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The Requirements for Engaging Learning Management Systems Mediated Tutorials in Mathematics Education: A Literature Survey

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ABSTRACT

This study examined the essential requirements for designing engaging Learning Management System (LMS)-mediated e-tutorials in undergraduate mathematics education. A qualitative literature survey method was employed to analyse and synthesise existing studies on adaptive learning, gamification, instructor facilitation, and interactivity in mathematics e-learnin1g environments. The findings revealed that effective e-tutorials require a cohesive integration of personalised learning paths, interactive feedback mechanisms, and teaching presence. Furthermore, the study highlighted the importance of aligning tutorial design with clear learning objectives, providing equitable access to digital resources, and offering structured support for lecturers. Based on these insights, recommendations were proposed for lecturers, institutions, and researchers, including a structured implementation checklist and an evaluation framework grounded in verification and validation principles. This study contributed to the scholarship by bridging fragmented literature and presenting a unified framework for enhancing student engagement, motivation, and learning outcomes through LMS-mediated tutorials in mathematics education..

Keywords: *e-Learning, Higher Education, Learning Management System (LMS), e-Tutorials, Mathematics Education, Engagement.*

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INTRODUCTION

The learning management system (LMS) is considered one of the tools that can be used to provide learning environments that facilitate the learning of students with diverse backgrounds and learning preferences.[1] In an LMS environment, the quality of student engagement is paramount in the design and structure of learning objects offered to students, especially true in mathematics due to its abstract nature.[2] Effective LMS-mediated e-tutorials in mathematics education must meet the diverse needs of both students and lecturers to foster engagement and learning outcomes.[3] However, existing LMS-mediated e-tutorials in mathematics education often fail to meet the complex demands of fostering meaningful engagement and deep conceptual understanding. While previous research highlights

[1] Md Abdullah Al Mamun, “The Role of Scaffolding in the Instructional Design of Online, Self-Directed, Inquiry-Based Learning Environments: Student Engagement and Learning Approaches” (The University of Queensland, 2018), https://doi.org/10.14264/uql.2018.607.

[2] Hasan Tinmaz and Jin Hwa Lee, “An Analysis of Users’ Preferences on Learning Management Systems: A Case on German versus Spanish Students,” *Smart Learning Environments* 7, no. 1 (December 14, 2020): 30, https://doi.org/10.1186/s40561-020-00141-8.

[3] Violeta Morari et al., “Exploring the Use and Impact of Online Digital Resources in a Mathematics Module,” *European Journal of Science and Mathematics Education* 12, no. 3 (July 1, 2024): 335–55, https://doi.org/10.30935/scimath/14605.

various strategies for developing e-tutorials, a significant gap remains in articulating the specific requirements for effective e-tutorials tailored to the unique challenges of mathematics education. This study seeks to bridge this gap by identifying and developing a structured framework of key requirements for planning, implementing, and evaluating engaging LMS-mediated e-tutorials in mathematics education.

The concept under study is "requirements for engaging LMS-mediated e-tutorials in mathematics education." In mathematics education, where comprehension often relies on step-by-step guidance and practice, the addition of engaging e-tutorials is crucial to support meaningful learning experiences.[4] As online learning grows in prominence, particularly in higher education, the effectiveness of LMS platforms depends on their ability to hold students' attention and foster a sense of connection to the material.[5] Hence, investigating the requirements for engaging e-tutorials in LMS environments is essential in addressing critical student engagement and comprehension gaps, particularly in challenging subjects like mathematics. By identifying and optimising these requirements, this study's findings will serve as a valuable resource to enhance the quality of online education, ensuring it meets the academic and engagement needs of students in mathematics education.

A prerequisite for developing (planning, implementing and evaluating) an educational intervention (e.g. the LMS-mediated e-tutorials) is a robust needs analysis to identify the specific requirements to create a clear set of specifications for the development process.[6] This study, aligned with a postdoctoral research fellowship at Walter Sisulu University, was designed to address these requirements through a structured, phased approach. In Phase 2, an intensive requirements gathering and analysis stage, data will be collected from stakeholders through surveys, interviews, and focus groups. This study is the first part of Phase 2, focused on generating (from literature) requirements for developing engaging LMS-mediated e-tutorials for mathematics education. These will be used to design tools to collect data from stakeholders.

In an ideal e-learning environment, learning support systems (e.g. LMSs) would fully engage students, offering personalised, interactive, and flexible learning experiences that cater to individual needs, thus enhancing participation, retention, and learning outcomes.[7] However, many LMS-mediated tutorials, especially in mathematics education, fail to meet these expectations, leading to low student engagement and retention rates. For instance, a study by Engelbrecht and Borba highlights how LMS tutorials often lack interactive elements, resulting in diminished student motivation and poor conceptual understanding. and participation.[8] Similarly, a case study by Weigand et al. revealed that tutorials designed without adaptive learning paths led to disengagement among students with diverse learning styles, contributing to high dropout rates in foundational mathematics courses.[9] These shortcomings underscore the critical need for specific guidelines to design engaging e-tutorials that address these challenges, emphasising the importance of incorporating adaptive and interactive features to enhance student engagement.[10] The lack of detailed guidelines for implementing such features in mathematics education highlights a gap this study aims to address.

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4 Aibhin Bray et al., "What next for Universal Design for Learning? A Systematic Literature Review of Technology in UDL Implementations at Second Level," *British Journal of Educational Technology* 55, no. 1 (January 25, 2024): 113–38, https://doi.org/10.1111/bjet.13328.

5 Muhammad Furqon et al., "The Impact of Learning Management System (LMS) Usage on Students," *TEM Journal*, May 29, 2023, 1082–89, https://doi.org/10.18421/TEM122-54.

6 Hisham Hanfy Ayob et al., "The Effectiveness of Using Blended Learning Teaching and Learning Strategy to Develop Students' Performance at Higher Education," *Journal of Applied Research in Higher Education* 15, no. 3 (April 7, 2023): 650–62, https://doi.org/10.1108/JARHE-09-2020-0288.

7 Marc Berges et al., "Learning Support Systems Based on Mathematical Knowledge Management," in *International Conference on Intelligent Computer Mathematics* (Springer Nature Switzerland, 2023), 84–97, https://doi.org/10.1007/978-3-031-42753-4_6.

8 Johann Engelbrecht and Marcelo C. Borba, "Recent Developments in Using Digital Technology in Mathematics Education," *ZDM – Mathematics Education* 56, no. 2 (May 18, 2024): 281–92, https://doi.org/10.1007/s11858-023-01530-2.

9 Hans-Georg Weigand, Jana Trgalova, and Michal Tabach, "Mathematics Teaching, Learning, and Assessment in the Digital Age," *ZDM – Mathematics Education* 56, no. 4 (August 10, 2024): 525–41, https://doi.org/10.1007/s11858-024-01612-9.

10 Engelbrecht and Borba, "Recent Developments in Using Digital Technology in Mathematics Education"; Teo-Christian Ion and Elvira Popescu, "An Innovative Distance Learning Platform for Mathematics Education in Secondary Schools: Design, Development and Preliminary Studies," *Education and Information Technologies* 30, no. 5 (April 17, 2025): 5529–60, https://doi.org/10.1007/s10639-024-13040-z.

This study seeks to bridge this gap by identifying key requirements for planning, implementing, and evaluating engaging LMS-mediated e-tutorials in mathematics education. By focusing on elements such as adaptive learning paths, gamification, and teacher-student interaction, the research aligns directly with the central question:

- What are the key requirements for developing (planning, implementing and evaluating) LMS-mediated e-tutorials that enhance undergraduate students' engagement in mathematics education in higher education?

The question aims to address the issue by clearly defining the requirements for each stage of the e-tutorial development process through the following sub-research questions:

- What planning elements are necessary to ensure LMS-mediated e-tutorials are engaging for undergraduate mathematics students?
- What implementation elements are necessary to ensure LMS-mediated e-tutorials are engaging for undergraduate mathematics students?
- How can the effectiveness of LMS-mediated e-tutorials be evaluated to sustain student engagement and undergraduate mathematics learning outcomes?

The study aims to explore the key requirements for developing (planning, implementing and evaluating) engaging LMS-mediated e-tutorials through an exploration of relevant literature. By doing this, the following objectives will guide the study:

- To analyse at least 50 peer-reviewed studies (published between 2020 and 2024) on e-learning in mathematics education and identify at least 10 best practices for creating engaging e-tutorials.
- To identify specific requirements that enhance LMS-mediated e-tutorials in mathematics education by synthesising the results into a checklist of at least 10 requirements that address the planning, implementation, and evaluation phases.
- To translate the findings into actionable recommendations for mathematics education lecturers that include at least five key requirements for engaging LMS-mediated e-tutorials in mathematics education.

The study begins with a theoretical overview that explores how conceptions of mathematics teaching influence the design of LMS-mediated tutorials. This is followed by a discussion of the methodology employed in the literature survey, detailing the selection criteria, data sources, and analysis techniques. The findings section presents key themes drawn from the literature, including learning, teaching, and usage requirements necessary for effective LMS-mediated tutorials in mathematics education. These are organised into tables and discussed to highlight interdependencies and practical considerations. The discussion section synthesises these findings, connecting them to broader pedagogical frameworks and existing scholarship. Based on this, the study offers practical recommendations for lecturers, institutions, and researchers, focusing on the implementation and evaluation of engaging e-tutorials. The paper concludes by suggesting future research directions, particularly in evaluating the effectiveness and practicality of the proposed requirements through both verification and validation processes.

METHODOLOGY

This study explored the requirements for developing (planning, implementing, and evaluating) engaging LMS-mediated e-tutorials in mathematics education. The intention was to comprehensively understand the effective design and use of e-tutorials, providing valuable insights for lecturers, researchers and policymakers. This study adopted a qualitative systematic literature survey design to identify and synthesise previous research on the requirements for developing engaging LMS-mediated e-tutorials in mathematics education.[11] The qualitative approach suited well with the study's aim of exploring perceptions, needs, and experiences, which are critical in understanding the factors

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[11] J. Synder, *From Voting to Violence: Democratization and Nationalist Conflict* (New York: W.W. Norton, 2000).

contributing to effective and engaging online tutorials.[12] A systematic, rapid Artificial Intelligence (AI) supported review was conducted in three stages to ensure rigour and relevance.[13]

The Preliminary Literature Survey

The preliminary literature survey explored ongoing debates and issues in the e-learning field in mathematics education. The objective was to comprehend the current state of knowledge in this field as a foundation for addressing the study's central question. This preliminary search helped to identify optimal search terms, including further keywords. Scholar GPT (by awesomegpts.ai, with 200M+ resources and access to Google Scholar, PubMed, bioRxiv, arXiv, and more) was chosen to enhance the search. The Search Strategy targeted keywords derived from the review question (e.g., 'e-Learning, Higher Education, Learning Management System (LMS), e-Tutorials, Mathematics Education and Engagement. Filters, such as publication year (2020–2024) and peer-reviewed status, ensured focused results.

Sampling criteria

The keywords derived from the preliminary literature survey review were used for a further, more focused literature survey. The following sampling (inclusion and exclusion) criteria guided the selection of articles to ensure a focused, methodologically sound review and relevance of the included studies to the research question. The inclusion criteria required articles focusing on e-tutorials in higher education to ensure relevance to the study's context, emphasising e-tutorials in mathematics education to align with the study's aim. Only peer-reviewed articles published between 2020 and 2024 were considered to reflect recent advancements and ensure methodological rigour. Additionally, selected articles had to be directly related to the study's objectives and research focus and have working DOI links for quick access. The exclusion criteria eliminated studies on primary or secondary education due to differing learner needs, non-English articles to avoid misinterpretation, and grey literature to maintain academic reliability.

Data Analysis

The data gathered in this study was secondary, focusing on qualitative insights from previous studies. This data was analysed using qualitative approaches involving Thematic analysis. Thematic analysis is a flexible qualitative method for identifying and analysing patterns of meaning in data.[14] Thematic Analysis aims to identify, analyse, and report patterns (themes) within the qualitative data.[15] To achieve this objective, this study prioritised transparency, rigour, and methodological reflexivity to ensure validity and reliability when conducting Thematic analysis. Firstly, the articles were read multiple times to familiarise the researchers with the data. Then, a coding process was employed to identify key factors influencing the success of e-tutorials. Keywords and phrases related to key requirements were identified and categorised into themes. These themes were compiled and presented as a data display matrix (table). Each display matrix was followed by a brief discussion of individual elements (emerging from the data) that gave specific insights into student engagement.

FINDINGS

This study addressed the critical gap in articulating specific requirements for developing engaging LMS-mediated e-tutorials in mathematics education. Guided by the research question **(**What are the specific requirements for planning, implementing, and evaluating engaging LMS-mediated e-tutorials in mathematics education?), the findings illuminate the key elements necessary to enhance student engagement and learning outcomes. The preliminary literature survey revealed emerging themes

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[12] Mikkel Godsk and Karen Louise Møller, "Engaging Students in Higher Education with Educational Technology," *Education and Information Technologies* 30, no. 3 (February 6, 2025): 2941–76, https://doi.org/10.1007/s10639-024-12901-x.

[13] Godsk and Møller, "Engaging Students in Higher Education with Educational Technology."

[14] Jean-Frédéric Morin, Christian Olsson, and Ece Özlem Atikcan, "Thematic Analysis," in *Research Methods in the Social Sciences: An A-Z of Key Concepts* (Oxford University Press, 2021), 283–88, https://doi.org/10.1093/hepl/9780198850298.003.0066.

[15] Kevin Fuchs, "A Systematic Guide for Conducting Thematic Analysis in Qualitative Tourism Research," *Journal of Environmental Management and Tourism* 14, no. 6 (September 29, 2023): 2696–2703, https://doi.org/10.14505/jemt.v14.6(70).17.

related to usage, teaching, learning and content requirements, offering actionable insights for designing more effective e-tutorials tailored to the unique demands of mathematics education. The final findings revealed 18 key requirements for engaging LMS-mediated e-tutorials in mathematics education. These are categorised into four tables: 1) Usage, 2) Teaching, 3) Learning, and 4) Content. Each table contains the design elements, requirements, analysis, implementation strategies and references.

Preliminary Literature Survey Results

This initial literature survey provided a foundational understanding of the debates and issues around LMS-mediated e-tutorials. It highlighted the key terms that could be used in the systematic literature search, as summarised below in Table 1.

Table 1: Preliminary Literature Survey Results

Debates and issues	Related key terms
Mathematics Engagement • fostering deep understanding and sustained participation in mathematics education • transitioning from instrumental understanding to relational understanding • need for multiple representations, such as visual aids, real-world applications, and peer collaboration, to enhance mathematical comprehension and problem-solving skills	Interactivity, Accessibility, Quality content, Timely feedback Engagement barriers Learning outcomes Performance Tracking Multimedia Integration e-Content Visualisation Tools
Engaging learning • Adaptive learning, which tailors content delivery to individual student needs • Teacher-student interaction also plays a pivotal role in engagement. • Flexible and multimedia-based learning environments. • Social isolation hinders student engagement.	Scaffolded Learning Social learning features Social interaction Peer teaching Self-Paced Learning Diverse learning styles Adaptive Learning
Engaging teaching • Gamification to enhance engagement. • Feedback mechanisms are another essential aspect of evaluation. • Learning analytics ensuring the effectiveness of LMS-mediated tutorials.	Motivation and retention Gamification Cognitive load Differentiation Resource provision Teaching presence
LMS usage • The lack of interactivity, where LMS platforms are primarily used for content delivery. • Limited personalisation. LMS platforms frequently adopt a one-size-fits-all approach. • Engagement barriers persist due to poor design elements.	Flexibility Adaptive/conditional release function Purposeful resource provision Performance Tracking Performance Monitoring Feedback mechanisms

The preliminary literature survey highlights key debates and issues in LMS-mediated e-tutorials in mathematics, emphasising the need for interactive, adaptive, and multimedia-rich learning environments to foster deep engagement and understanding. Challenges such as limited personalisation, social isolation, and poor design elements hinder student participation, necessitating strategies like gamification, scaffolded learning, peer collaboration, and adaptive content delivery to enhance motivation and retention. Learning analytics, feedback mechanisms, and performance tracking are essential for evaluating tutorial effectiveness and ensuring continuous improvement in mathematics education.

Mathematics Engagement Requirements

Mathematical engagement is essential for fostering deep understanding and sustained participation in mathematics education, yet it is often interpreted in various ways, leading to theoretical complexities. Different models define mathematical engagement, such as Kilpatrick et al.'s Mathematical Proficiency Model, which emphasises conceptual understanding, procedural fluency and adaptive reasoning, while De Corte's Mathematical Disposition Model focuses on mathematics as a problem-solving and sense-making activity.[16] Ma and Sfard, ideas suggest that effective LMS-mediated e-tutorials should integrate both procedural skills and conceptual understanding through interactive learning, real-world applications, and collaborative problem-solving. [17] Understanding mathematics also requires transitioning from instrumental understanding (solving problems mechanically) to relational understanding, which enables students to apply knowledge flexibly in different contexts.[18] Research highlights the need for multiple representations, such as visual aids, real-world applications, and peer collaboration, to enhance mathematical comprehension and problem-solving skills. [19] Table 2 summarises the mathematics requirements for engaging e-tutorials based on the literature review of the conceptions of mathematics engagement and understanding discussed above.

Table 2: Mathematics Engagement Requirements

	Design Element	**Requirement**	**Analysis**	**Enactment**	**Sample References**
1	Visualisation Tools	Use dynamic visual aids to clarify abstract concepts	Enhances understanding of complex mathematical relationships	Integrate graphs, interactive models, and problem-based manipulatives	Shea & Bidjerano (2020)[20], Ngwabe & Sakyiwaa (2025)[21]
2	Varied Practice	Offer diverse problems for deeper conceptual understanding	Encourages flexible thinking and relational understanding	Use adaptive quizzes with varied difficulty levels to challenge different kinds of reasoning	Bernardi et al. (2024)[22]Egara & Mosimege (2024)[23]

[16] Jeremy Kilpatrick, Jane Swafford, and Bradford Findell, *Adding It up: Helping Children Learn Mathematics* (Washington, DC: National Academy Press, 2001); Erik De Corte, "Mainstreams and Perspectives in Research on Learning (Mathematics) From Instruction," *Applied Psychology* 53, no. 2 (April 3, 2004): 279–310, https://doi.org/10.1111/j.1464-0597.2004.00172.x.

[17] Liping Ma, *Knowing and Teaching Elementary Mathematics* (Mahwah, NJ: Lawrence Erlbaum Associates, 1999), https://doi.org/10.4324/9781410602589; Anna Sfard et al., "Moving Between Discourses: From Learning-As-Acquisition To Learning-As-Participation," in *AIP Conference Proceedings*, 2009, 55–58, https://doi.org/10.1063/1.3266753.

[18] John Walle, Karen Karp, and Jennifer Bay-Williams, *Elementary and Middle School Mathematics: Teaching Developmentally, Http://Lst-Iiep.Iiep-Unesco.Org/Cgi-Bin/Wwwi32.Exe/[In=epidoc1.in]/?T2000=026901/(100)*, 2009.

[19] Emas Marlina et al., "Multiplication and Division Learning Assistance Using the Fun Learning Method Assisted by Recycling Teaching Aids at Kober Bina Warga Mekarjaya," *Inaba of Community Services Journal* 2, no. 1 (June 30, 2023): 36–42, https://doi.org/10.56956/inacos.v2i01.193.

[20] Peter Shea and Temi Bidjerano, "Understanding Distinctions in Learning in Hybrid, and Online Environments: An Empirical Investigation of the Community of Inquiry Framework," *Interactive Learning Environments* 21, no. 4 (August 2013): 355–70, https://doi.org/10.1080/10494820.2011.584320.

[21] Abongile Ngwabe and Sakyiwaa Boateng, "Visualising Mathematical Concepts through Dual Digital and Non-Digital Teaching Tools on Preservice Teachers' Pedagogical Content Knowledge," *Open Books and Proceedings*, March 10, 2025, https://doi.org/10.38140/obp3-2025-03.

[22] Giulia Bernardi, Domenico Brunetto, and Gaia Turconi, "The Secondary-Tertiary Transition in Mathematics: Insight through Personal Journals in a Math Class," in *10th International Conference on Higher Education Advances (HEAd'24)* (Valencia: Universitat Politècnica de València, 2024), https://doi.org/10.4995/HEAd24.2024.17200.

[23] Felix Oromena Egara and Mogege Mosimege, "Exploring the Integration of Artificial Intelligence-Based ChatGPT into Mathematics Instruction: Perceptions, Challenges, and Implications for Educators," *Education Sciences* 14, no. 7 (July 6, 2024): 742, https://doi.org/10.3390/educsci14070742.

3	Multimedia Integration	Incorporate videos, simulations, and visual elements	Keeps students engaged and supports different learning preferences	Use a mix of videos, podcasts, screencasts, and interactive demonstrations in lessons	Costa et al. (2021)[24], Clark & Mayer (2021)[25]
4	Scaffolded Learning	Gradually increase complexity from instrumental to relational understanding	Guides students through stages of conceptual mastery	Implement scaffolded exercises that transition from basic to advanced topics	Bernardi et al. (2024)[26] Suh & Roscioli (2023)[27]

Table 2 outlines the Mathematical engagement requirements for engaging e-tutorials, emphasising dynamic visualisation tools, varied practice, multimedia integration, and scaffolded learning. Visualisation aids enhance understanding of complex concepts, while varied practice encourages flexible thinking through adaptive quizzes. Multimedia elements such as videos and simulations keep students engaged and cater to different learning preferences. Scaffolded learning ensures a structured progression from basic to advanced understanding. These strategies support an engaging, more personalised, and interactive learning experience. Building on the essential role of mathematical engagement in fostering deep understanding and active participation, it is equally important to examine the broader learning requirements that shape effective LMS-mediated e-tutorials as discussed below.

Learning Requirements

Learning facilitated through LMSs plays a crucial role in higher education by offering flexible and multimedia-based learning environments, particularly in mathematics education.[28] Engaging learning requires interactive and collaborative learning spaces, such as small group discussions and blended learning approaches, which have been shown to enhance cognitive presence and student performance.[29] However, challenges such as varying levels of digital literacy and social isolation hinder student engagement, emphasising the need for targeted digital skills training and synchronous learning tools.[30] Future directions in e-learning emphasise adaptive learning technologies and gamification to personalise instruction and make learning more interactive and enjoyable.[31] To maximise the benefits of LMS-mediated e-learning, institutions must implement comprehensive lecturer training and evaluation frameworks to ensure continuous improvement and effectiveness.[32] Table 3 summarises the

[24] Sidonie F. Costa, Eliana Costa e Silva, and Aldina Correia, "Guidelines for Creating Video Podcasts in Mathematics Higher Education," *International Journal for Technology in Mathematics Education* 28, no. 2 (June 1, 2021): 93–105, https://doi.org/10.1564/tme_v28.2.03.

[25] Ruth Colvin Clark, Richard E. Mayer, and Will Thalheimer, "E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning," *Performance Improvement* 42, no. 5 (May 2003): 41–43, https://doi.org/10.1002/pfi.4930420510.

[26] Bernardi, Brunetto, and Turconi, "The Secondary-Tertiary Transition in Mathematics: Insight through Personal Journals in a Math Class."

[27] Jennifer M. Suh and Kate Roscioli, "Learning Trajectory-Based Formative Assessment and Sequenced Digital Learning Activities in Math Class," in *Preparing Pre-Service Teachers to Integrate Technology in K-12 Classrooms: Standards and Best Practices* (IGI Global, 2022), 271–94, https://doi.org/10.4018/978-1-6684-5478-7.ch015.

[28] Olena Kosovets et al., "Digital Technologies as a Means of Adaptive Learning for Higher Education Informatics and Mathematics," *Physical and Mathematical Education* 33, no. 1 (April 2, 2022): 14–19, https://doi.org/10.31110/2413-1571-2022-033-1-002.

[29] Kosovets et al., "Digital Technologies as a Means of Adaptive Learning for Higher Education Informatics and Mathematics."

[30] Winiswa Mavutha and Tshepo Mabotja, "Digital Literacy: A Foreign Language for Students from Rural Areas in South Africa," *International Journal of Research in Business and Social Science (2147- 4478)* 13, no. 5 (August 20, 2024): 784–93, https://doi.org/10.20525/ijrbs.v13i5.3315.

[31] Luis Fernando Calvo, Raúl Herrero Martínez, and Sergio Paniagua Bermejo, "Influencia de Procesos de Ludificación En Entornos de Aprendizaje STEM Para Alumnos de Educación Superior," *Trilogía Ciencia Tecnología Sociedad* 12, no. 22 (January 31, 2020): 35–68, https://doi.org/10.22430/21457778.1604.

[32] Costa, Silva, and Correia, "Guidelines for Creating Video Podcasts in Mathematics Higher Education."

learning requirements for engaging e-tutorials based on the literature review of the conceptions of learning discussed above.

Table 3: Learning Requirements

	Design Element	Requirement	Analysis	Enactment	Sample References
11	Interactive Problem Solving	Encourage higher-order thinking and reasoning	Promotes deeper engagement with content beyond procedural methods	Incorporate interactive exercises, simulations, and collaborative tasks	Meles & Ali (2024)[33] Patero (2023)[34]
12	Peer Collaboration	Facilitate peer collaboration and teaching	Engages students in collaborative problem-solving and peer learning	LMS tools like discussion forums, group work, and shared whiteboards foster collaboration	Garrison & Vaughan (2020)[35] Nungu et al. (2023)[36]
13	Real-World Applications	Connect mathematics to practical scenarios	Helps students relate theoretical knowledge to everyday situations	Include real-world problem sets and applications in exercises	Yonathan & Seleky (2023)[37]
14	Self-Paced Learning	Allow flexibility for individual learning styles	Promotes self-regulation and adaptive learning experiences	LMS with self-paced modules and progress-tracking tools	Cirstea (2022)[38] Dhaka (2023)[39]

Table 3 highlights the learning requirements for engaging e-tutorials, focusing on interactive problem-solving, peer collaboration, real-world applications, and self-paced learning. Encouraging higher-order thinking, collaboration among peers, and real-world applications deepens students' understanding and makes content more relatable. Additionally, providing flexibility through self-paced modules empowers students to regulate their learning and progress at their own pace. These elements foster a more engaged, collaborative, and personalised learning environment. While learning requirements focus on fostering student engagement through interactive, collaborative, and flexible

[33] Christina Meles and Siti Rahaimah Ali, "Mathematics Education Values Applied Among Primary School Students," *International Journal of Modern Education* 6, no. 21 (June 20, 2024): 93–111, https://doi.org/10.35631/IJMOE.621008.

[34] Judelyn L. Patero, "Revolutionizing Math Education: Harnessing ChatGPT for Student Success," *International Journal of Advanced Research in Science, Communication and Technology* 3, no. 1 (July 30, 2023): 807–13, https://doi.org/10.48175/IJARSCT-12375.

[35] D. Randy Garrison and Norman D. Vaughan, *Blended Learning in Higher Education* (Wiley, 2007), https://doi.org/10.1002/9781118269558.

[36] Leonard Nungu, Evode Mukama, and Ezechiel Nsabayezu, "Online Collaborative Learning and Cognitive Presence in Mathematics and Science Education. Case Study of University of Rwanda, College of Education," *Education and Information Technologies* 28, no. 9 (September 8, 2023): 10865–84, https://doi.org/10.1007/s10639-023-11607-w.

[37] Andrew Billy Yonathan and Jacob Stevy Seleky, "Realistic Mathematics Education to Optimize Students' Understanding of Mathematical Concepts," *JOHME: Journal of Holistic Mathematics Education* 7, no. 2 (December 4, 2023): 143, https://doi.org/10.19166/johme.v7i2.6233.

[38] Arina Cirstea, "Engaging Students Online: An Analysis of Students' Motivations for Seeking Individual Learning Development Support," *Journal of Learning Development in Higher Education*, no. 23 (March 16, 2022): 1–22, https://doi.org/10.47408/jldhe.vi23.809.

[39] Bed Prasad Dhakal, "Digital Pedagogy for Self-Paced Learning in Mathematics Education," *Journal of Mathematics Education* 5, no. 1 (December 21, 2023): 1–14, https://doi.org/10.3126/jme.v5i1.60846.

learning strategies, teaching requirements emphasise the instructional strategies and support systems necessary for effectively implementing LMS-mediated e-tutorials to enhance student comprehension and participation, as discussed below.

Teaching Requirements

E-tutorials provide a flexible and interactive learning experience, making education more accessible and adaptable to students' needs.[40] Effective teaching using LMS-mediated e-tutorials involves defining objectives, setting measurable learning outcomes, curating relevant content, and ensuring resource availability to enhance engagement and comprehension. Implementation requires integrating pedagogical strategies with technology, such as discussion forums, live chats, and multimedia demonstrations, to facilitate student interaction and support.[41] Challenges in e-tutorial development include addressing digital literacy gaps, ensuring accessibility, and maintaining student motivation, which requires adaptive instructional strategies and continuous evaluation. Evaluating LMS-mediated e-tutorials through data analytics, student feedback, and performance assessments helps refine content delivery and improve overall learning outcomes. Table 4 summarises the teaching requirements for engaging e-tutorials based on the literature review of the conceptions of teaching discussed above.

Table 4. Teaching Requirements

	Design Element	**Requirement**	**Analysis**	**Enactment**	**Sample References**
7	Relational Understanding	Focus on why methods work, not just how	Encourages deeper conceptual grasp of mathematical principles	Provide explanations, interactives content, purposeful resource provision	Yonathan & Seleky (2023)[42] Inci et al. (2023)[43]
8	Differentiation for Students	Adapt to varying levels of student ability	Enables instructors to respond effectively to diverse learning needs	Utilise LMS tools for adaptive learning pathways and tailored interventions	Idowu (2024)[44] Taylor et al. (2021)[45]
9	Teacher Support	Enhance communication between instructors and students	Teacher presence impacts student engagement and learning outcomes	Utilise chat systems, and regular feedback in LMS	Zhang et al. (2024)[46] Engelbrecht and Borba (2023)[47]

[40] Letsela B. Motaung and Makombe Rodwell, "Tutor Experiences of Online Tutoring as a Basis for the Development of a Focused Tutor-Training Programme," *The Independent Journal of Teaching and Learning* 16, no. 2 (November 1, 2021): 101–17, https://doi.org/10.10520/ejc-jitl1-v16-n2-a9.

[41] Clark, Mayer, and Thalheimer, "E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning."

[42] Yonathan and Seleky, "Realistic Mathematics Education to Optimize Students' Understanding of Mathematical Concepts."

[43] Alper Mustafa, Bilge Peker, and Naci Küçükgençay, "Realistic Mathematics Education," ed. O. Cardak and S. A. Kiray (ISRES Publishing, 2023), 66–83.

[44] Emmanuel Idowu, *Personalized Learning: Tailoring Instruction to Individual Student Needs*, 2024, https://doi.org/10.20944/preprints202411.0863.v1.

[45] Deborah L. Taylor, Michelle Yeung, and A. Z. Bashet, "Personalized and Adaptive Learning," in *Innovative Learning Environments in STEM Higher Education: Opportunities, Challenges, and Looking Forward*, 2021, 17–34, https://doi.org/10.1007/978-3-030-58948-6_2.

[46] Yanle Zhang et al., "Effects of Perceived Teacher Support on Student Behavioral Engagement in the Blended Learning Environment: Learning Experience as a Mediator," *Journal of Contemporary Educational Research* 8, no. 5 (June 12, 2024): 297–316, https://doi.org/10.26689/jcer.v8i5.6666.

[47] Engelbrecht and Borba, "Recent Developments in Using Digital Technology in Mathematics Education."

				Implement in computer lab setting	
10	Facilitation and Guidance	Provide timely facilitation for complex topics	Builds a supportive learning environment and reduces student confusion	Use forums, peer-tutoring, and live sessions to clarify difficult concepts	Clark & Mayer (2021)[48] Ni'mah et al. (2025)[49]

Table 4 outlines the teaching requirements for engaging e-tutorials based on the conceptions of teaching discussed above, emphasising relational understanding, differentiation for students, teacher support, and facilitation. Lecturers are encouraged to focus on why concepts work to promote deeper understanding, while LMS tools help adapt lessons to individual needs. Effective communication and regular feedback between instructors and students are key to maintaining engagement and facilitating complex topics in a timely manner through forums and live sessions to support a collaborative and clear learning experience. By incorporating these teaching requirements, lecturers can create a dynamic and inclusive LMS-mediated learning environment that fosters deeper comprehension, active participation, and sustained student engagement in the e-tutorials.

Usage Requirements

While effective LMS-mediated e-tutorials must foster interactive and adaptive learning experiences to engage students, ensuring that LMS platforms provide the necessary flexibility, performance tracking, and interactive elements is essential for sustaining student participation and optimising learning outcomes. Learning Management Systems (LMS) serve as centralised platforms for delivering, tracking, and managing online learning experiences, offering tools such as chat rooms, whiteboards, and assessments to support both synchronous and asynchronous learning.[50] In higher education, LMS platforms like Moodle have enhanced student engagement and performance, particularly in mathematics education, through AI-driven assessments and blended learning approaches.[51] Key LMS functions include automated student performance analysis, adaptive learning, and gamification, all of which contribute to improved teaching and learning outcomes.[52] LMS-mediated e-tutorials allow students to engage with learning materials at their own pace while benefiting from teacher support, which plays a crucial role in maintaining engagement, especially in blended learning environments.[53] To maximise effectiveness, LMS-mediated e-tutorials must integrate AI for performance assessment, offer adaptive learning tools, support blended learning, and utilise learning analytics for tracking student progress.[54] Table 5 summarises the usage requirements for engaging e-tutorials based on the literature review of the conceptions of LMS use discussed above.

[48] Clark, Mayer, and Thalheimer, "E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning."

[49] Alifatun Ni'mah et al., "Problem-Based Learning (PBL) Methods Within An Independent Curriculum(A Literature Review)," *Sintaksis : Publikasi Para Ahli Bahasa Dan Sastra Inggris* 2, no. 4 (July 3, 2024): 165–74, https://doi.org/10.61132/sintaksis.v2i4.859.

[50] Stephen Kigundu, "Design of an LMS-Mediated Tutorial to Support Deep and Effective Engagement in the Process of Learning Mathematics" (Rhodes University, 2023), https://doi.org/10.21504/10962/431565.

[51] Abd. Syakur et al., "Web-Based Learning Management System as Media in Teaching ESP for Mathematics Students in Higher Education," *Jurnal Konseling Dan Pendidikan* 11, no. 3 (September 30, 2023): 142, https://doi.org/10.29210/1102500.

[52] Varit Rungbanapan et al., "To Dev or to Doc?: Predicting College IT Students' Prominent Functions in Software Teams Using LMS Activities and Academic Profiles," in *2022 26th International Computer Science and Engineering Conference (ICSEC)* (IEEE, 2022), 105–10, https://doi.org/10.1109/ICSEC56337.2022.10049348.

[53] Cirstea, "Engaging Students Online: An Analysis of Students' Motivations for Seeking Individual Learning Development Support."

[54] Raj Thakare et al., "Automative Feedback System for Descriptive Answers in LMS Using Machine Learning Algortihm," in *2023 IEEE Pune Section International Conference (PuneCon)* (IEEE, 2023), 1–6, https://doi.org/10.1109/PuneCon58714.2023.10450028.

Table 5: Usage Requirements

	Design Element	Requirement	Analysis	Enactment	Sample References
1	LMS Flexibility	Support for both synchronous and asynchronous learning	Accommodates diverse schedules and learning preferences	Blend real-time interactive sessions with self-paced learning paths	Osman (2022)[55] Husak & Radzihovska (2021)[56]
2	Adaptive Learning	Personalisation based on student needs	Enhances learning outcomes by tailoring to individual abilities and progress	Use LMS-driven pathways to adjust content based on performance	Thakare et al. (2023)[57] Contrino et al. (2022)[58]
3	Gamification	Foster student motivation through interactive elements	Enhances engagement and enjoyment in learning mathematics	Use badges, challenges, and rewards to promote active participation	Limantara et al. (2023)[59]
4	Performance Tracking and Monitoring	Automate evaluation of student performance	Provides insights into student progress and helps identify learning gaps	Use LMS-based analytics and dashboards to track performance trends	Thakare et al. (2023),[60] Park et al. (2022)[61]
5	Social Interaction	Enable spontaneous verbal peer communication	Accommodates individual computer work in face-to-face social group settings	Encourage face-to-face social interaction and peer communication (e.g., in a computer lab setting)	Kigundu (2023) [62]
6	Purposeful resource provision	Balance information delivery and	Prevents cognitive overload	Include big picture items (e.g., pdf notes) to provide awareness of the scope of the topic, precession items	Kigundu (2023)[63]

55 Siti Zuraidah Md Osman, "Combining Synchronous and Asynchronous Learning: Student Satisfaction with Online Learning Using Learning Management Systems," *Journal of Education and E-Learning Research* 9, no. 3 (August 10, 2022): 147–54, https://doi.org/10.20448/jeelr.v9i3.4103.

56 Ludmyla Husak and Larisa Radzihovska, "Use of the Moodle Learning Management System in the Process of Distance Learning of Higher and Applied Mathematics," *Scientific Bulletin of Uzhhorod University. Series: «Pedagogy. Social Work»*, no. 1(48) (May 27, 2021): 104–7, https://doi.org/10.24144/2524-0609.2021.48.104-107.

57 Thakare et al., "Automative Feedback System for Descriptive Answers in LMS Using Machine Learning Algortihm."

58 Monica F. Contrino et al., "Using an Adaptive Learning Tool to Improve Student Performance and Satisfaction in Online and Face-to-Face Education for a More Personalized Approach," *Smart Learning Environments* 11, no. 1 (February 5, 2024): 1–24, https://doi.org/10.1186/s40561-024-00292-y.

59 Natalia Limantara et al., "Designing Gamified Learning Management Systems for Higher Education," *International Journal of Information and Education Technology* 13, no. 1 (2023): 25–32, https://doi.org/10.18178/ijiet.2023.13.1.1776.

60 Thakare et al., "Automative Feedback System for Descriptive Answers in LMS Using Machine Learning Algortihm."

61 Hee Joo Park et al., "Change of Paradigm on LMS for Online Education: LMS Implementing Learning Analytics and Online Assessment," *The Institute for Educational Research* 35, no. 2 (June 30, 2022): 49–72, https://doi.org/10.35283/erft.2022.35.2.49.

62 Kigundu, "Design of an LMS-Mediated Tutorial to Support Deep and Effective Engagement in the Process of Learning Mathematics."

63 Kigundu, "Design of an LMS-Mediated Tutorial to Support Deep and Effective Engagement in the Process of Learning Mathematics."

		student absorption		(e.g., video clips) to provide details and embedded help (e.g., example of model answers) to provide "just-in-time" instruction that informs and guides students through a task	

Table 5 highlights the key usage requirements for engaging e-tutorials, emphasising the importance of LMS flexibility, personalised learning, and interactive elements to foster student engagement. Adaptive learning paths and LMS-driven performance tracking enable personalised support, while gamification enhances motivation and participation. Social interaction, both face-to-face and virtual, fosters collaboration, and the flexible use of multiple tools ensures that diverse learning needs are met. Finally, purposeful resource provision prevents cognitive overload, ensuring that students can focus on relevant material. These usage elements create a dynamic and student-centred learning environment, ensuring that LMS-mediated e-tutorials are both effective and engaging.

DISCUSSION

This study aimed to identify key requirements for planning, implementing, and evaluating engaging LMS-mediated e-tutorials in mathematics education. The findings indicate that the effectiveness of e-tutorials depends on integrating several key design elements. The challenge lies in deciding which features to focus on during the three phases (planning, implementing, and evaluating) of e-tutorial development. This challenge is addressed through the discussion of findings, which is organised with the help of the following sub-questions, which were related explicitly to the research question:

- *What planning elements are necessary to ensure LMS-mediated e-tutorials are engaging for undergraduate mathematics students?*
- *What implementation elements are necessary to ensure LMS-mediated e-tutorials are engaging for undergraduate mathematics students?*
- *How can the effectiveness of LMS-mediated e-tutorials be evaluated to sustain student engagement and learning outcomes?*

Responding to these research questions, this discussion integrates previous research, offering a nuanced understanding of key requirements for planning, implementing, and evaluating LMS-mediated e-tutorials in mathematics education. The objective is to identify best practices that can enhance engagement and learning outcomes.

Planning Requirements

What planning elements are necessary to ensure LMS-mediated e-tutorials are engaging for undergraduate mathematics students?

Effective planning for LMS-mediated e-tutorials in undergraduate mathematics education requires a structured approach that integrates clear and measurable learning objectives, standardised templates for objectives, purposeful learning support material provision, and accessible resource provision. To ensure engagement, e-tutorials must incorporate *clear**,** specific and measurable learning outcomes* and *scaffolded learning approaches* that support the transition from instrumental to relational understanding.[64] Establishing *specific and measurable learning outcomes* is crucial to help guide the tutorial's structure, ensure alignment with educational goals and facilitate progress tracking.[65] Planning should also include *continuous formative assessments* (e.g. quizzes and interactive problem-solving

[64] Kilpatrick, Swafford, and Findell, *Adding It up: Helping Children Learn Mathematics*; Bernardi, Brunetto, and Turconi, "The Secondary-Tertiary Transition in Mathematics: Insight through Personal Journals in a Math Class."

[65] Thakare et al., "Automative Feedback System for Descriptive Answers in LMS Using Machine Learning Algortihm"; Park et al., "Change of Paradigm on LMS for Online Education: LMS Implementing Learning Analytics and Online Assessment."

tasks) to improve conceptual comprehension and make mathematical content more relatable.[66] This study's findings further emphasise the dual role of formative assessments in improving learning outcomes and serving as a mechanism for adaptive learning paths.[67] This approach challenges static assessment models by advocating for dynamic, real-time adjustments based on student performance, a concept underexplored in earlier studies. This ensures *flexibility, allowing students to progress at their own pace* while benefiting from performance tracking and feedback mechanisms embedded within the LMS.[68] However, challenges such as digital literacy gaps and social isolation must be mitigated through comprehensive lectures and collaborative workshops in the use of SMART templates to define clear objectives, integrate analytics for progress tracking and how to create measurable learning goals for abstract mathematical concepts.[69]

Implementation Requirements

What implementation elements are necessary to ensure LMS-mediated e-tutorials are engaging for undergraduate mathematics students?

Implementing LMS-mediated e-tutorials requires a combination of adaptability, interactive learning strategies, instructor-student interaction and accessible content. These elements ensure that students remain motivated, actively participate in learning, and develop a deep understanding of mathematical concepts.

The findings of this study highlight the importance of *adaptive learning and personalisation*. Customisable, adaptive learning pathways powered by LMSs allow students to engage at their own pace and receive targeted support, adapting to their cognitive needs and learning styles.[70] These findings highlight key features of LMS platforms that align with engaging e-tutorials in mathematics education. For example, *customisability* allows content to be tailored to individual learners' needs, supporting the notion that personalisation enhances engagement, improving students' academic performance and motivation.[71] *Accessibility* is another significant feature, as LMS platforms provide flexible access to materials, facilitating continuous learning anytime and anywhere, consistent with Kosovets et al.[72] This study further highlights the importance of *monitoring and analytics* to identify gaps and actively guide the personalisation of future learning content, an area underexplored in previous research.

Including *gamification and interactive elements* such as badges, challenges, and performance dashboards corroborates the findings of Limantara et al., who reported that gamification enhances motivation and makes learning enjoyable.[73] However, this study noted that while gamification is effective, poor integration can distract students and detract from their focus on core mathematical concepts.[74] This implies that students need active *instructor facilitation and support* to foster a supportive learning environment. Instructor guidance helps clarify difficult concepts, which is especially important in mathematics. The importance of teacher-student communication tools, such as discussion forums and live feedback, echoes the conclusions of Zhang et al., who emphasised the

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[66] Meles and Ali, "Mathematics Education Values Applied Among Primary School Students"; Yonathan and Seleky, "Realistic Mathematics Education to Optimize Students' Understanding of Mathematical Concepts."

[67] Weigand, Trgalova, and Tabach, "Mathematics Teaching, Learning, and Assessment in the Digital Age."

[68] Cirstea, "Engaging Students Online: An Analysis of Students' Motivations for Seeking Individual Learning Development Support"; Dhakal, "Digital Pedagogy for Self-Paced Learning in Mathematics Education."

[69] Mavutha and Mabotja, "Digital Literacy: A Foreign Language for Students from Rural Areas in South Africa"; Eddie M. Mulenga and José M. Marbán, "Is COVID-19 the Gateway for Digital Learning in Mathematics Education?," *Contemporary Educational Technology* 12, no. 2 (April 18, 2020): ep269, https://doi.org/10.30935/cedtech/7949.

[70] Kosovets et al., "Digital Technologies as a Means of Adaptive Learning for Higher Education Informatics and Mathematics."

[71] Aliya Makhambetova, Nadezhda Zhiyenbayeva, and Elena Ergesheva, "Personalized Learning Strategy as a Tool to Improve Academic Performance and Motivation of Students," *International Journal of Web-Based Learning and Teaching Technologies* 16, no. 6 (August 25, 2021): 1–17, https://doi.org/10.4018/IJWLTT.286743.

[72] Kosovets et al., "Digital Technologies as a Means of Adaptive Learning for Higher Education Informatics and Mathematics."

[73] Limantara et al., "Designing Gamified Learning Management Systems for Higher Education."

[74] Armando M. Toda, Pedro H. D. Valle, and Seiji Isotani, "The Dark Side of Gamification: An Overview of Negative Effects of Gamification in Education," in *Communications in Computer and Information Science*, vol. 832 (Springer Cham, 2018), 143–56, https://doi.org/10.1007/978-3-319-97934-2_9.

critical role of instructor guidance in mathematics education.[75] However, this study suggests that instructor facilitation should also leverage learning analytics to provide targeted interventions, ensuring that support is both timely and tailored to individual student needs. By leveraging *data-driven support*, instructors can identify struggling students and ensure timely assistance tailored to individual needs.[76] This contribution highlights a synergy between technology and pedagogy that previous research has only touched upon.

The findings of this study extend the literature by integrating adaptive learning, gamification, and instructor facilitation into a cohesive framework for implementation. While previous research has examined these elements individually, this study emphasises their interplay. It demonstrates how their combined use addresses the specific challenges of engagement, personalisation, and interactivity in implementing LMS-mediated e-tutorials in mathematics education. However, challenges such as *maintaining student motivation*, *technical or accessibility barriers* and *time constraints* must be mitigated through the implementation of adaptive learning, strategic instructional design, robust technical support, and flexible scheduling to ensure the effectiveness of these e-tutorials.[77]

Evaluation Requirements

How can the effectiveness of LMS-mediated e-tutorials be evaluated to sustain student engagement and learning outcomes?

The effectiveness of LMS-mediated e-tutorials in sustaining student engagement and improving learning outcomes can be evaluated through a combination of *learning analytics, feedback mechanisms, performance tracking, and pedagogical strategie***s** that enhance mathematical engagement, interactive learning, and knowledge retention.

The use of *learning analytics and performance tracking* to monitor student performance and engagement is widely recognised in the literature. Learning analytics and performance tracking help lecturers monitor student progress by identifying engagement patterns, tracking time spent on tasks, and analysing quiz performance.[78] For example, Fernández-Morante et al. demonstrated the potential of analytics tools in identifying areas where students struggle and enabling instructors to adapt tutorials accordingly.[79] This study supports these findings but extends them by emphasising the need for real-time analytics that allow for immediate interventions. Unlike traditional methods, where data is reviewed post hoc, current studies suggest that continuous monitoring and on-the-fly adjustments can significantly improve engagement and outcomes. Continuous tracking and monitoring require *feedback collection and continuous improvement*. Collecting qualitative and quantitative feedback from students helps identify challenges they face with the material, leading to refined content and more effective tutorials.[80] Feedback mechanisms, such as *automated feedback* and *instructor responses*, ensure that students receive timely support and can self-correct misconceptions. Hence, feedback mechanisms can improve the relevance and effectiveness of e-tutorials.[81] While this study agrees with these conclusions, it also highlights the importance of integrating automated feedback collection tools, such as in-tutorial surveys or engagement metrics, to streamline the process. Furthermore, the findings reveal that feedback collection should focus on user experience, such as ease of navigation and accessibility, an area sometimes overlooked in previous studies.

This study also identified *pedagogical strategies* which enhance mathematical engagement, interactive learning, and performance. These include active learning strategies (such as Problem-based

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[75] Dongsong Zhang et al., "Can E-Learning Replace Classroom Learning?," *Communications of the ACM* 47, no. 5 (May 2004): 75–79, https://doi.org/10.1145/986213.986216.

[76] Park et al., "Change of Paradigm on LMS for Online Education: LMS Implementing Learning Analytics and Online Assessment."

[77] N Morze et al., "Implementation of Adaptive Learning at Higher Education Institutions by Means of Moodle LMS," *Journal of Physics: Conference Series* 1840, no. 1 (March 1, 2021): 012062, https://doi.org/10.1088/1742-6596/1840/1/012062.

[78] Park et al., "Change of Paradigm on LMS for Online Education: LMS Implementing Learning Analytics and Online Assessment."

[79] Carmen Fernández-Morante et al., "Adaptive Learning Supported by Learning Analytics for Student Teachers' Personalized Training during in-School Practices," *Sustainability* 14, no. 1 (December 23, 2021): 124, https://doi.org/10.3390/su14010124.

[80] Anderson Pinheiro Cavalcanti et al., "Automatic Feedback in Online Learning Environments: A Systematic Literature Review," *Computers and Education: Artificial Intelligence* 2 (2021): 100027, https://doi.org/10.1016/j.caeai.2021.100027.

[81] Beth Porter and Burcin Bozkaya, *Assessing the Effectiveness of Using Live Interactions and Feedback to Increase Engagement in Online Learning*, 2020, https://doi.org/10.48550/arXiv.2008.08241.

learning), collaborative learning strategies (such as peer tutoring), technology-enhanced strategies (e.g. Online resources) and feedback and assessment strategies (e.g. formative assessment).[82]

Detailed *reporting and structured reflection* on the effectiveness of e-tutorials are necessary for continuous improvement. As Lousberg et al. observed, structured reflection by lecturers and administrators is vital for optimising tutorial design.[83] This study corroborates their findings while contributing further by emphasising the need for data visualisation tools, such as dashboards, to make insights observable by lecturers and administrators.[84] Moreover, reflection should include student involvement, creating a *collaborative feedback loop* that promotes shared responsibility for tutorial improvement.

The evaluation requirements identified in this study highlight existing research on the importance of learning analytics, feedback collection, and structured reporting. The literature survey findings further contribute to the field by advocating for *real-time analytics*, automated feedback tools, and collaborative reflection frameworks. By emphasising a more dynamic and integrated approach, this study offers a comprehensive guide for evaluating LMS-mediated e-tutorials in mathematics education, paving the way for more adaptive and student-centred learning experiences. However, challenges such as *privacy concerns*, the complex nature of *interpreting analytics for actionable insights* and *continuous improvement demands* may arise in meeting these requirements. Addressing these challenges requires institutions to establish robust data privacy policies that comply with relevant laws and ensure ethical data use, fostering trust among students and lecturers. To simplify interpreting analytics for actionable insights, professional development programs should focus on training lecturers in data analysis and decision-making, supported by intuitive visualisation tools like dashboards. Institutions must also invest in sustainable strategies for continuous improvement, such as phased updates to LMS features and leveraging open-source tools to reduce costs. By prioritising institutional support, technological solutions, and professional development, these measures can help overcome the challenges of applying dynamic and effective evaluation practices for LMS-mediated e-tutorials in mathematics education.

Examination of Implications

This study demonstrates that effective LMS-mediated e-tutorials in mathematics education require a structured framework encompassing clear planning, dynamic implementation, and robust evaluation strategies. The study asserts that addressing challenges such as low engagement, lack of interactivity, and inadequate personalisation in existing LMS tutorials is essential for improving learning outcomes. It identifies key requirements, such as clear objectives, adaptive learning paths, gamification, accessibility, and analytics-driven feedback mechanisms, that together form a comprehensive guide for creating engaging, inclusive, and student-centred e-tutorials tailored to the unique demands of mathematics education.

RECOMMENDATIONS

This section provides key recommendations for lecturers, researchers and institutions to enhance the effectiveness of LMS-mediated e-tutorials in mathematics education by integrating best practices in planning, implementation, and evaluation.

For Lecturers

For lecturers, these recommendations are based on the key requirements for creating engaging LMS-mediated e-tutorials in mathematics education, organised as a checklist. That checklist integrates the study's findings into a structured framework, addressing the critical requirements for planning, implementing, and evaluating LMS-mediated e-tutorials.

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[82] Kigundu, "Design of an LMS-Mediated Tutorial to Support Deep and Effective Engagement in the Process of Learning Mathematics."

[83] Louis Lousberg et al., "Reflection in Design Education," *International Journal of Technology and Design Education* 30, no. 5 (November 25, 2020): 885–97, https://doi.org/10.1007/s10798-019-09532-6.

[84] Teo Susnjak, Gomathy Suganya Ramaswami, and Anuradha Mathrani, "Learning Analytics Dashboard: A Tool for Providing Actionable Insights to Learners," *International Journal of Educational Technology in Higher Education* 19, no. 1 (December 14, 2022): 12, https://doi.org/10.1186/s41239-021-00313-7.

Table 7 provides a concise and structured overview of the requirements for each phase, focusing on creating engaging, adaptive, and inclusive tutorials that respond to the needs of mathematics students in higher education.

Table 7: Key requirements for creating engaging LMS-mediated e-tutorials in mathematics education.

Phase	Requirement	Recommendations
Planning	Clear and Measurable Learning Objectives	Develop SMART (Specific, Measurable, Achievable, Relevant, Time-bound) goals to align tutorials with learning outcomes.
	Standardised Templates for Objectives	Provide customisable templates for lecturers to ensure consistency and clarity across tutorials.
	Purposeful Learning Support material provision	Balance information delivery and student absorption.
	Accessible Resource Provision	Ensure equitable access to devices and the internet via lending programs or resources.
	Faculty Training on LMS-mediated e-tutorial design	Attend workshops to train in instructional design, gamification, adaptive learning, and interactive content creation.
Implementation	Adaptive Learning Features	Incorporate personalised pathways such as using quizzes and exercises with feedback tailored to individual student performance.
	Gamification Elements	Integrate features like badges, leaderboards, and rewards to enhance motivation and engagement.
	Teacher-Student Interaction	Implement the e-tutorial in a group setting (e.g. computer lab) to facilitate continuous social interaction and real-time support.
	Inclusive and Accessible Content	Design e-tutorials with accessibility features, such as captions for videos, screen-reader compatibility, and intuitive navigation.
Evaluation	Learning Analytics for Refinement	Use LMS analytics to track engagement metrics, identify gaps, and refine tutorial design based on data-driven insights.
	Standardised Feedback Mechanisms	Implement structured processes for collecting feedback, such as activity journals, mid-course surveys and end-of-module evaluations.
	Data Privacy and Ethical Practices	Ensure compliance with data protection laws and communicate privacy policies clearly to build trust among students and faculty.

For Researchers

The recommended key requirements aim to build interactive, personalised e-tutorials responsive to student needs, ultimately enhancing learning outcomes in mathematics education. To achieve this aim, these requirements need to be evaluated. Therefore, future research should evaluate whether these requirements meet the expectations of mathematics education students and lecturers. In e-learning, the term "evaluation" can be effectively used to certify that both aspects of ensuring that a product or process meets the specified requirements (verification) and learning outcomes (validation) are accurately met.[85] The *Verification* process should confirm that the requirements are complete, correct, and consistent. This involves systematically reviewing requirements documentation to ensure all necessary elements are addressed and aligned with institutional objectives. The *Validation* should also ensure that the requirements align with the expectations of students and lecturers while fulfilling the intended objectives and functions of the tutorials.[86] This can be achieved through pilot testing, user feedback collection, and iterative refinements. By incorporating both verification and validation processes, researchers can ensure that LMS-mediated e-tutorials are not only well-designed but also effective in meeting educational goals and user needs. Future research should prioritise this dual-purpose evaluation to certify the practicality and impact of the proposed requirements.

For Institutions

To enhance the effectiveness of LMS-mediated e-tutorials in mathematics education, institutions must invest in comprehensive faculty training programs that equip lecturers with skills in adaptive learning, gamification, and instructional design. Providing hands-on workshops and ongoing professional development ensures that lecturers can effectively integrate interactive and engaging elements into their tutorials. Additionally, institutions should allocate resources for infrastructure improvements, including reliable LMS platforms, multimedia tools, and accessibility features to support diverse learning needs. Institutional policies must also emphasise data privacy, ethical usage of learning analytics, and student feedback integration to refine and improve tutorial design. By fostering a supportive ecosystem that prioritises innovation and engagement, institutions can create a more effective and inclusive digital learning environment for mathematics education.

CONCLUSION

In conclusion, this study has outlined the essential requirements for developing (planning, implementing and evaluating) engaging LMS-mediated e-tutorials in mathematics education. Key requirements (clear objectives, adaptive learning, gamification, accessibility, teacher-student interaction, and continuous evaluation) are fundamental to creating a learning environment that conveys mathematical concepts effectively and fosters student motivation and retention. These components are integral in addressing the challenges of online mathematics education and ensuring that e-tutorials meet the diverse needs of students. The study emphasised that by establishing these requirements, institutions and lecturers can bridge the engagement gap in LMS-based mathematics learning, leading to enhanced learning outcomes and better retention rates. By focusing on a blend of personalisation, interactivity, and consistent feedback, LMS-mediated e-tutorials can significantly improve the online learning experience for mathematics students, making abstract concepts more accessible and stimulating. This study calls on lecturers and institutions to prioritise these requirements in e-tutorial development. By investing in training, technology, and resources that align with these standards, stakeholders can ensure that LMS-mediated e-tutorials in mathematics are not only effective but also engaging and supportive. Meeting these requirements is essential for advancing the quality of online mathematics education and preparing students with the skills needed for success in today's academic and professional landscapes.

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[85] Bruno Emond, "Verification and Validation of Adaptive Instructional Systems: A Text Mining Review," in *International Conference on Human-Computer Interaction* (Springer Cham, 2024), 25–43, https://doi.org/10.1007/978-3-031-60609-0_3.

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