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Developing a Digital Platform Ecosystem for Distance Learning and STEM Education

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ABSTRACT

In this study, we design an online digital platform ecosystem that addresses the learning needs of students in both traditional education and STEM-focused instruction within educational institutions. The platform will be Internet-based, enabling access for learners wherever an Internet connection is available. As part of this research, we will pilot five learning modules tailored to the platform's environment. A controlled experiment will then be conducted involving two groups of 100 students each: one group will receive instruction through traditional face-to-face methods, while the other will engage with the same content via the digital platform. This design allows us to evaluate the effectiveness of the digital platform model. Data will be collected and assessed based on the following criteria: (1) the average learning outcomes across each course, (2) instructors' feedback on the platform's capacity to achieve course objectives, and (3) a comparison of learning outcomes between the two groups using statistical hypothesis testing through a t-test.

Keywords: Laboratory learning model, Virtial learning environment, Moodle, Teaching ecosystem, Educational digital platform.

1. INTRODUCTION

In the context of rapidly advancing science and technology, growing bodies of knowledge, and increasingly diverse learning needs - particularly in terms of format, content, and pace - traditional face-to-face instruction is no longer sufficient to meet all student demands (Dias et al., 2020). This shift has led to the emergence of various non-traditional learning formats, with online learning standing out as one of the most prominent and widely adopted (Magalhães et al., 2020). Thanks to its flexibility, diversity, and potential for global collaboration, the online learning ecosystem provides educators with a variety of tools to deliver content, interact with students, and inspire learning. At the same time, students are offered multiple pathways to engage with materials and personalize their learning experiences (Pumahapinyo & Suwannatthachote, 2014a). As a result, digital classrooms play an increasingly important role in enhancing the effectiveness of teaching and learning. Online learning environments are now widely adopted by educational institutions, instructors, and learners alike (Abuhassna & Yahaya, 2018; Hmelo-Silver, 2004). The global disruptions caused by the Covid-19 pandemic accelerated the digital transformation of higher education, highlighting the necessity of internationalization and the ability to access education anytime, anywhere (Smolyaninova & Bezyzvestnykh, 2019). Personalized and lifelong learning have since emerged as dominant educational trends. However, the pandemic also exposed many universities' limited capacity for implementing online education effectively, especially when students are unable to attend physical classes (Anyaoku, 2008; Bignell & Parson, 2010; Koneru, 2017; O'Donnell, 2012). Research on STEM education globally spans multiple areas, including STEM pedagogy, online STEM learning, STEM teacher training, and the development of students' STEM competencies (Sergis et al., 2017). Notably, online STEM education has proven highly effective, as it leverages multimedia—such as images, videos, and instructional materials—on digital platforms to encourage learner engagement. These resources allow learners to revisit materials multiple times, reinforcing understanding and promoting active learning.

This study proposes the development of a digital learning ecosystem designed to support fully online instruction via internet-based platforms. The system will specifically accommodate remote education needs, including the implementation of online STEM learning.

2. THEORETICAL FRAMEWORK

In the study of online STEM education (Hobbs et al., 2018), the authors Zi-Yu Liu and colleagues conducted research on 'Online Technologies in STEM Education'. This study aims to understand the impact of integrating STEM education into third-year engineering and pedagogy students in enhancing the quality of education. In the study on diversity in STEM education implementation, this research (Hobbs et al., 2018) illustrated the diversity of activities in class that can arise from a comprehensive STEM vision. The research is indicating that a STEM vision requires more than discrete activities through direct classroom teaching. There needs to be methods for deploying teaching and learning activities that are suitable for the development of digital platforms. In the study (Jackson, 2017), Emerson Abraham Jackson investigated 'The Impact of the MOODLE Platform on Teachers' and Students' Pedagogical Methods: A Comparison through Training Programs'. The study also highlights the importance of the MOODLE learning platform and its contribution to promoting flexible teaching and the need for supported action to assist teachers/instructors in developing diverse learning resources with a dual purpose of improving flexibility in student learning outcomes and assessments. There is also a need to promote collaborative partnerships between curriculum fields through management intervention to enhance teachers' confidence in developing interactive teaching and learning resources. In the study by the author team led by Littenberg-Tohias, the research team proposed the 'Content-Collaboration-Context Model,' a model applicable for implementing online learning for learners from anywhere to participate in courses, and the courses are designed to simulate real-world learning experiences (Littenberg-Tobias & Slama, 2022). In the study by the author team led by Altinpulluk on the trends of using digital learning management tools, LMS is an open-source tool, and it is the most widely used system for learning management and deployment in online education (Altinpulluk & Kesim, 2021).

Learning ecosystems are deployed based on the needs and orientations of each country and educational institution. These ecosystems are used to manage, implement, and evaluate the learning process. In several studies (Hrastinski, 2008; Jothi et al., 2011; Setiadi et al., 2021; Siemens, 2005), proposals have been made regarding the assessment of learning outcomes in digital environments. In this context, the research team proposes a self-assessment model within the LMS ecosystem, applied across various pedagogical activities.

Another study on evaluating course effectiveness through the Moodle learning management system was conducted by Rianne Conijn and colleagues (Conijn et al., 2017). The study provided a theoretical framework for analyzing learning and identified common predictive factors used in similar research. The researchers analyzed 17 courses involving 4,989 students at an institution using the Moodle LMS. Student performance was predicted using variables extracted from the LMS and mid-term assessments, applying both multilevel and standard regression models. The analysis revealed significant variation in predictive model outcomes across courses, even within a single institution. Therefore, the generalizability of prediction models across different courses was found to be limited. In studies on distance education in digital environments (Oguguo et al., 2021; Pumahapinyo & Suwannatthachote, 2014b), researchers examined the impact of live-streamed lectures on student achievement and attendance. The findings suggest that live streaming reduces performance among low-ability students but enhances performance for high-ability students. Students tend to use live streaming occasionally, particularly when attending in-person lectures becomes difficult due to unforeseen events. However, the availability of live-streamed lectures only slightly reduced overall attendance rates.

Digital platform-based teaching is widely adopted in the context of Industry 4.0. With the development of teaching and learning management tools such as Moodle, Edmodo, MOOCs, and Google Classroom, the implementation of educational processes on digital platforms has become increasingly convenient (Ahmed & Mesonovich, 2019). Online pedagogy involves accessing and applying digital resources from a pedagogical perspective. Digital pedagogy has become a prominent trend, emphasizing the delivery of instruction in virtual environments to produce learners who can adapt to the needs of the digital economy and society (Chemsi et al., 2020). According to Oxford University Press (2015), a virtual learning environment (VLE) is a system that delivers educational content to learners via the web.

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These systems typically include assessment tools, student tracking, and collaborative communication features. They are accessible both on and off campus, enabling 24/7 support for student learning.

3. METHODOLOGY

The structure of learning resources for a training program on the UTEx learning ecosystem is described in the following flowchart, Figure 1. From the flowchart diagram in Figure 1, we proceed to build the UTEx system according to the system overview diagram in Figure 2.

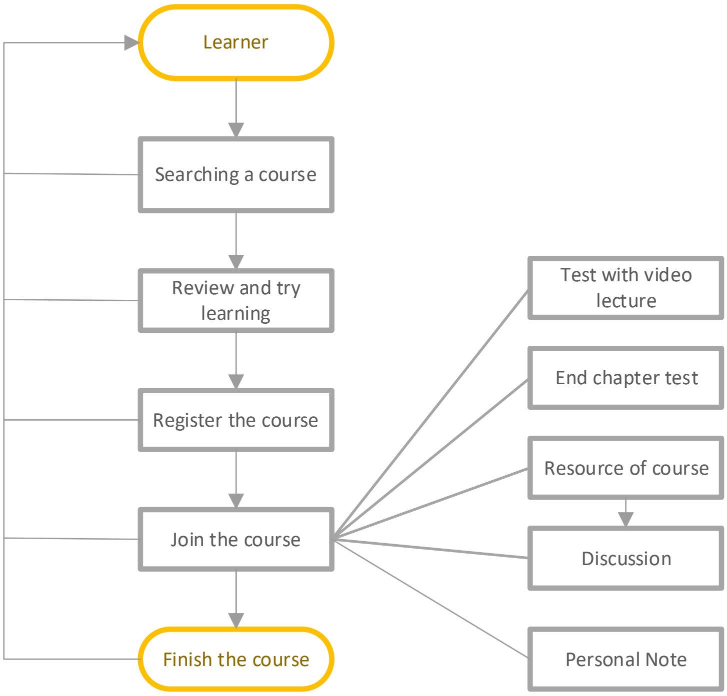

Figure 1. Flowchart of system

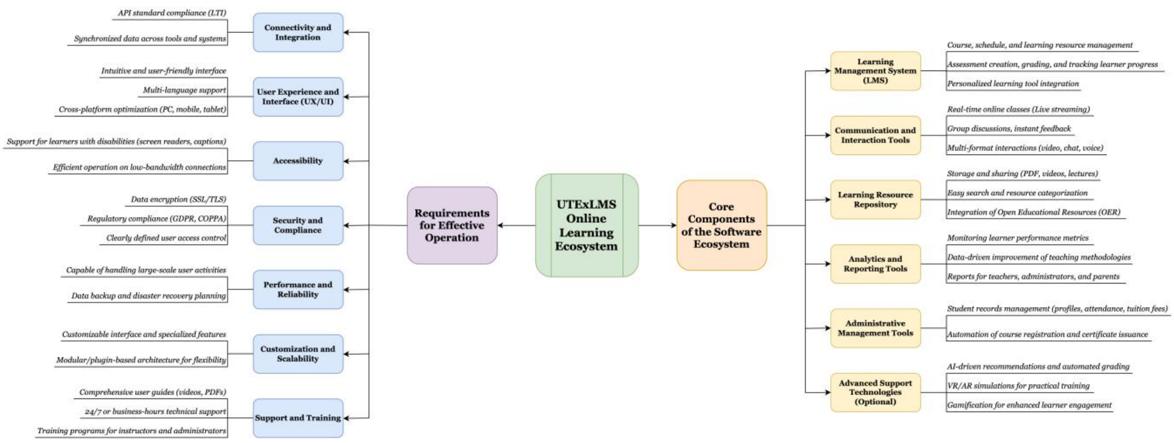

Figure 2. System diagram

This study employs a mixed-methods approach to design, implement, and evaluate an online learning ecosystem based on an internet platform. The research methodology comprises several interconnected phases, integrating both qualitative and quantitative methods to ensure a comprehensive analysis of the ecosystem's effectiveness.

System Design and Development: The first phase involves the design and development of the UTEx learning ecosystem. This platform is structured to support the entire teaching and learning process online and is accessible to learners via any internet-connected device. The system architecture follows a flowchart (Figure 1) that outlines the learner's journey from course selection to completion. The ecosystem offers a wide range of courses across various

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disciplines, including foreign languages, electrical and electronics, information technology, mechanical engineering, construction, family economics, fashion and garment technology, and STEM education.

Course Structure and Content Development: Each course within the ecosystem is meticulously structured to include the following components: a video player interface, a course content table, a course overview, information about participating instructors, student reviews, a quick preview video, course registration (purchase) options, and links to explore other courses. Content development involves collaboration with subject matter experts to produce video lectures, accompanying images, and PDF reference materials for each course unit. This phase emphasizes the creation of engaging and interactive content that aligns closely with the learning objectives of each course.

Pilot Implementation: The ecosystem will be piloted at Ho Chi Minh City University of Technology and Education. This phase involves the following steps: Selecting a representative sample of courses across various disciplines; Recruiting a diverse group of learners to participate in the pilot; Training instructors and support staff on the system's functionalities; Implementing the courses according to the designed structure

Data Collection: Multiple data collection methods will be employed to gather comprehensive insights. System Analytics: Tracking learner engagement, progress, and completion rates; Surveys: Pre- and post-course questionnaires to assess learner expectations and satisfaction; Performance Assessments: End-of-unit tests and overall course grades.

Qualitative Feedback: Discussion forum content analysis and instructor observations

User Experience Evaluations: Focused on system usability and accessibility

Assessment and Certification Process: The study will implement and evaluate the assessment and certification process, which includes: Immediate assessment upon completion of each course unit; Calculation of overall course grades based on unit averages; Issuance of completion certificates with competency assessments.

Interaction Analysis: Researchers will analyze the quality and frequency of interactions between: Learners and instructors, Learners and course content, Learners and their peers This analysis will involve both quantitative metrics (e.g., frequency of interactions) and qualitative assessment (e.g., content analysis of discussion forums).

Comparative Analysis: To evaluate the effectiveness of the UTEx ecosystem, a comparative analysis will be conducted: Comparing learning outcomes between UTEx courses and traditional classroom-based courses; Analyzing learner performance across different disciplines within the ecosystem; Evaluating the impact of various course components (e.g., video lectures, interactive elements) on learning outcomes

Data Analysis: The collected data will be analyzed using a combination of statistical methods for quantitative data (e.g., t-tests, ANOVA) and thematic analysis for qualitative data. This mixed-methods analysis will provide a comprehensive understanding of the ecosystem's effectiveness, user satisfaction, and areas for improvement.

Ethical Considerations: The research will adhere to strict ethical guidelines, including informed consent from all participants, data privacy protection, and confidentiality of personal information.

Through this comprehensive methodology, the study aims to provide a thorough evaluation of the UTEx learning ecosystem, offering insights into its effectiveness, user experience, and potential for scaling in higher education contexts.

4. RESULTS AND DISCUSSIONS

We will be testing a new approach in the Basic Electronic Theory course, which is part of the Automation major program at Ho Chi Minh City University of Technology and Education, Vietnam. This course is worth two credits and spans 15 weeks, with 25 students per class. We will experiment with this approach in two groups of 200 students. The first group, consisting of 100 students (95 males, 5 females, divided into four classes), will follow the traditional in-person classroom teaching model. The second group, also consisting of 100 students (93 males, 7 females), will engage with the "Digital Platform Environment" online learning model.

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The research results will demonstrate that the model yields higher efficiency than the traditional method, based on assessing student scores through statistical analysis that compares the average scores of the two student groups. Both groups will undergo evaluation tests on the same assessment and in the same format, which is a direct in-class assessment. The model will also survey the opinions of 50 instructors teaching in the same field regarding the Course Learning Outcomes (CLOs) that meet AUN-QA standards. A statistical model will be applied to evaluate the survey results and determine the model's achievement rate. The measurements used in this model are mean, variance, and standard deviation. In our study, the online learning management system employed for remote training is Moodle, which was chosen for its proven effectiveness and demonstrated popularity.

We performed an independent samples t-test to analyze the final exam scores for the Basic Electronic Theory course: the face-to-face learning group and the online learning group, using a 10-point scale, as shown in Table 1. The final grades of the course are evaluated on a 4-level scale as follows: Level 5 (Fail): Points < 4.5; Level 4: Points 4.0 - 5.4; Level 3: Points 5.5 - 6.9; Level 2: Points 7.0 - 8.4; Level 1: Points 8.5 - 10.0.

The results are summarized in Figure 3, with "Series 1" representing the face-to-face classroom model and "Series 2" representing the online learning model. The statistical analysis of the final course grades indicates that the average scores for both learning models are comparable. The average score for the classroom learning model is 6.70, while the online learning model averages 7.17. Overall, the grades for both models are similar. In the online learning model, higher levels of self-motivation and self-directed learning are required from students. As a result, the dropout rate is slightly higher compared to the face-to-face classroom model. However, in the online learning model, students have the advantage of reviewing instructional materials and receiving guidance from the teacher multiple times, which contributes to higher scores in the top level (Level 1) compared to the face-to-face classroom model. On the other hand, students without autonomy may not perform well. In contrast, students who study directly in class with direct supervision by teachers (like those in Level 5) tend to pass more successfully than those studying independently online.

Table 1. Average Scores and Score Distribution

Method	Nx,y	Mx,y	Varx,y
Face-to-Face (X)	100	6.70	3.20
Online (Y)	100	7.17	3.07

When assessing the content of average scores, we compare the average scores of two experimental groups: face-to-face classes and online classes. Since these two groups are independent, we use the "t-test" method. During this evaluation, we use a pair of hypotheses:

H0: $\mu_X = \mu_Y$

H1: $\mu_X > \mu_Y$

Where μ_X is the average score of the group of online classes

μ_Y is the average score of the group of face-to-face classes

The calculated results indicate that, with a significance level of 0.05, the rejection region: $W\alpha = (-1.64, +\infty)$

The calculated results indicate that, with a significance level of 0.05, the Rejection Region: $W\alpha = (-1.64, +\infty)$, the observed value of the test statistic is Zqs = -1.06. Since Zqs $\in$ Wα, so Reject the H0 hypotheses. We can conclude that the average of final scores of the online classes are higher than face to face class in classroom.

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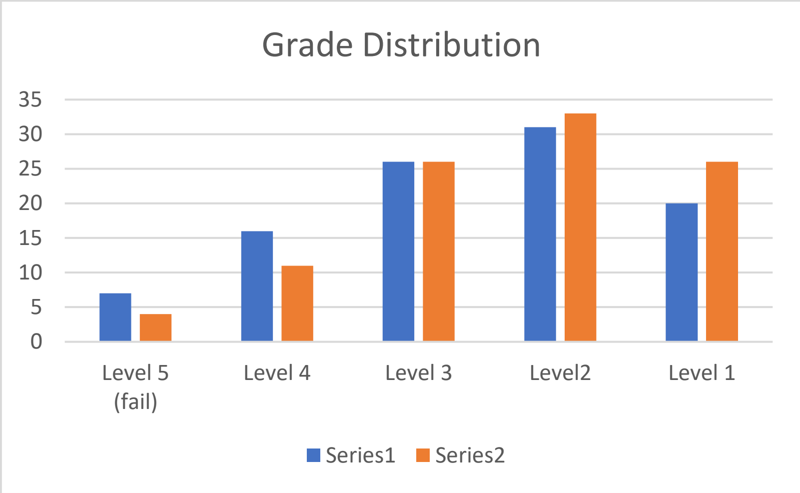

Figure 3. Final Course Grade Distribution

For the expert survey, we conducted a survey with 50 lecturers working in the same field. The survey content consisted of 9 Course Learning Outcomes (CLOs) of the course that have been standardized by AUN-QA (CLO1 - CLO9). The assessment content for each CLO was Achieved/Not Achieved. The statistical results showed an achievement rate of 96%, with a standard deviation of 0.029 and a variance of 0.001. The lowest frequency was 92%, and the highest frequency was 100%. The statistical results indicated that the model was evaluated with a relatively high achievement rate, corresponding to low standard deviation and small result fluctuation range. The statistical survey results are presented in Table 2 and Figure 4.

Table 2. Expert Survey Statistics

N	Medium	Standard	Variance	Minimum Frequency	Maximum Frequency
50	0.96	0.029	0.001	92%	100%

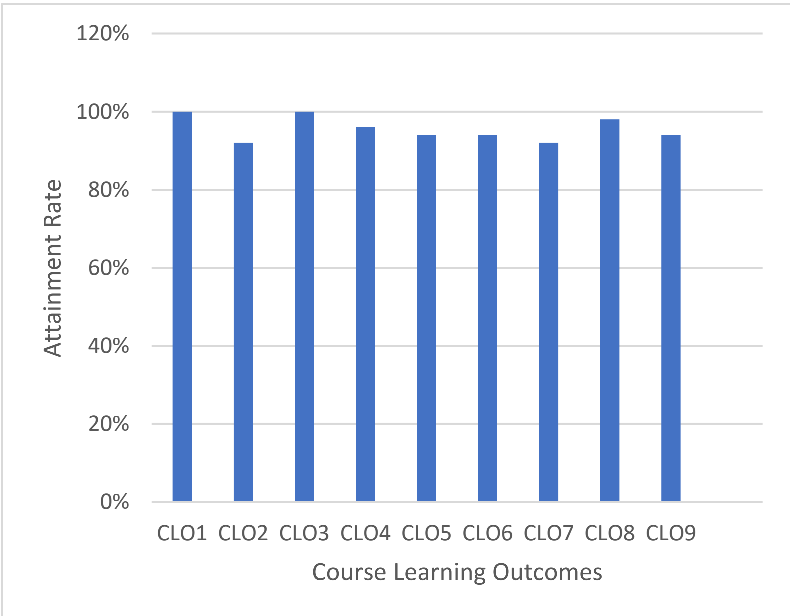

Figure 4. Attainment rate of CLOs

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5. CONCLUSION

This study aimed to develop and evaluate an ecosystem of application software for remote learning and STEM education at the university level, specifically within the Engineering and Technology sector at the UTEx MOOC educational institution. This research addresses a significant gap in the literature by providing empirical evidence and practical insights into the effectiveness of digital learning platforms in comparison to traditional face-to-face instruction, particularly within a specific institutional and disciplinary context.

The primary finding from the comparative analysis of learning outcomes reveals that students enrolled in the online learning environment achieved significantly higher average scores than those in traditional face-to-face classes. This finding carries significant theoretical implications, suggesting that digital learning platforms, when designed effectively, can facilitate deeper learning and knowledge acquisition compared to traditional methods. This aligns with constructionist learning theories, which posit that learners actively construct knowledge through interaction and engagement with the learning environment, something potentially enhanced by the multimedia and interactive elements often found in online platforms.

Further strengthening the support for online learning, the expert survey highlighted the efficacy of the developed online learning model. Experts overwhelmingly agreed that the model successfully met the intended learning outcomes, evidenced by the high pass rate (92%-100%) and the impressive average score of 96% with a small standard deviation of 2.9%. This finding reinforces the potential of well-designed online learning environments to deliver high-quality education and achieve desired learning objectives.

Overall, this study suggests that digital learning platforms can be a valuable and effective tool for STEM education at the university level. The findings have significant implications for educational theory, practice, and policy. Theoretically, the study supports the effectiveness of constructionist approaches embedded within digital environments. Practically, it encourages educators and institutions to embrace and invest in developing high-quality online learning experiences. From a policy perspective, this research advocates for the integration and support of digital learning initiatives within higher education systems.

Despite the promising results, this study has limitations. The sample size of 100 students per group, while substantial, may limit the generalization of findings to other contexts. Additionally, the study was conducted within a specific institution and disciplinary focus, potentially influencing the outcomes. Future research should aim for larger, more diverse samples across multiple institutions and disciplines to enhance generalization. Longitudinal studies tracking student performance over time would provide valuable insights into the long-term impact of online learning.

Future research should explore the specific design elements and pedagogical approaches within the digital learning platform that contribute most significantly to student learning and engagement. Investigating the impact of various digital tools and resources, personalized learning pathways, and collaborative learning activities within the online environment would further enhance our understanding of effective online STEM education. Additionally, exploring the role of instructor presence and student support services in online learning environments is crucial for maximizing their effectiveness.

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