information offered by the system to be satisfactory but not outstanding, while 23.07% rate it as it can improve. This indicates that students feel no difference between the digital content and the printed manual. This result may be connected with the one obtained in Content 2. Content-5 reveals that most students consider the output important, similar to the answers in Content-3, with a rating of 5 given by 61.54% of the students.

Figure 9 displays the outcomes of the accuracy dimension. The responses for Accuracy-1 indicate a high level of satisfaction with the system's accuracy since the ratings were predominantly in

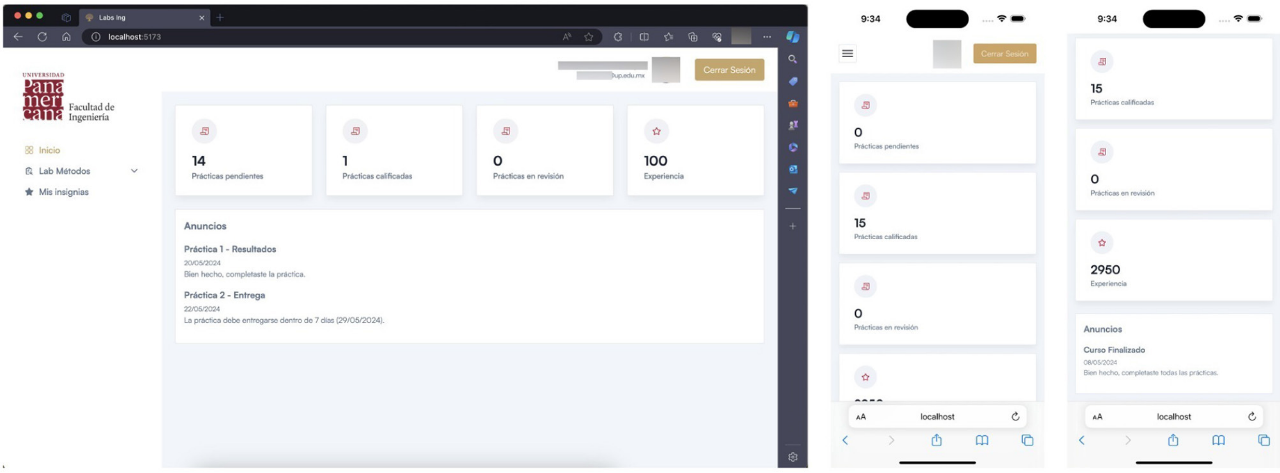

FIGURE 3
Dashboard views: **(left)** desktop interface showing the student's progress and the professor's announcements, **(middle)** mobile interface indicating that the student has completed all activities, and **(right)** mobile interface displaying the student's total experience achieved and a final announcement from the professor.

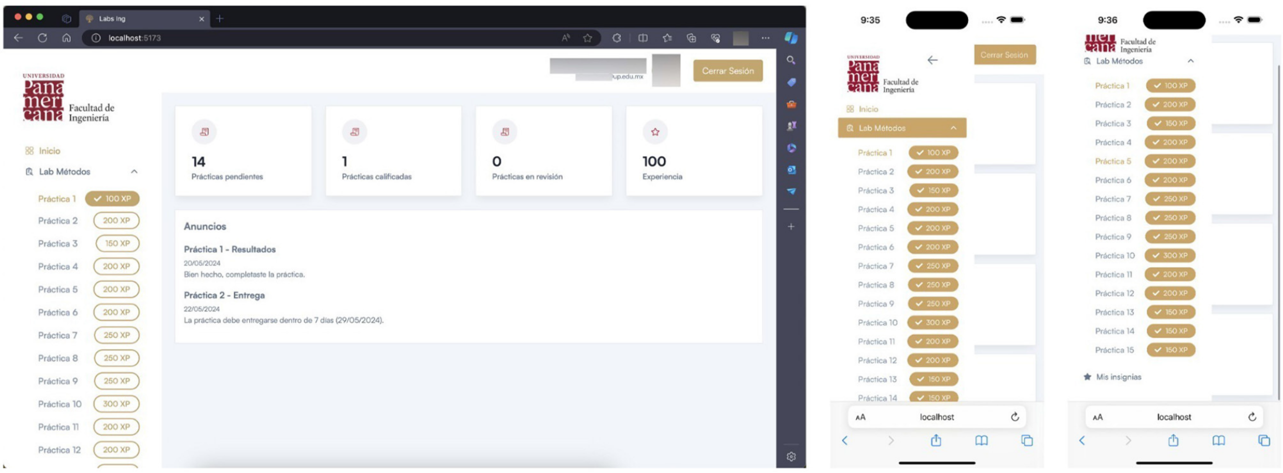

FIGURE 4
Sidebar views: **(left)** desktop interface showing the student's completed and pending laboratories, **(middle)** mobile interface displaying all the activities performed by the student, and **(right)** mobile interface displaying all the activities performed by the student (cont.).

the range of 4 and 5 (50% and 42.30%, respectively). Accuracy-2 likewise got high ratings (73.08%), suggesting that the digital resource is reliable and precise in delivering correct information. Moreover, Accuracy-3 obtained a high level of satisfaction (88.46%), and Accuracy-4 only achieved ratings of 5 and 4. The high ratings across all questions can be attributed to the validation of the content by the references of each laboratory and the recognition it received from upper-semester students, as some of them are currently employed in companies.

Figure 10 indicates the format dimension received varied ratings depending on the question. For Format-1, most participants rated it with a 5 (88.46%), revealing they liked how the information was presented. Nonetheless, Format-2 and Format-3 obtained scores of 4 and 3, indicating that while most students are satisfied with the platform's UI and information, some feel that the platform's UX and the clarity of the information have areas for improvement. This implies that the laboratories' contents could be improved to increase students' engagement. Including more effective diagrams and multimedia, such as pictures, videos, or animations, could enhance the platform's educational value and address students' different learning.

Figure 11 demonstrates that the ease of use dimension received consistently high ratings for all questions. The majority of students rated them with a score of 5. This means that students found the platform user-friendly and easy to use, suggesting that the design and interface of the platform successfully meet the student's needs. Additionally, Figure 12 points out that a similar distribution was obtained in the timeliness dimension. Most students perceived that the system displayed current information in the right amount of time,

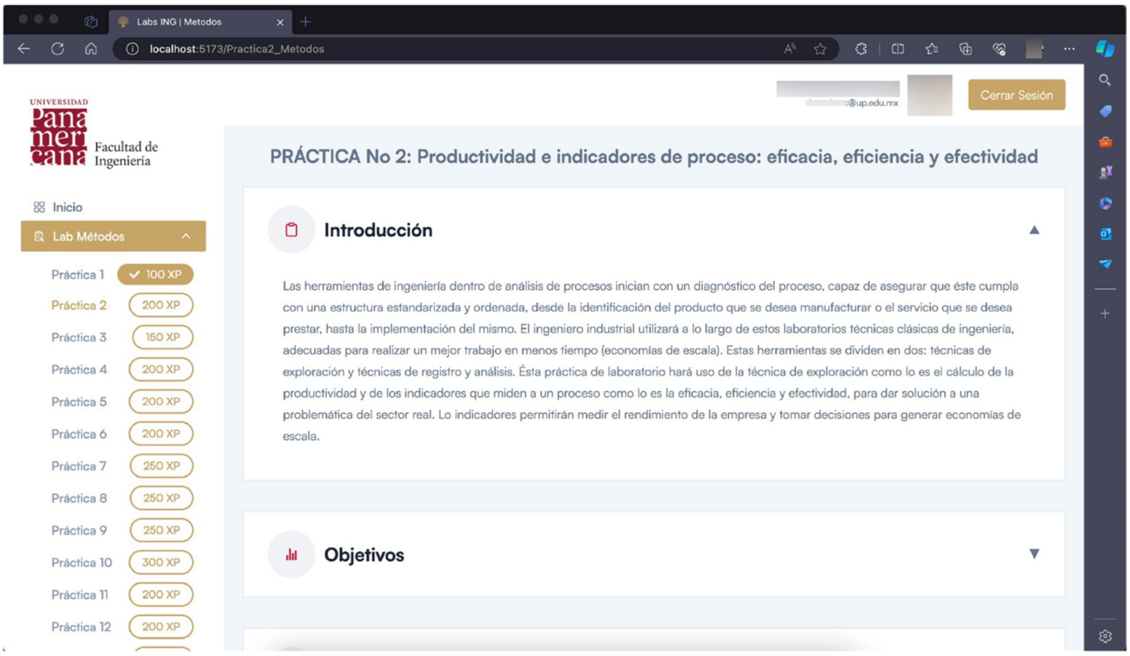

FIGURE 5
Laboratory's content view: the student can navigate the laboratory and review its introduction, objectives, and instructions.

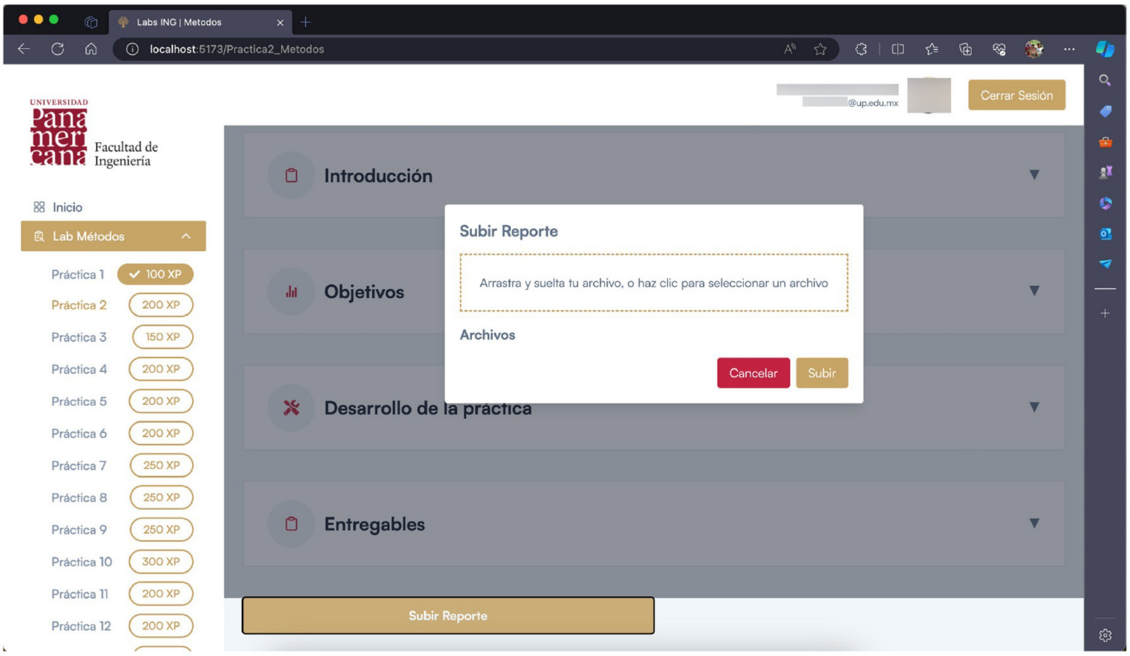

FIGURE 6
Upload module view: the student can submit his laboratory's report for grading.

indicating that the digital learning platform is responsive and reliable.

Lastly, Table 2 shows that most students liked the platform. They agreed that the digital resource helped them track their progress and motivated them to complete the laboratories to obtain the completion badge. Moreover, students praised the academic and development team for their effort in providing new learning resources. Several students inquired when the platform would be available in the course and suggested other classes with a laboratory component where they would find this resource valuable.

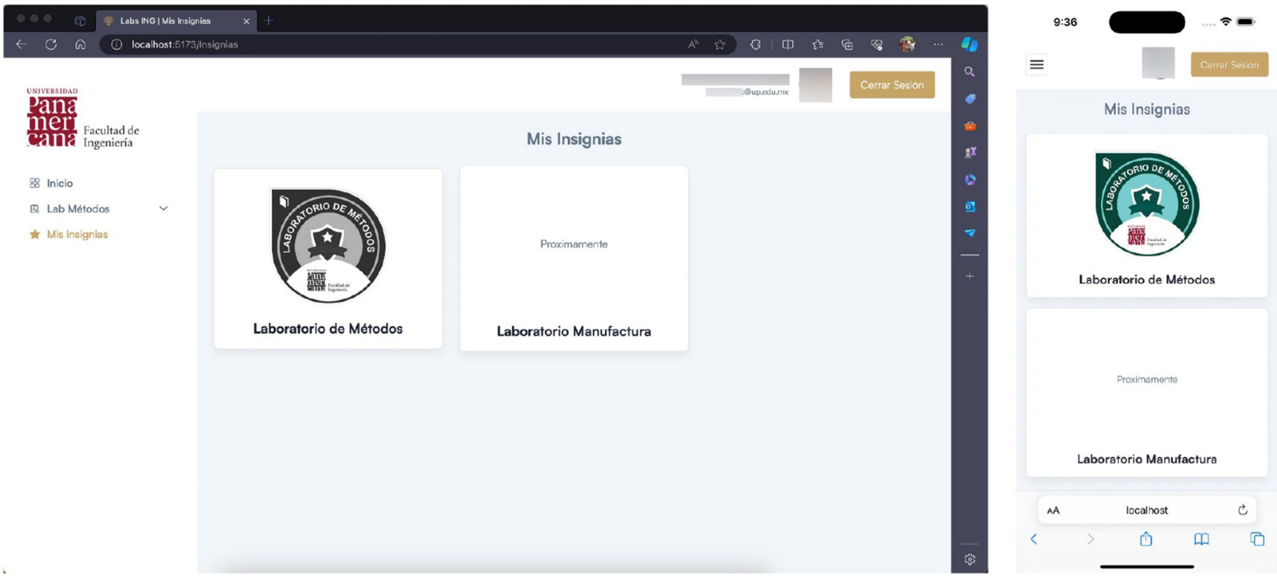

FIGURE 7
"My Badges" view: **(left)** the student has not completed all laboratories, and **(right)** the student has completed all laboratories.

5 Discussion

5.1 Main findings

This study introduces a digital platform that aims to support and enhance methods engineering and work study education. he platform uses current technological advances and incorporates gamification elements to motivate students to complete the activities. The platform adapts the curriculum of the methods engineering course at Universidad Panamericana, providing detailed instructions and tasks for each laboratory practice. The results from Doll and Torkzadeh's end-user computer satisfaction survey indicate that students value the platform's accuracy, ease of use, and timeliness. This finding aligns with the current trends in the area to emphasize the importance of digital tools in facilitating effective learning environments and promoting continuous education (Brown et al., 2015; Dabbagh and Fake, 2017).

5.1.1 Analysis of research questions

The study shows the potential of the proposed digital resource to provide a comprehensive and engaging learning experience. Regarding our initial research question, the high satisfaction ratings regarding accuracy and timeliness suggest that the digital platform significantly impacts students' ability to follow their assignments. Students reported that the platform provided precise and reliable information, which helped them complete their tasks effectively. The detailed instructions and promptness likely contributed to better assignment completion rates. Additionally, students' comments, such as "The digital resource could be a great addition to the course. Overall, I am very satisfied with the platform" and "I really enjoyed using the platform for my labs, as it was very user-friendly" underscore the platform's positive impact on their ability to perform their assignments.

TABLE 1 Doll and Torkzadeh (1988)'s end-user computing satisfaction survey.

Item code	Item description
Content-1	Does the system provide the precise information you need?
Content-2	Does the information content meet your needs?
Content-3	Does the system provide reports that seem to be just about exactly what you need?
Content-4	Does the system provide sufficient information?
Content-5	Do you find the output relevant?
Accuracy-1	Is the system accurate?
Accuracy-2	Are you satisfied with the accuracy of the system?
Accuracy-3	Do you feel the output is reliable?
Accuracy-4	Do you find the system dependable?
Format-1	Do you think the output is presented in a useful format?
Format-2	Is the information clear?
Format-3	Are you happy with the layout of the output?
Format-4	Is the output easy to understand?
Ease-1	Is the system user-friendly?
Ease-2	Is the system easy to use?
Ease-3	Is the system efficient?
Timeliness-1	Do you get the information you need in time?
Timeliness-2	Does the system provide up-to-date information?

For our second research question, students' feedback highlighted the effectiveness of the progress-tracking feature. Most students rated the platform's ease of use with a score of 5, indicating high satisfaction. Moreover, Format-1 and Format-4 obtained high ratings, indicating that the platform's intuitive design and user-friendly interface allowed students to navigate the content effortlessly and monitor their progress efficiently. Comments like "The progress tracking feature is very helpful. I liked how I could see which labs I had completed." "The dashboard helped me check the progress of my assignments" and "I liked how I could see which labs I had completed" reflect the platform's usability in tracking progress and provide a sense of accomplishment.

Regarding our third research question, the platform's gamification elements, such as the experience system and completion badges, significantly influenced students' motivation. Results indicate that these features made the learning process more engaging and encouraged students to complete their laboratories. Students appreciated the ability to track their progress and earn recognition for their efforts. For instance, a student mentioned, "This platform makes the lab activities more engaging. I wanted to finish the laboratories to obtain my badge." This suggests that the gamification elements provided an additional incentive for students to stay committed to their coursework. Moreover, this aligns with the European Commission's recommendation for implementing micro-credentials to encourage lifelong learning and improve employability (European Commission, 2022). Micro-credentials validate knowledge and skills acquired from brief educational experiences, such as a course, training plan, or short capacitation.

The survey results indicate a favorable reception of the digital platform, thereby addressing our research questions. However, the results also highlight areas that need further development to enhance the platform's effectiveness and user experience. While the platform's accuracy, ease of use, and timeliness were highly rated, the content and format dimension received mixed ratings, suggesting that improvements are necessary in how information is presented. Some students felt that the content could be more engaging and visually appealing. Incorporating more interactive elements like diagrams, videos, and animations could address these concerns and cater to different learning styles. This finding highlights the importance of researching how students' competencies and learning preferences impact their overall experience (Gonzalez-Nucamendi et al., 2022). Consequently, the platform's features' positive reception and the participants' constructive feedback provide a foundation for future development.

5.2 Ethical considerations and data privacy

Ensuring the ethical use of student data and compliance with relevant data protection regulations is crucial in any digital application. The proposed platform has a secure login module, as described in Section 3.2, that uses Google Sign-In for secure access. This module requests users to allow authorization to access their name, email, language preference, and profile image, giving them complete control over their data. Users can control and revoke these privileges at any given moment, guaranteeing the preservation of their data privacy. On the other hand, Firebase, a cloud computing service provided by Google, was used to host the platform's database. Firebase guarantees the secure storage and management of user data, adhering to industry data protection and privacy standards. In addition, the platform's design ensures that only authorized staff can access critical information, effectively protecting student data from illegal usage or breaches.

5.3 Limitations

Despite its contributions, the present study's limitations must be acknowledged. One significant limitation was the small sample size, as the study relied on a single experimental group. Having only a small sample of participants limits the generalizability of the findings, as the scores and comments gathered may not accurately reflect the experiences and viewpoints of a larger population sample. Additionally, some students experienced difficulties in completing all the laboratory assignments. This challenge could be attributed to a lack of prior knowledge of the topics or time constraints, as these activities are typically performed across the semester, and some participants were in their second semester.

Another limitation involved adapting certain laboratory practices due to the lack of access to specialized methods engineering laboratories. Some activities on the platform were adapted to allow students to complete the tasks using common materials available at their homes instead of specialized lab equipment. Without access to the specialized lab, students' understanding of the activity's objectives could be hindered, potentially affecting the depth and quality of their learning experience. The adaptations to the laboratory exercises were necessary to ensure that all students could participate, regardless of their access to specialized facilities. While this approach provided a feasible solution under the circumstances, it may have also influenced the results, as students working with non-specialized materials might not have gained the same level of practical understanding as those using professional lab equipment.

Several measures can be considered to mitigate these limitations in future platform iterations. Increasing the sample size by involving multiple experimental groups across different semesters and institutions would enhance the generalizability of the findings. Additionally, providing supplementary resources, such as video demonstrations, could help bridge the gap for students without access to physical labs. This approach would ensure that all students receive a comprehensive hands-on experience, regardless of their physical location.

Although there were several limitations, the study emphasizes the beneficial effect of interactive digital learning experiences on students' motivation and interest in methods engineering and work study. The findings underscore the need for meaningful learning opportunities to improve educational outcomes.

5.4 Future work

Future work will focus on enhancing the digital platform's educational impact. A follow-up study will increase the number of participants involved in testing the platform and aim to use the proposed digital resource to complement the methods engineering course. This approach could guarantee students sufficient time,

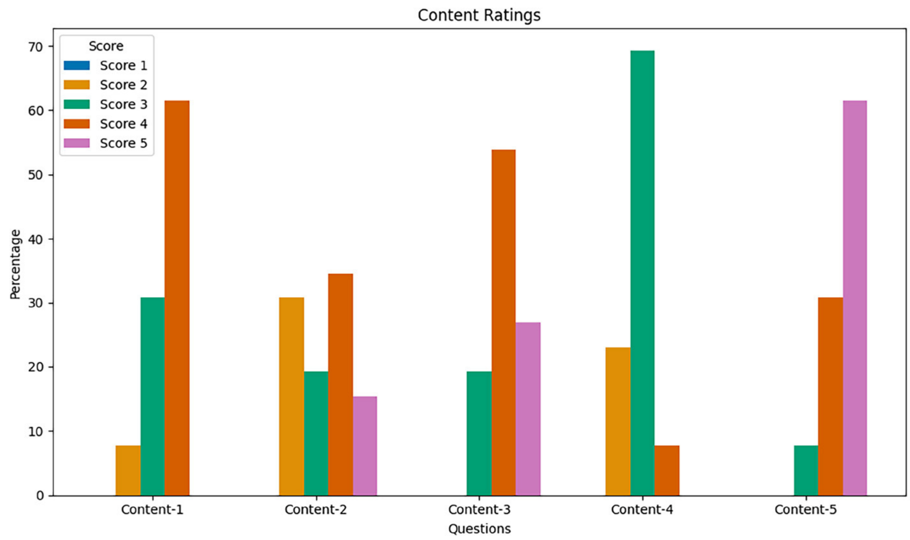

FIGURE 8
Distribution of student ratings for the content dimension questions in the end-user computing satisfaction survey.

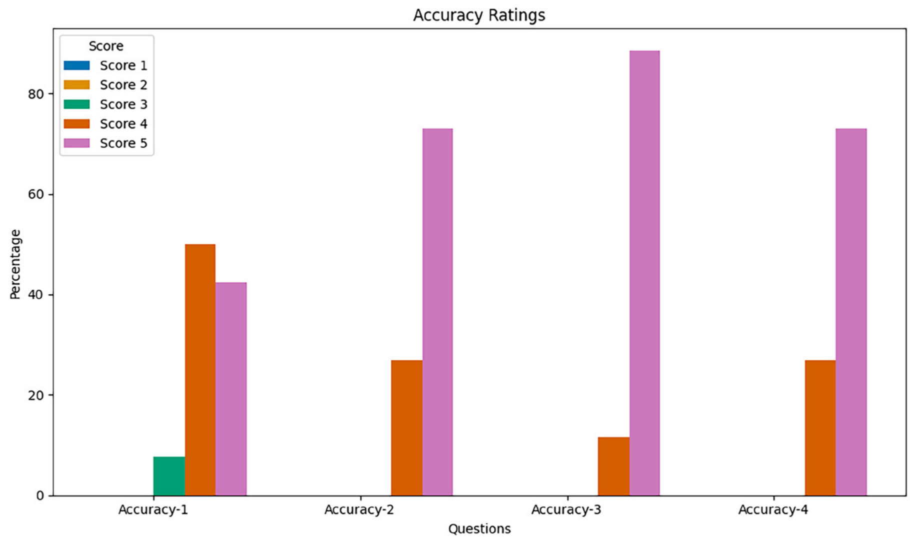

FIGURE 9
Distribution of student ratings for the accuracy dimension questions in the end-user computing satisfaction survey.

resources, and assistance to finish all the laboratories' activities. Moreover, by increasing the number of participants, the platform can be evaluated in terms of its ability to deliver results within a specific timeframe. The increased number of users in the system could impact its performance. As a result, the platform will be transferred to a cloud service provider, such as Amazon Web Services (AWS), to guarantee the ability to handle the increased workload and maintain consistent performance. These actions will enable the platform to integrate more robust technologies to store information and improve data reliability, such as MySQL. Unlike Firebase's non-relational database architecture, MySQL is a relational database management system (RDBMS) that can handle complex queries and large datasets.

Another planned study intends to improve the platform by incorporating adaptive learning technology to customize the educational experience according to the individual needs and progress of each student (Liu et al., 2017; Muñoz et al., 2022). As technology has progressed, emerging technologies, such as generative AI and virtual assistants, are becoming interested in the research community to explore their potential in education (Baidoo-anu and Ansah, 2023; Chheang et al., 2024). Moreover, this study will incorporate quantitative metrics such as assignment completion rates, grades, time spent on tasks, frequency of platform use, and active engagement levels. These metrics will provide a more comprehensive understanding of the platform's impact on student performance

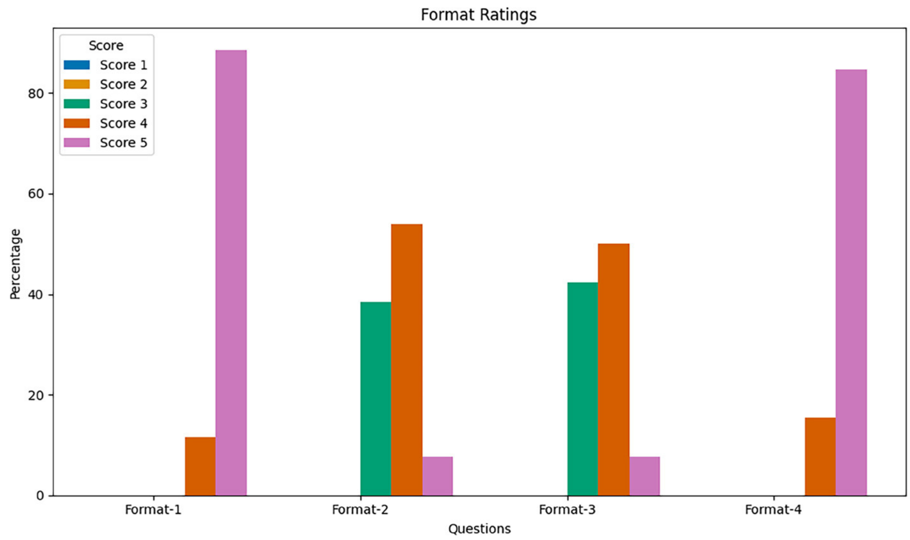

FIGURE 10
Distribution of student ratings for the format dimension questions in the end-user computing satisfaction survey.

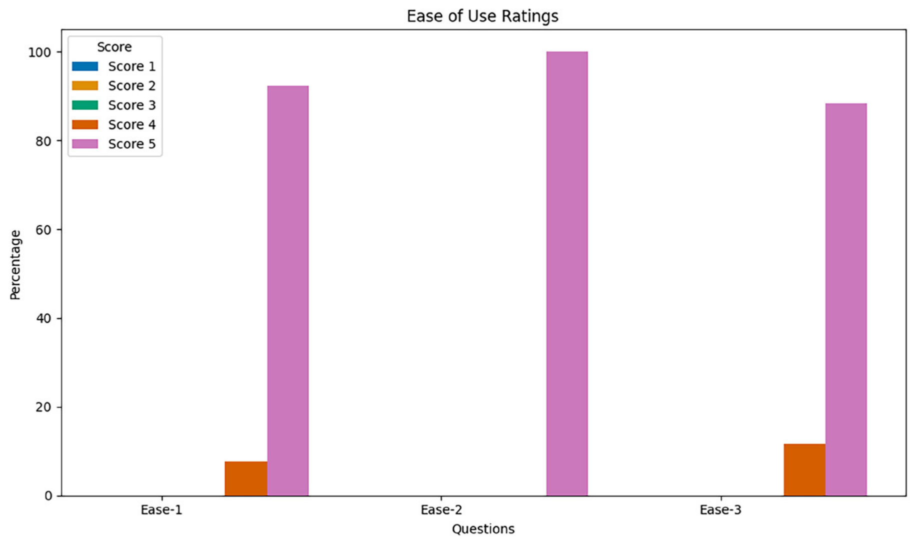

FIGURE 11
Distribution of student ratings for the ease of use dimension questions in the end-user computing satisfaction survey.

and engagement. By combining adaptive learning technologies with these quantitative metrics, the study will aim to provide a deeper insight into how personalized education and gamification can enhance student learning experiences and outcomes.

Finally, there are plans to develop and issue micro-credentials at our institution and restructure the platform to incorporate laboratory courses from other engineering disciplines. Micro-credentials prove students' abilities and can be linked to digital resumes, such as LinkedIn profiles. As mentioned in the findings, students were motivated to complete their activities to obtain the platform's badge. To incorporate the platform into other engineering courses, the upcoming development stage will involve redesigning and restructuring the platform's infrastructure to ensure scalability and flexibility. Additionally, since the progression tracker received positive participant feedback, this development stage will consider adding gamified elements such as leaderboards and reward systems (Ratinho and Martins, 2023). However, careful planning and design are necessary to ensure these elements do not interfere with educational objectives or diminish the participants' learning experience. Depending on the course type, it is essential to investigate and balance gamification elements to maintain their effectiveness and relevance while supporting educational goals.

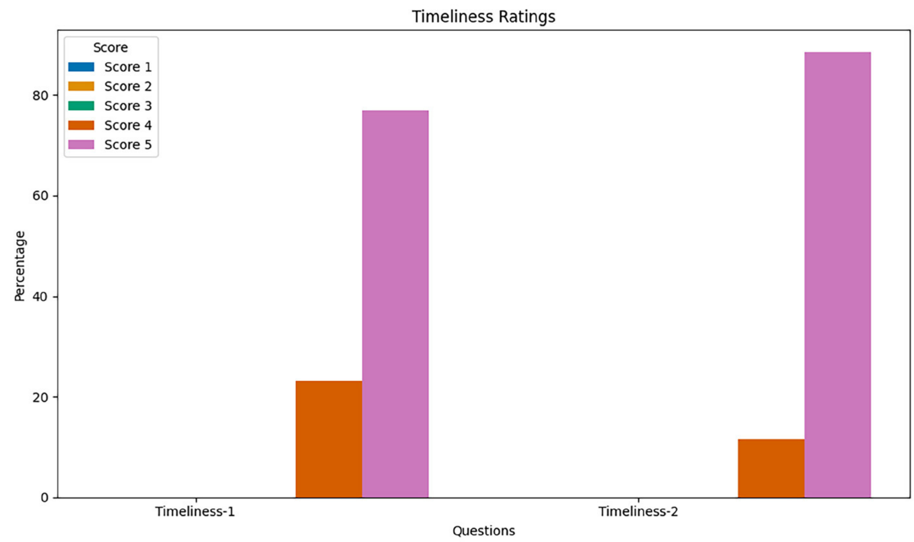

FIGURE 12
Distribution of student ratings for the timeliness dimension questions in the end-user computing satisfaction survey.

TABLE 2 Summary of students' comments obtained from the two additional open questions at the end of the study.

Students' statements
I really enjoyed using the platform for my labs, as it was very user-friendly.
The digital resource could be a great addition to the course. Overall, I am very satisfied with the platform.
This platform makes the lab activities more engaging. I wanted to finish the laboratories to obtain my badge.
The progress tracking feature is very helpful. I liked how I could see which labs I had completed.
The dashboard helped me check the progress of my assignments. The team did a great job with this platform.
When will this platform be available for all courses? Is there a plan to link the badge to my LinkedIn profile?
Please consider this for other engineering labs.

6 Conclusion

This study presents a digital platform designed to assist work study and methods engineering education by incorporating current technological advances and gamification elements to motivate students. The platform provides an organized and flexible approach to learning, including activity instructions, progress tracking, and effort recognition. The research addressed three main questions:

1. Impact on Students' Ability to Follow and Perform Assignments: The high satisfaction ratings regarding accuracy and timeliness suggest that the digital platform significantly improved students' ability to follow and complete their assignments effectively. Detailed instructions and visual feedback likely contributed to better assignment completion rates and overall student satisfaction.
2. Usability for Tracking Progress: Students' feedback highlighted the platform's effectiveness in tracking progress. Most students rated the platform highly for its ease of use, intuitive design, and user-friendly interface, which allowed them to navigate content effortlessly and monitor their progress efficiently. The progress-tracking feature provided a sense of accomplishment and motivation.
3. Influence on Students' Motivation: The platform's gamification elements, such as the experience system and completion badges, significantly influenced students' motivation. These features made learning more engaging and encouraged students to complete their laboratories. Students appreciated the ability to track their progress and earn recognition for their efforts, aligning with the European Commission's recommendation for implementing micro-credentials to encourage lifelong learning and improve employability.

The survey results indicate a favorable reception of the digital platform, thereby addressing our research questions. However, the results also highlight areas that need further development to enhance the platform's effectiveness and user experience. While the platform's accuracy, ease of use, and timeliness were highly rated, the content and format dimensions received mixed ratings, suggesting that improvements are necessary in how information is presented. More interactive elements like diagrams, videos, and animations could address these concerns and fit different learning styles.

Although incorporating new technology into educational environments can be challenging, digital platforms offer an interactive resource to improve student involvement and academic outcomes. The current findings are positive, but further research is required to enhance and validate the platform's efficacy. Future research will focus on improving the platform's modules, increasing the number of users, incorporating new courses into the platform's catalog, and addressing identified areas for improvement. Efforts in this area should be dedicated to providing strong evidence that modernizing education is essential for ensuring employment opportunities and fostering a culture of continuous learning.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval were waived for this study as it was deemed "research without risk," and the research intervention poses a risk comparable to that of a standard classroom environment. Moreover, given that the use of the digital platform was not invasive, the rights of the experimental students were respected following the Declaration of Helsinki.

Author contributions

DavE-C: Conceptualization, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. IS-N: Data curation, Software, Visualization, Writing – original draft. JN: Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. DaiE-C: Formal analysis, Investigation, Project administration, Visualization, Writing – review & editing. LB-G: Conceptualization, Resources, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

ACGIH (2022). *TLV physical agents introduction - ACGIH*. Available at: https://www.un.org/sustainabledevelopment/economic-growth/ (accessed May 7, 2024).

Alarcón Jiménez, E., López Peralta, J., and Rocha Pérez, M. A. (2013). *Estudio del Trabajo: Una Nueva Visión*. GRUPO Editorial Patria, primera edition.

Alhammad, M. M., and Moreno, A. M. (2018). Gamification in software engineering education: a systematic mapping. *J. Syst. Softw.* 141, 131–150. doi: 10.1016/j.jss.2018.03.065

Anna Hurlimann, A. M., and Robins, J. (2013). University curriculum development - stuck in a process and how to break free. *J. High. Educ. Policy Manag.* 35, 639–651. doi: 10.1080/1360080X.2013.844665

Asgari, S., Trajkovic, J., Rahmani, M., Zhang, W., Lo, R. C., and Sciortino, A. (2021). An observational study of engineering online education during the COVID-19 pandemic. *PLoS ONE* 16:e250041. doi: 10.1371/journal.pone.0250041

Baidoo-anu, D., and Ansah, L. O. (2023). Education in the era of generative artificial intelligence (ai): understanding the potential benefits of chatgpt in promoting teaching and learning. *J. AI* 7, 52–62. doi: 10.61969/jai.1337500

Benavides, L. M. C., Tamayo Arias, J. A., Arango Serna, M. D., Branch Bedoya, J. W., and Burgos, D. (2020). Digital transformation in higher education institutions: a systematic literature review. *Sensors* 20:3291. doi: 10.3390/s20113291

Brown, M., Dehoney, J., and Millichap, N. (2015). *The next generation digital learning environment*. Technical report, EDUCAUSE Learning Initiative.

Chheang, V., Sharmin, S., Márquez-Hernández, R., Patel, M., Rajasekaran, D., Caulfield, G., et al. (2024). "Towards anatomy education with generative ai-based virtual assistants in immersive virtual reality environments," in *2024 IEEE International Conference on Artificial Intelligence and eXtended and Virtual Reality (AIxVR)*, 21–30. doi: 10.1109/AIxVR59861.2024.00011

Chou, P.-N. (2012). The relationship between engineering students self-directed learning abilities and online learning performances: a pilot study. *Contemp. Issues Educ. Res.* 5, 33–38. doi: 10.19030/cier.v5i1.6784

Coşkun, S., Kayikcı, Y., and Gençay, E. (2019). Adapting engineering education to industry 4.0 vision. *Technologies* 7:10. doi: 10.3390/technologies7010010

Dabbagh, N., and Fake, H. (2017). College students' perceptions of personal learning environments through the lens of digital tools, processes and spaces. *J. New Appr. Educ. Res.* 6, 28–36. doi: 10.7821/naer.2017.1.215

Doll, W. J., and Torkzadeh, G. (1988). The measurement of end-user computing satisfaction. *MIS Quart.* 12, 259–274. doi: 10.2307/248851

Dondi, M., Klier, J., Panier, F., and Schubert, J. (2021). *Defining the skills citizens will need in the future world of work*. Available at: https://www.mckinsey.com/industries/public-sector/our-insights/defining-the-skills-citizens-will-need-in-the-future-world-of-work (accessed August 22, 2023).

Ehlers, U.-D., and Kellermann, S. A. (2019). *Future skills: The future of learning and higher education*. Available at: https://www.learntechlib.org/p/208249 (accessed August 22, 2023).

Escobar-Castillejos, D., Barrera-Animas, A., Lozada-Flores, O., and Noguez, J. (2024). "Enhancing steam in education 4.0: a review of data-driven technological improvements," in *Data-Driven Innovation for Intelligent Technology*, eds. H. Ponce, J. Brieva, O. Lozada-Flores, L. Martíez-Villaseñor, and E. Moya-Albor (Cham: Springer), 39–65. doi: 10.1007/978-3-031-54277-0_2

European Commission (2015). *Europe's future is digital*. Available at: https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_15_4772 (accessed May 7, 2024).

European Commission (2022). *A european approach to micro-credentials*. Available at: https://education.ec.europa.eu/education-levels/higher-education/micro-credentials (accessed May 7, 2024).

Fuchs, M., and Wolff, C. (2016). "Improving programming education through gameful, formative feedback," in *2016 IEEE Global Engineering Education Conference (EDUCON)*, 860–867. doi: 10.1109/EDUCON.2016.7474653

García Criollo, R. (2005). *Estudio del Trabajo. Ingenieria Metodos y Medicion del Trabajo*. New York: McGraw Hill, 2nd edition.

Gonzalez-Nucamendi, A., Noguez, J., Neri, L., Robledo-Rella, V., García-Castelán, R. M. G., and Escobar-Castillejos, D. (2022). Learning analytics to determine profile dimensions of students associated with their academic performance. *Appl. Sci*. 12:10560. doi: 10.3390/app122010560

Kanawaty, G. (2014). *Introducción al Estudio del Trabajo*. Lorca: Limusa, 4th edition.

Khan, A., Egbue, O., Palkie, B., and Madden, J. (2017). Active learning: Engaging students to maximize learning in an online course. *Electr. J. e-Learning* 15, 107–115.

Kirchherr, J.-W., Klier, J., Lehmann-Brauns, C., and Winde, M. (2018). *Future skills: Which skills are lacking in germany*. Available at: https://www.stifterverband.org/medien/which-skills-are-lacking-in-germany (accessed August 22, 2023).

Koretsky, M. D., and Magana, A. J. (2019). *Using Technology to Enhance Learning and Engagement in Engineering*. Washington, DC: American Society for Engineering Education.

Laursen, L. N., and Ryberg, T. (2024). Digitalisation of engineering design education: structured freedom, flipped engagement, hybridity, and transparency. *Eur. J. Eng. Educ*. 2024, 1–20. doi: 10.1080/03043797.2024.2331257

Liu, M., McKelroy, E., Corliss, S. B., and Carrigan, J. (2017). Investigating the effect of an adaptive learning intervention on students' learning. *Educ. Technol. Res. Dev*. 65, 1605–1625. doi: 10.1007/s11423-017-9542-1

Luckin, R., Bligh, B., Manches, A., Ainsworth, S., Crook, C., and Noss, R. (2012). *Decoding Learning: The Proof, Promise and Potential of Digital Education*. Nesta.

Meyers, F. E. (2013). *Estudio de tiempos y movimientos para la manufacturaágil*. Hoboken: Prentice Hall, 2nd edition.

Miranda, J., Navarrete, C., Noguez, J., Molina-Espinosa, J.-M., Ramirez-Montoya, M.-S., Navarro-Tuch, S. A., et al. (2021). The core components of education 4.0 in higher education: Three case studies in engineering education. *Comput. Electr. Eng*. 93:107278. doi: 10.1016/j.compeleceng.2021.107278

Mora, A., Planas, E., and Arnedo-Moreno, J. (2016). "Designing game-like activities to engage adult learners in higher education," in *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality, TEEM '16* (New York, NY, USA: Association for Computing Machinery), 755–762. doi: 10.1145/3012430.3012603

Mourtzis, D., Vlachou, E., Dimitrakopoulos, G., and Zogopoulos, V. (2018). Cyber-physical systems and education 4.0 - the teaching factory 4.0 concept. *Procedia Manuf*. 23, 129–134. doi: 10.1016/j.promfg.2018.04.005

Muñoz, J. L. R., Ojeda, F. M., Jurado, D. L. A., Peña, P. F. P., Carranza, C. P. M., Berríos, H. Q., et al. (2022). Systematic review of adaptive learning technology for learning in higher education. *Eur. J. Educ. Res*. 98, 1–14.

National Research, Council Committee on the Education, Utilization of the Engineer, and Panel on Continuing Education (1985). *Continuing Education of Engineers*. Washington, DC: National Academies Press.

Niebel, B., and Freivalds, A. (2014). *Ingeniería Industrial: Métodos, Estándares y Diseño del Trabajo*. New York: McGraw Hill, 12th edition.

Qureshi, M. I., Khan, N., Raza, H., Imran, A., and Ismail, F. (2021). Digital technologies in education 4.0: does it enhance the effectiveness of learning? A systematic literature review. *Int. J. Inter. Mobile Technol*. 15, 31–47. doi: 10.3991/ijim.v15i04.20291

Rampazzo, M., and Beghi, A. (2018). Designing and teaching of an effective engineering continuing education course: modeling and simulation of HVAC systems. *Comput. Applic. Eng. Educ*. 26, 739–748. doi: 10.1002/cae.21916

Ratinho, E., and Martins, C. (2023). The role of gamified learning strategies in student's motivation in high school and higher education: a systematic review. *Heliyon* 9:e19033. doi: 10.1016/j.heliyon.2023.e19033

Ryan, A., and Tilbury, D. (2013). *Flexible pedagogies: New pedagogical ideas*. Technical report, The Higher Education Academy.

Stewart, B., Khare, A., and Schatz, R. (2016). "Volatility, uncertainty, complexity and ambiguity in higher education," in *Managing in a VUCA World*, eds. O. Mack, A. Khare, A. Krämer, and T. Burgartz (Cham: Springer), 241–250. doi: 10.1007/978-3-319-16889-0_16

UNESCO (2023). *Digital learning and the transformation of education*. Available at: https://www.unesco.org/en/digital-education (accessed August 22, 2023).

United Nations (2023). *Promote inclusive and sustainable economic growth, employment and decent work for all*. Available at: https://www.un.org/sustainabledevelopment/economic-growth/ (Accessed May 7, 2024).

Yarychev, N. U., and Mentsiev, A. U. (2020). Impact of digital education on traditional education. *J. Phys*. 1691:012132. doi: 10.1088/1742-6596/1691/1/012132

Zea Restrepo, C. M., Magana, A. J., Lalinde-Pulido, J. G., Rodriguez, A., and Bueno Pizarro, N. A. (2013). "An engineering approach for continuous improvement in engineering education," in *2013 ASEE International Forum* (Atlanta, Georgia: ASEE), 21.10.1–21.10.9. doi: 10.18260/1-2–17215