



Learning Management System-Mediated e-Tutorials in Mathematics Education: A Case Study of South Africa

Stephen Kigundu^{1*}

¹Department of Mathematics Education, Walter Sisulu University, South Africa

*Correspondence to: skigundu@wsu.ac.za

Abstract: The study examines the impact of LMS-mediated e-tutorials on student engagement and learning outcomes in mathematics at a South African university. Grounded in constructivist theory, it explores how interactive LMS tools enhance engagement and knowledge construction. The research follows a qualitative case study approach within the interpretivist paradigm, focusing on student performance, learning strategies, perceptions, and system usability. A convenience sample of 129 first-year mechanical engineering students was selected. Data were collected through questionnaires, interviews, observations, screen capture videos, and journals. Thematic analysis identified key patterns related to learning outcomes, student actions, emotional responses, and system affordances. Findings indicate that LMS-mediated e-tutorials enhance student engagement and performance, particularly when they incorporate interactive features and personalized feedback. However, technical challenges, such as rigid input requirements, hinder optimal engagement. Students adopted problem-solving strategies like rough work and social collaboration. The study highlights the potential of LMS tools to bridge learning gaps in mathematics education. Recommendations include enhancing system flexibility, improving feedback mechanisms, fostering collaboration, and incorporating gamification. Continuous evaluation and refinement of LMS features are crucial to maximizing their effectiveness across diverse educational contexts.

Keywords: e-tutorials; learning management systems; mathematics education; student engagement

Recommended citation: Kigundu, S. (2026). Learning Management System-Mediated e-Tutorials in Mathematics Education: A Case Study of South Africa. *Journal of Innovation in Educational and Cultural Research*, 7(1), 114-123.

INTRODUCTION

This paper explores the quality of the student engagement in learning mathematics afforded by the LMS-mediated e-tutorial. The aim was to evaluate how the design of the e-tutorial, notably e-tutorial tools, facilitated or constrained the engagement in the mathematics learning process. This paper was extracted from a PhD study to develop innovative learning intervention strategies to assist first-year students in bridging the gap between their prior knowledge and the demands of higher education. The concept of this study centered around student engagement in mathematics learning through LMS-mediated e-tutorials. LMSs offer digital platforms that facilitate online learning (Munna et al., 2024) and facilitate online course delivery, administration, and evaluation (Jagtap et al., 2024). This study used the LMS to mediate tutorial processes, aiming to enhance students' interaction with mathematical content. The study explored how LMS tools, such as quizzes and feedback systems, influenced students' actions, learning outcomes, and overall experiences during mathematics learning. Student performance, aiming for an 80% student success rate, based on the WSU Teaching and Learning Strategy (2014-2017) (Dwayi, 2017), was categorized into four levels: at risk (below 50%), borderline (50-59%), competent (60-74%), and proficient (75% and above) with 60% set as the benchmark for reasonable success.

In preparation for the study, the LMS-mediated e-tutorial was planned and developed as a testbed to investigate how these e-learning tools can help students learn to do math. A Trigonometry module, which included course content and exercises to help students explore, practice, and apply right triangle ideas, was used to analyze and develop the e-tutorial design. The initial formulation and design of the LMS-mediated e-tutorial involved conceptualizing the tutorial, identifying its content, learning objectives, and basic requirements. The requirements for the e-tutorial were identified through conversations with the involved lecturers. The e-tutorial was designed to cover the basics of foundational trigonometry necessary for mechanics calculations, allowing students to navigate it with minimal support from the lecturer. The system was expected to provide content, practice exercises, and tutorial questions to test understanding. Moreover, it automatically offers the results without requiring the lecturer's involvement.

The tutorial design conceptualized the learning environment to identify essential components that engage students in active learning. Guided by Jonassen's (1999) four essential components of constructivist learning environments, the design focused on the environment, related activities, cognitive tools, and resources (Jonassen, 1999). The learning process was divided into three tasks: acquiring and integrating knowledge, extending and refining knowledge, and using knowledge meaningfully. Related activities and cognitive tools,

including both learning and electronic tools, were integrated into each task to enhance student engagement and participation. Resources such as YouTube videos, SlideShare presentations, and interactive activities were included to provide depth and support for the learning process. The objective of this process was to assemble the components of the tutorial, supported by LMS tools, to facilitate learning by presenting Tasks and their corresponding instructions, educational content, and activities.

Learning Management Systems (LMS) play a crucial role in fostering student engagement and supporting ubiquitous learning in higher education, particularly in South Africa. LMS tools like discussion forums, group chats, and collaborative platforms can enhance interactivity and engagement in online environments (Simelane-Mnisi, 2023). For students in South Africa, where disparities in access to quality primary and secondary education are prevalent (Branson & Lam, 2021), this study is crucial in determining whether LMS-mediated e-tutorials can serve as an equalizer, enhancing student learning experiences and outcomes. In mathematics, a subject known for its cognitive demands, fostering engagement through the exploration of LMS-mediated e-tutorials is essential as universities shift towards digital or blended learning environments. Previous studies indicate the importance of online engagement, showing that active learning strategies, when integrated with technology, can improve performance in mathematics courses (Wang, 2019).

Research into LMS-based learning has gained traction globally and regionally in recent years. Internationally, LMS tools such as Moodle and Blackboard have been investigated for their role in enhancing student interaction, with studies revealing positive outcomes in student engagement and learning performance (Rekha, 2024). In Southern Africa, LMS adoption is relatively new, but it has proven essential in addressing learning inequalities and offering flexible learning solutions. For example, Makumane (2023) in Lesotho found that the use of LMS seemed to influence factual knowledge (content knowledge) but did not promote technological knowledge (social perceptions). In Zanzibar, Shaame et al. (2023) observed that the use of a personalized Moodle LMS can attract and motivate students in learning activities. Research at South African institutions has explored the role of LMS platforms in providing individualized learning experiences for students and improving mathematics learning (Afolabi & Ajani, 2023). For example, Mlotshwa et al. (2020) piloted e-tutorials that use Moodle to improve Grade 10 learners' conceptual understanding of the topic and functions in mathematics. However, the quality of student engagement, particularly in terms of active participation and the use of LMS tools, has not been comprehensively explored (Veluvali & Suriseti, 2022).

While LMS tools have been adopted in South Africa for mathematics learning, there is a significant gap in understanding the quality of student engagement they facilitate. Previous studies have focused more on the accessibility of LMS platforms and the technological challenges students face, rather than a deep dive into how these tools specifically affect engagement in mathematics tutorials. This study aims to fill that gap by examining how e-tutorials in LMS environments shape students' actions, learning strategies, and overall experiences. Hence, this paper explored the quality of student engagement in learning mathematics facilitated by an LMS-mediated e-tutorial at one South African university. It specifically focuses on evaluating the design and functionality of e-tutorial tools and investigating how these tools facilitate or constrain engagement. This paper analyzed four key areas: 1) Learning Outcomes, Assessed through students' performance and identified common errors; 2) Student Actions, Identified through students' reading habits, problem-solving strategies, and social interactions within the e-tutorial; 3) Student Experiences, Gauged through students' frustrations and satisfaction levels with the system and 4) System Use: Investigated through the system's affordances and limitations, including technical challenges students face while using LMS e-tools.

In an ideal situation, an LMS-mediated e-tutorial should actively engage students in the learning process, leading to improved learning outcomes, enhanced problem-solving strategies, and higher satisfaction levels. However, the reality often deviates from this ideal. Students may face technical difficulties, inadequate guidance, or LMS tools that fail to promote meaningful interaction with the content or peers (Amporful, 2023; Cao, 2023). At the South African university under study, students struggle to bridge the gap between their prior knowledge and the demands of tertiary-level mathematics. This study explored how to use the LMS-mediated e-tutorials to bridge this gap. This study is significant because it seeks to identify both the benefits and shortcomings of LMS-mediated e-tutorials in enhancing engagement. The findings offer critical insights into improving the design of these LMS-mediated e-tutorials and providing targeted support for first-year students, ultimately leading to better learning outcomes.

The gap addressed in the preliminary study was the disparity between high school and university-level mathematics proficiency, particularly in trigonometry, which is essential for engineering students. Existing e-learning tutorial systems primarily emphasize drill, memorization, and recall, which do not adequately support conceptual understanding or engagement. The preliminary study sought to tackle this gap through an LMS-mediated e-tutorial that fosters meaningful student interaction and supports the transition to university-level mathematics, focusing on basic trigonometry for engineering applications. However, this paper aims to explore how the e-tutorial system engaged students in the learning process through the following objectives: 1) To evaluate the learning outcomes achieved by students using the LMS-mediated e-tutorial for mathematics learning; 2) To investigate how students interact with LMS tools and identify the learning strategies they employ

during e-tutorial sessions; 3) To explore students' experiences with the LMS-mediated e-tutorial, including their engagement levels, frustrations, and satisfaction; 4) To analyze the system's affordances and limitations, including technical challenges, usability, and the effectiveness of LMS tools in facilitating meaningful student engagement; 5) To assess the impact of the LMS-mediated e-tutorial in bridging the gap between high school and university mathematics, particularly in foundational trigonometry for engineering students, and; 6) To provide recommendations for improving LMS-mediated e-tutorial design, enhancing feedback mechanisms, fostering collaboration, and integrating engaging features to optimize student learning experiences.

To guide this investigation, the following research questions were developed: 1) What learning outcomes are achieved by students using the LMS-mediated e-tutorial for mathematics learning?; 2) How do students interact with the LMS tools, and what learning strategies do they employ during e-tutorial sessions?; 3) What are students' experiences with the LMS-mediated e-tutorial?; 4) What are the system's affordances and limitations, including technical challenges students face while using the LMS-mediated e-tutorial?

METHODS

This paper explored the quality of student engagement in learning mathematics afforded by the e-tutorial system developed in the preliminary study. The preliminary study used a systematic Educational Design Research approach that followed an iterative and cyclical process (McKenney & Reeves, 2013). It moved through three distinct phases: the Preliminary Phase (prepare for the experiment), the Intervention Phase (test and formatively evaluate in the classroom), and the Evaluation Phase (conduct and document retrospective analyses) (Kigundu, 2023). This study used a qualitative case study methodology to examine first-year mathematics courses in the foundation and extended Faculty of Science, Engineering and Technology (FSET) programs. The case study technique was chosen to thoroughly examine the experiences and difficulties that students experience when participating in LMS-mediated e-tutorials. Case studies are an excellent tool for examining intricate phenomena in their natural environments, providing a deep comprehension of the particular problems being studied (Yin, 2018).

This preliminary study was carried out as a small-scale research project employing convenience sampling to facilitate implementation and cost-effectiveness (Jager et al., 2017), and it saved time because the researcher was also a tutor in this class. This approach's main drawback was that it was impossible to determine whether the results were representative. However, the aim was not to generalize the findings beyond the sample but to use the sample as a testbed during the design and development of the e-tutorial in response to the main research question. Hence, although the target population comprised all first-year students taking mathematics in the foundation and extended programs in the Faculty of Science, Engineering and Technology (FSET), the population included only engineering students enrolled in Mathematics 1. The sample consisted of 129 students from the mechanical engineering department (Kigundu, 2023).

The Intervention Phase of the preliminary study was the main source of data from four design-development cycles. The research objective was to use various techniques (i.e., student work samples, questionnaires, interviews, observations, screen capture videos, and learning journals) to acquire data on the students' engagement with the e-tutorial from multiple angles and triangulate findings (Creswell & Poth, 2016). Students' rough work samples were collected, and their answers to e-tutorial questions were retrieved from the LMS and printed. The questionnaire was used as a student survey to establish the students' profiles. Post-tutorial focus group interviews were used to obtain more in-depth, richer data on students' experiences as they worked through the e-tutorial. Observations consisted of direct observation of students as they worked through the e-tutorial tasks. Learning journals were used to collect students' reflections about personal experiences as they used the e-tutorial.

Due to the iterative nature of educational design research and the exploratory nature of this study, data analysis was conducted throughout the four design-development cycles, rather than just once at the end. Using constant comparison (Corbin & Strauss, 1990), a single round of data analysis conducted during a development cycle informed decisions to improve the intervention in the next cycle (McKenney & Reeves, 2013). Thematic analysis was conducted to identify and present recurring patterns or themes in data (Morin et al., 2021). This entailed line-by-line coding of the data to identify patterns, followed by categorization into themes such as learning outcomes, student actions, student perceptions, and system affordances. Briefly discussing these themes individually provided local themes of regularly occurring insights into student engagement (Kigundu, 2023). This paper explores how the e-tutorial system engaged students in the mathematics learning process through the following four key themes: Learning Outcomes, Student Actions, Student Feelings, and System Use.

RESULT AND DISCUSSION

The results of this study provide a comprehensive understanding of how LMS-mediated e-tutorials engaged students in the learning process. The results are analyzed under four key themes (Learning Outcomes, Student Actions, Student Experiences, and System Use), which directly correspond to the study's objectives.

Each theme highlights how the e-tutorial system facilitated or constrained student engagement, offering insights into its effectiveness in supporting mathematics learning. The Learning Outcomes evaluate the impact of LMS-mediated e-tutorials on student performance and the extent to which the e-tutorial objectives were achieved. In particular, what students could achieve due to their engagement in the learning process. This is summarized in Table 1.

Table 1. Analysis of Learning Outcomes

Aspect	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Student Performance	The average correct attempt was only 7%, and 50% of questions had no correct answers.	Less than 80% success in 5/6 activities. Two activities had reasonable success rates (~70%).	Performance improved significantly, with an average success rate of 88% and average activity scores of 80.6%.	High performance sustained, with an 84% success rate and average activity scores of 81.3%.
Student Errors	Errors included spelling and typing mistakes, formatting issues, and a lack of understanding of the content or question intent.	Common errors included difficulty solving equations with fractions, incorrect inputs, and spelling or rounding mistakes.	Similar errors persisted, such as spelling, not squaring, rounding, and using incorrect information in answers.	The same types of errors as in Cycle 3 continued (e.g., spelling, rounding), indicating a persistent challenge in precision.

Table 1 analysis of learning outcomes highlights a clear trajectory of improvement in student performance across the four cycles. In Cycle 1, the average correct attempts were very low at 7%, and 50% of the questions had no correct responses. This poor performance was attributed to a combination of technical marking issues, such as formatting and spelling errors, and a lack of understanding of the content or question intent. By Cycle 2, there was moderate improvement, with 2 of 6 activities achieving reasonable success rates of approximately 70%. However, overall performance still fell short of expectations, primarily due to persistent errors in solving equations, entering correct information, and handling fractions. In Cycle 3, student performance improved significantly, with an average success rate of 88% and activity scores exceeding the target at 80.6%. This improvement reflected a combination of system enhancements, more effective feedback, and growing student familiarity with the e-tutorial platform. By Cycle 4, this high level of performance was sustained, with an average success rate of 84% and activity scores averaging 81.3%. The consistency in performance between Cycles 3 and 4 indicates that students had adapted well to the platform and had developed a firmer grasp of the required skills.

However, recurring errors remained a challenge throughout all cycles. Common issues included spelling mistakes, incorrect rounding, failure to square when necessary, and the use of inaccurate information in answers. These persistent errors suggest that, while students improved their understanding of the content, they still had gaps in precision and attention to detail. Addressing these errors requires a dual approach: enhancing the system's flexibility to account for minor input variations and providing targeted learning interventions to reinforce precision in problem-solving. The results above indicate that the LMS-mediated e-tutorial significantly supported student learning outcomes in mathematics by enhancing engagement, structured learning, and feedback-driven performance improvement. However, recurring input errors indicate the need for adaptive feedback and system flexibility. Student performance progressively improved across four learning cycles, with success rates rising from 7% (Cycle 1) to 84% (Cycle 4). This increase aligns with studies showing that when used effectively, LMS tools enhance self-regulated learning and metacognitive engagement (Zhang et al., 2022). The integration of interactive quizzes and conditional release functions in the LMS contributed to the observed improvements, a finding supported by recent research demonstrating the benefits of adaptive learning environments in mathematics education (Sukmawati & Purbaningrum, 2023).

Despite improved outcomes, persistent input errors in spelling, rounding, and incorrect problem-solving approaches suggest a need for flexible input handling within LMS platforms. Studies indicate that rigid input validation in digital learning environments can negatively impact learning by penalizing minor errors, thereby reducing motivation (Desai et al., 2023). Future LMS designs should integrate AI-driven error detection to allow for minor variations in student input while maintaining assessment accuracy. This study contributes to digital mathematics education by highlighting the role of structured feedback and engagement-driven e-tutorials. The findings underscore the importance of refining LMS functionalities to enhance user adaptability, ultimately bridging the gap between high school and university-level mathematics. The Student Actions section explores how students interacted with the system, demonstrating the evolution of engagement strategies. Insights from the evaluation related to accessing and reviewing resources, working through Quizlet and tutorial questions, and interacting with peers and tutors, as summarized in Table 2.

Table 2. Analysis of Student Actions

Aspect	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Student Reading	Students focused on calculations rather than reviewing content resources. Some skipped content, thinking they already knew the material.	Limited engagement with resources. Students prioritized doing Quizlet and calculations over studying the provided content.	Some improvement noted. Students either reviewed resources before Quizlet or referred to them when encountering challenges.	Significant improvement in resource use. Students studied the introduction and resources more thoroughly, achieving reasonable success.
Student Strategy	Students used rough-work strategies, solving problems on paper before entering their answers into the system.	Rough work strategies remained consistent. Students worked out answers on paper before entering them into the system.	Rough work strategies were still prevalent. Observations and interviews confirmed reliance on paper to solve questions.	Continued use of rough work strategies. Students worked out answers (neatly or roughly) on paper before inputting them.
Social Interaction	Students sought help from peers or tutors when facing technical or academic challenges.	Peer support was common for resolving technical and academic challenges.	Peer support remained vital. Observations noted groups collaborating to work through challenges.	Social interaction increased, with 30 requests for assistance logged in the first two tutorial sessions.

The analysis of Student Actions (student reading, student strategy, and social interaction) shows a consistent pattern of behavior across all cycles, with gradual improvements in resource engagement. In the early cycles, students prioritized calculations and tutorial questions over reviewing the provided content resources. Many assumed they already understood the material and skipped studying it altogether. This trend persisted in Cycle 2, where students clearly preferred working on Quizlet and calculations instead of engaging deeply with the learning materials. However, by Cycle 3, there was some improvement, as students began to review resources before starting Quizlet or when they encountered challenges with questions. In Cycle 4, resource engagement improved further, with students studying the introduction and content more thoroughly, leading to reasonable success in the associated activities.

Throughout all cycles, students consistently employed rough work strategies. They preferred solving problems on paper before entering their answers into the system, demonstrating their reliance on traditional methods. This approach remained unchanged, reflecting their comfort with manual problem-solving techniques even as they adapted to the digital platform. Additionally, social interaction played a critical role in supporting student learning. From the beginning, students relied heavily on their peers and tutors for help when they faced technical or academic challenges. This collaborative approach persisted across all cycles and intensified in Cycle 4, where increased assistance requests were logged, reflecting a proactive effort to overcome difficulties.

Students engaged in e-tutorials using a task-focused approach, prioritizing problem-solving over content review. They relied on rough work strategies and peer collaboration for learning support, suggesting that LMS-mediated learning should integrate more interactive, peer-supported activities to foster deeper engagement. Students initially skipped theoretical content in favor of jumping directly into problem-solving. This behavior persisted in early cycles but improved in Cycle 4, where students actively reviewed materials before engaging in problem-solving tasks. Similar trends have been noted in LMS-based mathematics learning, where students prefer immediate application over conceptual study (Dahleez et al., 2021). This highlights the need for LMS features that encourage active exploration of content, such as conditional release elements or mandatory pre-quiz content reviews.

The use of rough work (solving problems on paper before entering them into the system) was consistent across all cycles. While effective for mathematical reasoning, studies indicate that digital tools supporting real-time annotation (e.g., digital scratchpads) could improve workflow efficiency and engagement (Amriza et al., 2022). Additionally, peer collaboration played a vital role in problem-solving, particularly when addressing technical or mathematical difficulties. Studies show that social learning features (e.g., discussion boards and peer-assisted learning tools) enhance student engagement and retention (Rivera-Mamani et al., 2023). Future LMS development should integrate peer-assisted feedback and real-time collaboration tools to improve student engagement and problem-solving confidence further. This study contributes to e-learning engagement research by demonstrating how students adapt their strategies to digital learning environments. It further supports the integration of collaborative and interactive components in LMS platforms to enhance engagement in

mathematics education. The Student Experiences captures students' emotional responses, showing how students reacted to the e-tutorial and learning activities. Data was mainly obtained from the responses in the learning journal, as summarized in Table 3.

Table 3. Analysis of Student Experiences

Aspect	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Frustrations	Students were frustrated by system-marking errors (e.g., formatting, spelling), unclear questions, and technical challenges such as filling in blanks.	Frustrations arose from unclear Quizlet, navigation issues, and difficulty with particular mathematical concepts, such as fractions and trigonometry.	Novice computer users felt nervous and unclear, and the Quizlet feedback added to their frustrations.	Most students (51%) experienced no frustrations; however, some dissatisfaction persisted with Quizlet and a few technical challenges.
Satisfactions	Many students found the e-tutorial informative, interesting, and easy to use despite technical challenges.	70%+ of students found the system informative and easy to use. They appreciated the quick, clear feedback provided by the e-tutorial.	75%+ of students felt confident, satisfied, and found the e-tutorial interesting and easy to use, reflecting an overall positive experience.	50% of students found the e-tutorial interesting and easy to use. Positive reactions continued as the system became more user-friendly.

Table 3 analysis of student experiences reflects a combination of positive engagement and recurring challenges across the cycles. Students consistently reported high levels of satisfaction with the e-tutorial system, describing it as interesting, informative, and easy to use. In Cycles 1 and 2, over 70% of students found the tasks exciting and informative, while approximately 72% felt confident and noted that the system made tasks quick and easy to complete. By Cycle 3, the majority (84%) indicated they understood the topics well, attributing their success to the system's clarity and structured support. One student commented, *"It was not very difficult, but it needs you to focus and analyze the questions,"* while another stated, *"I asked everything I needed to know, so I think so far I am covered."*

Despite this positive feedback, frustrations were a recurring theme, particularly in earlier cycles. Students reported struggles with technical aspects, including using the calculator, navigating the math editor, and understanding certain concepts such as trigonometric ratios. One student noted, *"I found that using e-tools is not as easy as I thought,"* while another expressed difficulty in *"finding the missing angle"* or applying the sine rule. These frustrations diminished in later cycles as students became more familiar with the platform. By Cycle 4, a majority (51%) reported no frustrations, and comments such as *"The task was so clear and understandable"* and *"There was no strict period to finalize the test"* highlighted their comfort and improved confidence. However, challenges persisted for some, particularly in understanding complex questions and using feedback effectively.

Students' satisfaction was further enhanced by specific features of the system, such as immediate Quizlet feedback. In Cycle 4, 63% found the feedback easy to follow, with one student commenting, *"The feedback gives you a hint or information on what you must look at."* Another remarked, *"The Quizlet made it simple when answering the questions; it has shown me where I have forgotten and where I need to study."* These insights helped students identify areas needing improvement and boosted their confidence. However, a small percentage (7% in Cycle 4) still found the feedback unclear, with one student stating, *"Some questions in the Quizlet were a little confusing at the start."*

Students initially experienced frustration due to system rigidity, unclear quiz instructions, and navigation difficulties, but overall satisfaction increased as familiarity with the system grew. Enhancing LMS usability and providing clearer system guidance would improve student motivation and reduce frustration. Initial cycles revealed technical frustrations, including difficulty with the math editor, input errors, and unclear instructions. These issues align with Erdel (2022), who indicates that user frustration in digital learning environments stems primarily from system usability challenges. As students adapted, frustration levels declined, with 51% of students reporting no frustration by Cycle 4, supporting research that familiarity reduces technological anxiety in e-learning environments (Sapi et al., 2023).

Despite these challenges, most students reported that the e-tutorial was engaging, informative, and easy to use. Notably, gamified elements (Quizlet, immediate feedback, and progress tracking) were instrumental in sustaining engagement. Studies have shown that gamification increases motivation and persistence in STEM subjects (Cvetkovic et al., 2020; Tenório et al., 2021). However, confusing feedback mechanisms and occasional

ambiguous questions led to lingering dissatisfaction, indicating the need for more precise feedback tools and question validation. This study contributes to understanding affective engagement in e-learning by emphasizing that effective LMS-mediated e-tutorials in foundational mathematics require both usability improvements and motivational strategies. Future LMS-mediated e-tutorials should incorporate personalized adaptive learning features to address individual frustrations and improve the overall user experience.

System use examines how LMS affordances facilitated or constrained the students' engagement with the e-tutorial system. The following themes were identified: affordances of the e-tutorial, challenges while using the e-tools, challenges while doing mathematics, and system shortcomings, as shown in Table 4.

Table 4. Analysis of System Use

Aspect	Cycle 1	Cycle 2	Cycle 3	Cycle 4
System Affordances	The LMS provided content resources, tutorial questions, space for answers, marking, and feedback on results.	Affordances included Quizlet with immediate feedback, which directed students to review resources upon failure.	Quizlet supported question-by-question feedback and directed students to review resources. Tutorial questions offered space for responses.	The system effectively supported Quizlet, tutorials, and resource reviews, allowing students to achieve high success rates.
Problems in Use	Challenges included difficulty filling blanks, understanding system features, and technical navigation issues.	Students found Quizlet confusing, with unclear instructions for starting or repeating them.	Novice users faced technical challenges, like entering answers and navigating resources. Connectivity issues with videos were noted.	Most students (48%) experienced no challenges. Some struggled with scrolling PDFs, playing videos, and punching answers due to inexperience.
System Shortcomings	Rigid answer formats caused marking issues (e.g., no provision for abbreviations or alternate methods).	Quizlet lacked clarity in questions and feedback, and some answers appeared incorrect.	Issues persisted with unclear Quizlet questions, incomplete feedback, and flaws in system answers (e.g., rounding discrepancies).	Minimal shortcomings; however, one flawed question caused significant issues (0% correct answers) and demonstrated potential gaps in validation.

The analysis of System Use in Table 4 reveals a progression in the effectiveness of system affordances, alongside persistent challenges and shortcomings. The LMS provided foundational affordances in the early cycles, including content resources, tutorial questions, and spaces for answering and receiving feedback. These features supported student engagement and structured learning. By Cycle 2, the inclusion of Quizlet enhanced these affordances by providing immediate feedback that directed students to review resources when they answered incorrectly. This interactive functionality was further improved in Cycle 3, with question-by-question feedback and tutorial tools offering a more comprehensive learning experience. By Cycle 4, the system effectively supported resource review, Quizlet engagement, and tutorial activities, enabling students to achieve high success rates.

Despite these strengths, system use problems persisted, particularly for novice users. Early issues included difficulties with technical navigation, understanding system features, and completing tasks like filling in blanks. These challenges decreased in later cycles as students became more familiar with the platform. However, specific problems persisted, including confusion about Quizlet instructions, navigating resources such as PDFs, and connectivity issues with videos. Although most students in Cycle 4 reported no significant challenges, technical difficulties persisted for a small proportion of users. System shortcomings were another recurring issue, particularly the rigid answer formats, which led to correct answers being marked as incorrect due to minor variations, such as abbreviations or rounding differences. These issues were most prevalent in Cycle 1 but persisted in later cycles, leading to unclear or incorrect answers on Quizlet questions. Additionally, the feedback from Quizlet, while helpful, often lacked sufficient detail to guide students effectively. By Cycle 4, the overall quality of system design had improved, but isolated issues (such as a flawed question that caused significant errors) highlighted the need for more robust validation processes. LMS test tool affordances (i.e., presenting content resources and tutorial questions, providing space to answer tutorial questions, marking tutorial questions, and conveying results to the student) positively supported student engagement, including structured learning pathways, immediate feedback, and self-paced study options. Research confirms that LMS

tools enhance cognitive engagement by providing scaffolding for self-directed learning (Cao, 2023). However, technical rigidity, such as strict input validation and occasional quiz errors, emerged as a persistent shortcoming. Studies indicate that flexibility in response handling improves student confidence and learning outcomes (Darvin et al., 2021). Future systems should incorporate natural language processing (NLP) to support flexible answer recognition and reduce marking inconsistencies.

A key challenge was navigational difficulties, particularly in accessing PDFs, videos, and system instructions. While digital fluency improved over time, research suggests that LMS platforms should provide more intuitive user interfaces (Chemerys & Ponomarenko, 2022). Despite these limitations, Quizlet-based feedback was well received, with students finding it helpful in identifying gaps and reinforcing learning. However, some responses lacked clarity and were confusing. This aligns with research indicating that automated feedback must be designed to provide constructive and actionable guidance (Hossain et al., 2021). This study contributes to LMS usability research by emphasizing the need for flexible assessment tools and improved system navigability. Future developments should address technical and instructional challenges, as well as inflexible answer configurations that occasionally hinder usability. Addressing these issues through enhanced user support, better feedback mechanisms, and increased flexibility in answer formats would further improve the system's efficacy and user experience.

CONCLUSION

The findings emphasize the importance of adaptive learning systems, interactive peer-supported activities, and flexible input validation in enhancing digital learning outcomes. The study demonstrated that LMS-mediated e-tutorials significantly improved student engagement and learning outcomes in mathematics, with performance increasing from 7% in Cycle 1 to 84% in Cycle 4. Key findings highlighted that personalized feedback, interactive quizzes, and structured content delivery enhanced problem-solving skills, while persistent input errors and technical challenges hindered engagement. The research revealed that students preferred rough work strategies and peer collaboration, emphasizing the importance of integrating interactive and social learning elements in LMS platforms. Frustration levels decreased over time, indicating that familiarity and system improvements enhance user experience. The impact of these results extends beyond the study, suggesting that adaptive e-learning tools can bridge gaps in mathematical competency, improve digital literacy, and foster self-regulated learning. By refining LMS functionalities—particularly through flexible input validation, AI-driven feedback, and enhanced user interfaces—educational institutions can optimize digital learning environments, leading to higher student success rates and more inclusive mathematics education. Several key improvements are recommended to enhance the effectiveness of LMS-mediated e-tutorials in mathematics education. System flexibility should be increased by incorporating adaptive feedback mechanisms that accommodate variations in student input, such as different formats and rounding errors, to minimize unnecessary marking penalties. User experience enhancements, including more precise instructions, improved navigation, and better integration of multimedia resources, will help reduce technical frustrations and ensure smoother engagement. Encouraging peer collaboration and interactive learning, along with real-time assistance features, can further enhance student participation and problem-solving skills. Additionally, gamification elements such as conditional release and progress tracking should be expanded to boost motivation and sustained engagement. Finally, continuous evaluation and refinement of LMS tools, leveraging AI-driven analytics to personalize learning pathways, will ensure the LMS-mediated e-tutorial effectively bridges competency gaps and fosters self-regulated learning in mathematics education.

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