

Developing an AI-Based LMS to Support Self-Regulated Learning in Secondary Mathematics Education

Agus Arifin¹, Heni Pujiastuti², Hepsi Nindiasari³, Ediwarman⁴

- 1 Universitas Sultan Ageng Tirtayasa, Serang, Indonesia; arifin.gus@gmail.com
- 2 Universitas Sultan Ageng Tirtayasa, Serang, Indonesia; henipujiastuti@untirta.ac.id
- 3 Universitas Sultan Ageng Tirtayasa, Serang, Indonesia; hepsinindiasari@untirta.ac.id
- 4 Universitas Sultan Ageng Tirtayasa, Serang, Indonesia; ediwarman@untirta.ac.id

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ABSTRACT

Artificial Intelligence (AI) has the potential to enhance self-regulated learning (SRL) by offering adaptive feedback and personalized support. However, the development of AI-based Learning Management Systems (LMS) tailored to SRL in secondary mathematics education remains limited, particularly in the Indonesian context. This study addresses the need for a pedagogically grounded system by focusing on the Define phase of the 4D model to identify learner needs and design requirements. A research and development (R&D) approach was employed, using the Define phase of the 4D instructional design model. A needs analysis was conducted through a survey of 805 secondary and university students across Indonesia and a limited system trial with 26 teachers and students. Quantitative data were analyzed using descriptive statistics, complemented by qualitative feedback on usability and user expectations. Findings indicate students face significant SRL challenges, particularly in time management, sustained focus, and independent problem-solving. Participants perceived AI-supported features—such as personalized recommendations, automated feedback, and self-monitoring tools—as beneficial. The system prototype received high usability ratings across platforms, although participants emphasized that AI should complement, not replace, teacher guidance. The Define phase provided critical insights for aligning AI functionalities with SRL principles. This research offers a foundational framework for future development and highlights the importance of learner-centered, ethically grounded AI integration in mathematics education.

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Corresponding Author:

Agus Arifin
Universitas Sultan Ageng Tirtayasa, Serang, Indonesia; arifin.gus@gmail.com

1. INTRODUCTION

In recent years, artificial intelligence (AI) has emerged as a transformative force in education, offering new possibilities for personalization, formative assessment, and data-informed instructional decision-making (Zhai et al., 2021; Alotaibi, 2024). One of the most promising applications of AI lies in the development of intelligent Learning Management Systems (LMS) that can support not only content

delivery but also the development of essential learning competencies such as self-regulated learning (SRL). In secondary mathematics education, where students frequently encounter abstract, complex, and cumulative concepts, fostering SRL has become increasingly important to promote academic success and learner autonomy (Hwang & Tu, 2021; Ouyang et al., 2023).

Self-regulated learning refers to the capacity of learners to manage their cognitive, behavioral, and emotional processes in the pursuit of academic goals (Zimmerman, 2002). It encompasses key skills such as goal setting, time management, self-monitoring, help-seeking, and reflective evaluation—skills that are especially crucial in mathematics, where learning is often sequential and builds on prior understanding (Miller & Bernacki, 2019; Ciptaningtyas et al., 2018). However, evidence shows that many secondary students struggle to independently regulate their learning, particularly in digital environments where distractions are abundant and teacher supervision is minimal (Darvishi et al., 2023). These challenges highlight the need for instructional technologies that do not merely deliver content but also provide structured support for developing SRL skills.

Traditional LMS platforms used in schools often lack the adaptive functionality and scaffolding needed to support SRL processes effectively. They typically deliver standardized content without accounting for individual learning needs, motivation levels, or cognitive load (Gloerfeld et al., 2020; Chatti et al., 2021). As a result, students with poor SRL skills may disengage, fall behind, or fail to benefit from the intended learning outcomes. To address this, the integration of AI into LMS platforms offers a strategic pathway to create more responsive and learner-centered environments. AI-supported LMS can offer features such as real-time feedback, personalized learning recommendations, predictive analytics, and dynamic goal-setting assistance—all of which align with SRL principles and have the potential to enhance student engagement and learning outcomes (Bayly-Castaneda et al., 2024; Jin et al., 2023).

Despite these opportunities, there remains a significant gap in the development and implementation of AI-based LMS specifically designed to support SRL in the context of secondary education in Indonesia. Most existing platforms are designed for general content delivery or higher education use and are not tailored to the SRL challenges faced by Indonesian secondary school students, such as limited time management skills, low help-seeking behavior, and a strong reliance on teacher-led instruction (Nurjanah & Dahlan, 2018; Hastungkara & Triastuti, 2020). Moreover, while global studies have demonstrated the potential of AI to support SRL (Rana et al., 2024; Maghsudi et al., 2021), there is limited empirical research grounded in the Indonesian education context that explores students' readiness, needs, and expectations toward AI-based learning environments.

Mathematics education, in particular, poses unique cognitive and motivational challenges. Learners often face difficulties in maintaining sustained attention, connecting abstract concepts to real-world applications, and persisting through problem-solving tasks that require delayed gratification (Cîrneanu & Moldoveanu, 2024; Mustafa, 2024). These challenges can be compounded by a lack of real-time feedback and self-monitoring opportunities in conventional classrooms. A well-designed AI-based LMS could help bridge this gap by offering tailored scaffolding, metacognitive prompts, and formative feedback mechanisms that encourage students to take ownership of their learning (Demartini et al., 2024). However, the successful implementation of such a system must begin with a clear understanding of learner needs, learning difficulties, and pedagogical expectations, which is the primary concern of the current study.

This research adopts the 4D development model (Define, Design, Develop, and Disseminate) as a structured instructional design framework to guide the development of the AI-based LMS. The 4D model is widely used in educational technology to ensure systematic, theory-driven product development (Thiagarajan et al., 1974; Global Educational Studies Review, 2020). Of the four stages, the Define phase is especially critical, as it provides the conceptual foundation by identifying user needs, contextual constraints, and pedagogical goals. Through a front-end analysis, this phase enables developers to ground system features in real-world learning challenges and ensure that AI functionalities are aligned with SRL principles and curriculum standards (Kannan & Zapata-Rivera, 2022; Chatti et al., 2021).

Accordingly, this study focuses on the Define phase of AI-based LMS development. It seeks to answer the following central question: How can learner needs, challenges, and contextual factors be identified and analyzed to inform the early-stage design of an AI-supported LMS that facilitates SRL in secondary mathematics education? To address this, a mixed-methods needs analysis was conducted involving secondary and university students, as well as a small group of teachers. The study aims to produce an empirically grounded and context-sensitive foundation for subsequent system design, development, and evaluation.

By contributing a structured needs analysis specific to the Indonesian context and mathematics learning challenges, this study fills a critical gap in the literature on AI-enhanced educational technologies. Moreover, it offers practical insights for educators, instructional designers, and policymakers seeking to implement AI-supported tools that not only digitize instruction but also cultivate autonomous, self-regulated learners. The results are expected to inform the next phases of LMS development and serve as a model for similar innovations in other educational contexts.

2. METHODS

The research approach used in this investigation adopts a structured Research and Development (R&D) methodology based on the 4D instructional design model (Define, Design, Develop, and Disseminate) originally proposed by (Thiagarajan et al., 1974). This framework was selected to ensure that the development of the AI-based Learning Management System (LMS) follows a systematic, iterative, and theory-driven process aligned with best practices in educational technology research (Jin et al., 2023). Although the complete 4D model encompasses four sequential stages, this study explicitly focuses on the Define phase as the foundational stage for system development, while the subsequent phases are described conceptually to contextualize future work.

The first component involved a large-scale needs assessment conducted through an online survey administered via Google Forms. A total of 805 respondents, consisting of secondary school and university students from Banten, Jakarta, and East Java, Indonesia, participated in this phase. Participants were recruited using purposive and convenience sampling, targeting learners with prior experience in online learning environments. The survey instrument consisted of 28 Likert-scale items measuring four constructs: (1) challenges in mathematics learning, (2) SRL strategies, (3) experiences with existing LMS platforms, and (4) expectations toward AI-based LMS features. Content validity was reviewed by educational technology and mathematics education experts, and reliability analysis produced a Cronbach's alpha value above 0.80. Data were analyzed using descriptive statistics, including mean scores and standard deviations. Likert-scale responses were interpreted using categorical criteria (poor to excellent) to identify dominant learner needs.

The second component consisted of a limited system trial involving 26 users, including teachers and students. Participants were selected using purposive sampling, based on their familiarity with digital learning tools. A 20-item Likert-scale questionnaire was used to evaluate system usability, visual design, AI feature usefulness, and perceived SRL support. Descriptive statistics were applied to calculate mean scores and interpret system quality.

Ethical approval was obtained from the institutional research ethics committee. All participants provided informed consent prior to data collection. Participation was voluntary, responses were anonymous, and data confidentiality was strictly maintained.

After the Define phase was completed, the following sections present an overview of the initial system design and development results derived from the needs analysis. These descriptions are provided to illustrate the conceptual implementation of the findings and do not represent additional stages of the 4D research process evaluated in this study.

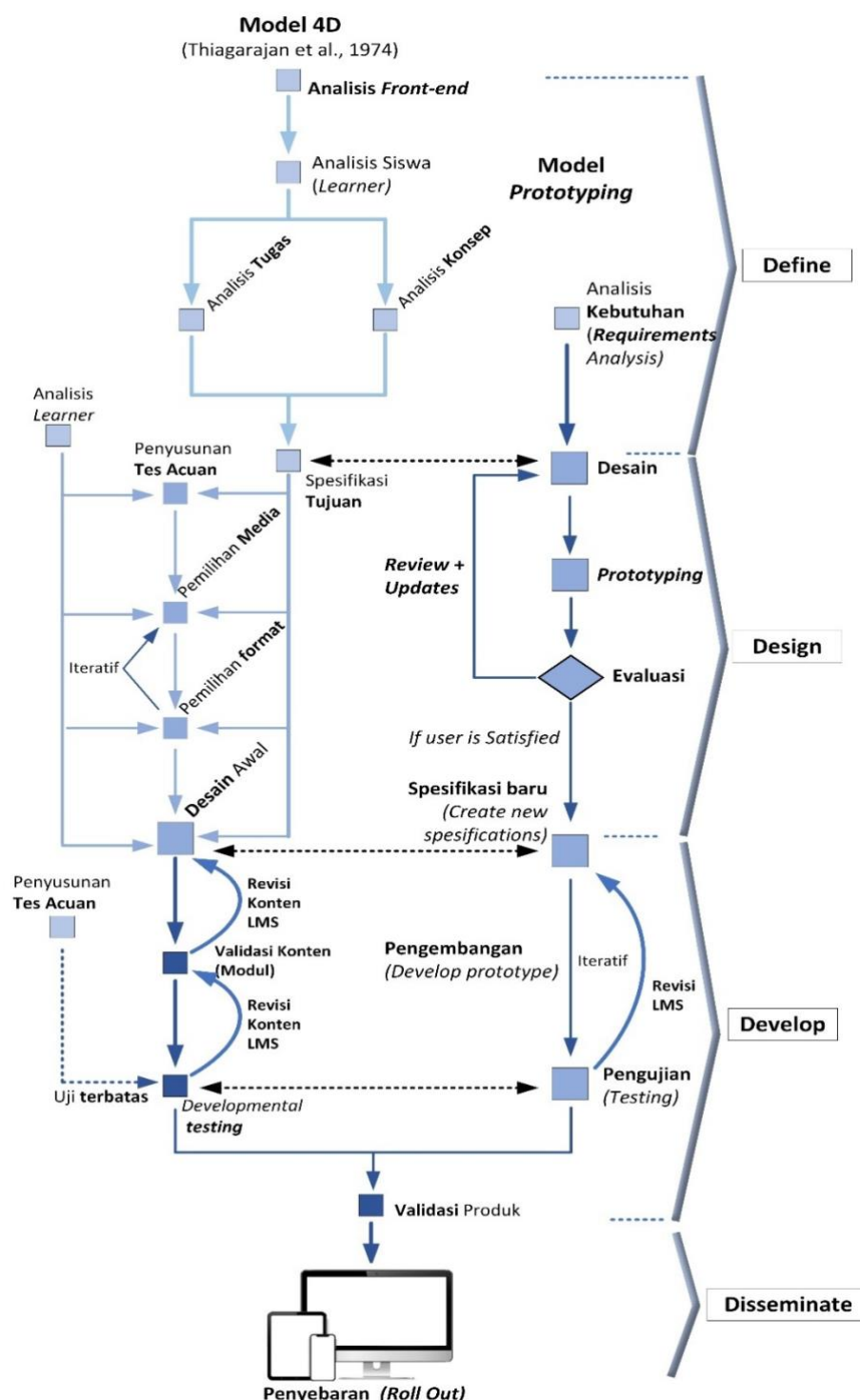


Figure 1. The 4D Development Model is integrated with the Prototyping Model

The Define phase of the 4D model starts with a comprehensive needs assessment to determine the precise demands of the target learners and their learning environment, aiming to clarify the core problems and desired educational outcomes. Building on these insights, the Design phase focuses on crafting a detailed blueprint for the AI-based Learning Management System (LMS), including specifications for its architecture, user interface, learning content, and AI components. This is followed by the Develop phase, where the LMS is constructed through software development, content creation,

and the integration of AI algorithms. Finally, the Disseminate phase involves delivering the completed AI-based LMS to the intended users, ensuring it reaches and benefits the target educational audience.

An initial online survey was administered using Google Forms, collecting responses from a total of 805 participants consisting of secondary school and university students located in Banten, Jakarta, and East Java, Indonesia. This survey served as a crucial instrument in gathering initial data to inform the needs analysis and guide the development of the LMS. Data from the Education Statistics indicates that in the 2023/2024 academic year, the total number of secondary school and undergraduate students in Indonesia reached 23,971,384, consisting of 5,400,167 senior high school pupils and 10,103,503 junior high school pupils. The insights gleaned from the survey and statistical data were instrumental in shaping the objectives and initial design of the AI-based LMS.

Based on these data sources, the Define phase emphasized identifying pedagogical gaps related to students' self-regulated learning (SRL) competencies, particularly in goal setting, time management, sustained attention, and independent help-seeking behaviors, which are critical for success in secondary mathematics learning (Ciptaningtyas et al., 2018; Jin et al., 2023).

This paper primarily focuses on the Define stage, which involves a comprehensive analysis of learner needs, task requirements, and learning objectives. The Define phase included several key activities: front-end analysis, learner analysis, task analysis, and concept analysis.

Front-end analysis focused on identifying persistent challenges in mathematics learning, including limited learner autonomy, fragmented feedback mechanisms, and insufficient personalization in commonly used LMS platforms ("Global Educational Studies Review," 2020). Learner analysis examined students' learning preferences, SRL strategies, motivation levels, and digital readiness, highlighting the need for structured scaffolding to support planning, monitoring, and reflection processes (Maghsudi et al., 2021; Ouyang et al., 2023). Task analysis identified essential mathematical competencies and learning activities that require sustained practice and formative feedback, while concept analysis ensured alignment with curriculum standards and conceptual coherence (Kannan & Zapata-Rivera, 2022).

Rather than emphasizing low-level system implementation, the Define phase conceptualized the LMS architecture as an AI-supported pedagogical ecosystem, in which learner data are used to enable adaptive feedback, learning recommendations, and reflective prompts that align with core SRL principles (goal setting, self-monitoring, and self-evaluation) (Khiat & Vogel, 2022; Chatti et al., 2021).

To clarify how the findings from the Define phase informed the conceptual design of the AI-based LMS, a high-level system architecture is presented to illustrate the pedagogical flow of data and AI-supported learning processes without detailing technical implementation.

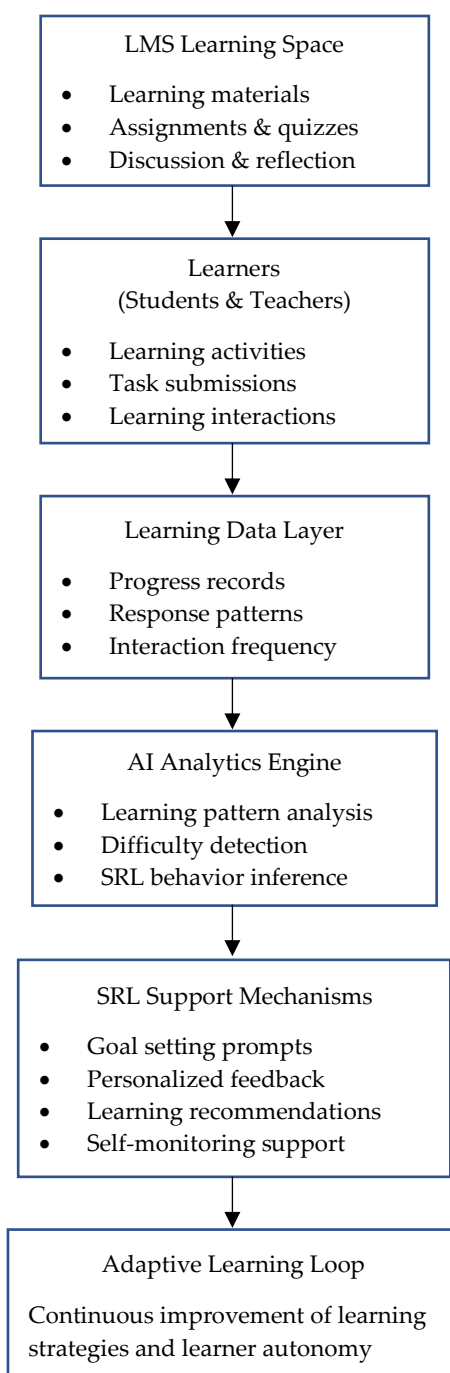


Figure 2. Conceptual Architecture of the AI-Based LMS to Support Self-Regulated Learning

The conceptual architecture presented in Figure 2 provides a pedagogical framework for understanding how learner interaction data can be meaningfully translated into AI-supported learning assistance. To ensure that this conceptual design was grounded in actual learner conditions and instructional needs, empirical data were collected and analyzed during the Define phase to identify prevalent challenges, learning behaviors, and expectations related to AI-assisted learning support in mathematics education. This approach emphasizes the importance of grounding system architecture in evidence-based insights rather than purely technical assumptions. By systematically examining learner experiences, cognitive difficulties, and patterns of engagement, the Define phase enabled the identification of instructional priorities that directly inform the alignment between AI functionalities

and pedagogical objectives. As a result, the conceptual architecture reflects not only technological possibilities but also the contextual realities of mathematics learning and self-regulated learning demands.

Descriptive statistics were used to analyze survey responses in order to identify dominant learner needs, challenges, and expectations regarding AI-assisted learning support. The findings indicated that students experienced difficulties maintaining focus, managing study time, and independently resolving learning obstacles, reinforcing the need for AI features that function as cognitive and metacognitive scaffolds rather than content replacements (Darvishi et al., 2023).

Conceptually, the AI component of the LMS was designed to process aggregated learning interaction data such as task completion patterns, response accuracy, and frequency of help requests to generate personalized learning recommendations and feedback. These processes were framed at a conceptual level to ensure transparency, pedagogical relevance, and alignment with ethical standards in educational data use (Bulut et al., 2024; Demartini et al., 2024).

All learner data were treated with strict confidentiality, anonymized for analysis, and used solely for educational purposes. Ethical considerations, including informed consent, data privacy protection, and the mitigation of algorithmic bias, were integral to the Define phase to ensure responsible AI deployment in educational settings (Rana et al., 2024; Alotaibi, 2024).

Users, including both students and teachers, serve as evaluators from a practical standpoint. Their feedback is essential for assessing user experience, navigation ease, clarity of instructions, and the usefulness of AI-driven features such as the “Ask AI” tool. They help determine how well the system supports actual learning activities and whether it aligns with their expectations and educational needs. Through structured trials, surveys, or interviews, users provide valuable insights that guide iterative refinements of the LMS, ensuring it remains user centered and pedagogically relevant.

In this study, user evaluation was framed primarily as a means of validating pedagogical usability namely, whether AI supported features effectively facilitate SRL processes rather than as a technical performance assessment, which is addressed separately in supplementary technical documentation.

3. FINDINGS AND DISCUSSION

The AI-based LMS was evaluated through a limited system trial involving users who interacted directly with the prototype system. The evaluation aimed to capture users’ perceptions regarding system usability, interface design, perceived usefulness, and its potential role in supporting Self-Regulated Learning (SRL). Data were collected using a structured Likert-scale questionnaire and complemented by qualitative feedback obtained during the trial sessions. To enhance clarity and transparency, the findings are organized into four main components: (1) user demographics, (2) user satisfaction and interface evaluation, (3) perceived usability and SRL support, and (4) qualitative feedback and identified usability issues.

A questionnaire utilizing Likert scales served as the tool for data collection. The results obtained from this questionnaire are evaluated according to the following score interpretations:

Score	%	Interpretation
1	0 - 20	Bad
2	21- 40	Poor
3	41- 60	Moderate
4	61- 80	Good
5	81-100	Excellent

$$\text{Score Interpretation Percentage} = \left(\frac{\sum \text{actual scores}}{\sum \text{maximum possible scores}} \right) \times 100\%$$

The limited trial involved 26 respondents, consisting of both teachers and students who had prior experience with digital learning platforms. Participants engaged with the AI-based LMS prototype in an average of 2–3 usage sessions per user, each session lasting approximately 30–45 minutes, during which they explored learning materials, interacted with AI-supported features, and completed evaluation instruments. The educational background of respondents showed that 53.8% held a master’s degree, 23.1% held a bachelor’s degree, 15.4% held a doctoral degree, and 7.7% were high school graduates. This demographic profile indicates that most participants possessed relatively high digital literacy and pedagogical awareness, which is relevant for interpreting their evaluative judgments regarding system functionality and learning support. The distribution of respondents’ academic qualifications and the types of devices used during the trial are presented in Figure 3.

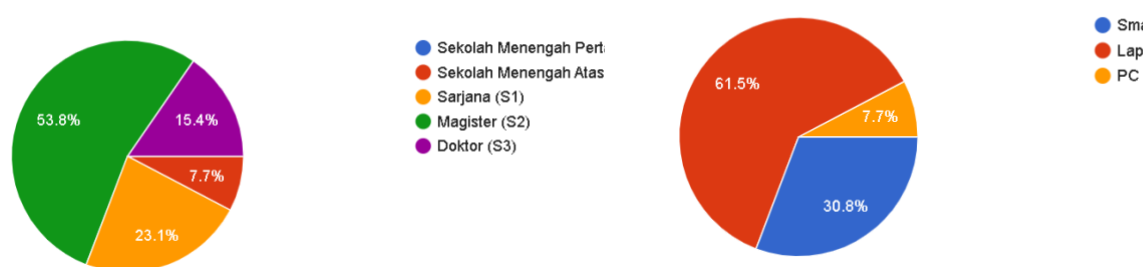


Figure 3. Respondents profile and the Gadgets they utilised for the survey

In terms of device usage, 51.5% of respondents accessed the system using laptops or PCs, while 30.8% used smartphones or mobile devices, confirming the cross-platform accessibility of the LMS prototype. The average scores for user satisfaction were notably high, with those using PCs or laptops scoring 85% and interpreting this as excellent, while mobile device users also rated their experience at 85%. Additionally, the scores for usability were consistent, with both groups achieving excellent ratings. This trend suggests that the majority of respondents are comfortable using portable technology for accessing online surveys, which may enhance participation rates in future research.

The survey’s average ratings show that respondents who used both mobile devices and PCs/laptops were very satisfied. Specifically, users of PCs/Laptops achieved an average score of 85%, which is interpreted as excellent, reflecting a strong positive experience. Additionally, another score of 85% also received an excellent interpretation, while a score of 80% was deemed good, suggesting that there is still room for improvement. On the other hand, mobile device users also reported high satisfaction, with an average score of 85% interpreted as excellent, and two scores of 82.5% also categorized as excellent. This consistent feedback highlights the effectiveness of both platforms in delivering a positive user experience.

In our study, we found that students face several challenges in applying SRL within online learning environments (Jin et al., 2023). Students reported difficulties in maintaining focus, managing time effectively, and seeking help when needed and prefer to ask teachers or friends.

To better understand students’ help-seeking behavior in online learning contexts, respondents were asked about their preferred sources of academic assistance. The distribution of help-seeking preferences is illustrated in Figure 4.



Figure 4. The survey results: Do you prefer to seek help from?

Our AI-based LMS includes a number of crucial elements intended to support SRL in order to overcome these issues: Personalized learning routes: By analyzing student performance data, the AI algorithms generate learning paths that are tailored to each learner's unique learning preferences and speed, thereby facilitating more focused learning experiences, adaptive pacing, and improved alignment with individual self-regulated learning needs over time.

Intelligent feedback: The method highlights students' strengths and weaknesses by giving them immediate feedback on their work.

Self-monitoring tools: With the help of integrated self-monitoring tools, students may establish objectives, keep tabs on their learning tactics, and measure their progress.

Because AI can analyze large datasets and provide meaningful insights, it offers instructors a new way to get a thorough picture of their pupils.

The creation of an AI-based learning management system is a big step in the direction of giving secondary school pupils more efficient and interesting arithmetic instruction. Teachers may make data-driven decisions and adapt their teaching methods thanks to AI-driven analytics that provide insights into student performance and engagement. Teachers may spend more time on teaching and providing tailored student assistance by automating repetitive operational tasks and simplifying data analysis (Çelik et al., 2022).

Students generally prefer to seek help from teachers or peers rather than relying solely on AI-based systems. This finding reinforces previous research suggesting that AI should serve as a complementary support, not a substitute for human interaction (Darvishi et al., 2023).

Discussion

This study aimed to explore the design and initial evaluation of an AI-based Learning Management System (LMS) developed to support Self-Regulated Learning (SRL) in mathematics learning. The discussion section critically interprets the findings by linking them to the research questions and situating them within existing literature on AI-supported learning environments and SRL frameworks.

In relation to the first research question concerning user perceptions of system usability and interface quality, the findings indicate a high level of user satisfaction, as reflected in the mean scores for visual design, navigation clarity, and overall system comfort. These results suggest that the interface design of the AI-based LMS was perceived as accessible and user-friendly by both teachers and students. This finding aligns with prior studies emphasizing that intuitive interface design is a key

prerequisite for effective adoption of AI-supported educational technologies (Çelik et al., 2022; Jin et al., 2023).

Importantly, the consistently high satisfaction scores across different device types indicate that the system's responsive design effectively accommodates diverse access contexts, which is particularly relevant in secondary education settings where learners frequently rely on mobile devices. Rather than making broad claims about technological transformation, the present findings support a more measured conclusion that well-designed AI-based systems can enhance usability and learner comfort when appropriately aligned with users' needs and contexts, as also noted by Darvishi et al. (2023).

With respect to the second research question regarding the perceived usefulness of the AI-based LMS in supporting SRL, the findings demonstrate that users viewed the system as a supportive learning scaffold. Participants reported that AI-supported feedback and personalized learning recommendations assisted them in monitoring progress and identifying learning gaps, which are core components of SRL processes. This result is consistent with SRL theory, which emphasizes goal setting, self-monitoring, and reflection as central mechanisms of autonomous learning (Chatti et al., 2021).

However, rather than suggesting that AI alone can foster fully autonomous learners, the findings indicate that AI functions more effectively as a complementary support tool, augmenting existing pedagogical practices rather than replacing teacher guidance. This interpretation is supported by respondents' preference for seeking help from teachers and peers, as illustrated in the findings, reinforcing previous research that highlights the social and instructional dimensions of effective learning regulation (Jin et al., 2023; Darvishi et al., 2023).

The qualitative feedback further enriches the interpretation of the quantitative results. Users positively evaluated the immediacy of AI-generated feedback and the system's ability to provide personalized learning paths, which contributed to more structured independent learning experiences. At the same time, users identified specific usability issues, such as the need for clearer explanatory feedback and improved navigation consistency, particularly when accessing AI assistance features. These findings underscore the importance of iterative, user-centered design in AI-based educational systems, as emphasized by Çelik et al. (2022).

Rather than making speculative claims about the transformative potential of AI in education, the present study provides empirical evidence of modest yet meaningful benefits, particularly in enhancing usability and supporting selected aspects of SRL. This restrained interpretation aligns with recent literature cautioning against overgeneralization of AI impacts without robust empirical validation (Demartini et al., 2024; Bulut et al., 2024).

From a pedagogical perspective, the findings also highlight the importance of aligning AI-based system design with established instructional principles rather than relying solely on technological novelty. The positive user responses toward AI-supported feedback and personalized learning pathways suggest that the system's value lies in its ability to operationalize pedagogical strategies, such as formative assessment and guided practice, within a digital environment. This supports the argument that AI effectiveness in education depends largely on how well it is embedded within instructional design frameworks, rather than on the sophistication of the algorithm alone (Çelik et al., 2022; Chatti et al., 2021).

Furthermore, the observed preference for human-mediated assistance over exclusive reliance on AI underscores the continued relevance of teachers in AI-enhanced learning environments. While the AI-based LMS provided timely feedback and learning recommendations, users still perceived teachers as essential facilitators of conceptual understanding and motivation. This finding reinforces existing literature that positions AI as an assistive tool that complements, rather than substitutes, pedagogical interaction and social learning processes (Jin et al., 2023; Darvishi et al., 2023).

The findings also suggest that AI-supported LMS platforms may contribute to reducing certain self-regulation challenges commonly encountered in online learning, particularly those related to learning organization and task monitoring. However, difficulties associated with sustained focus and independent problem-solving were still reported by users. This indicates that while AI can support

selected dimensions of SRL, it does not automatically address all aspects of learner autonomy. Such results caution against overly generalized claims regarding AI's capacity to fully transform learning behaviors without sustained instructional scaffolding and learner training (Bulut et al., 2024).

In addition, the qualitative feedback regarding usability issues provides valuable insight into areas where AI-based systems require further refinement. Requests for clearer explanatory feedback and more consistent navigation structures suggest that usability challenges can limit the pedagogical impact of AI features if not adequately addressed. These findings emphasize the necessity of continuous evaluation and iterative improvement during system development, particularly when integrating AI into educational contexts where cognitive load and clarity of instruction are critical factors (Demartini et al., 2024).

Despite these promising findings, several limitations must be acknowledged. First, the study involved a relatively small sample size, which limits the generalizability of the results. The participants were drawn from a limited trial context and largely consisted of users with relatively high digital literacy, which may have influenced their positive evaluations of the system. Second, the scope of the study was restricted to the Definition stage of the development model, focusing primarily on needs analysis, initial design, and early usability evaluation. As a result, the findings do not capture long-term learning outcomes or sustained changes in students' SRL behaviors over time. Third, the system trial was conducted over a relatively short testing period, with limited user interaction sessions. This short duration may not fully reflect how users would adapt to and integrate the AI-based LMS into their regular learning routines. Consequently, claims regarding long-term effectiveness or behavioral transformation were intentionally avoided.

Future studies are encouraged to involve larger and more diverse samples, extend the implementation to subsequent development stages, and conduct longitudinal evaluations to better assess the sustained impact of AI-supported LMS on SRL and academic performance. Additionally, future research may explore comparative designs to examine differences between AI-supported and non-AI learning environments, thereby strengthening causal inferences.

Overall, the discussion demonstrates that the AI-based LMS shows potential as a supportive educational tool when grounded in pedagogical theory and evaluated through empirical evidence, while also acknowledging its current limitations. This balanced interpretation strengthens the credibility of the study and aligns it with contemporary scholarly discourse on responsible AI integration in education (Demartini et al., 2024; Bulut et al., 2024).

4. CONCLUSION

This study concluded that the Define phase of the 4D model provides a critical foundation for developing an AI-based Learning Management System (LMS) designed to support Self-Regulated Learning (SRL) in secondary mathematics education. The findings revealed that students struggle with key SRL components such as time management, focus, and self-monitoring, and they positively perceive AI-supported features—such as personalized feedback, goal-setting tools, and adaptive learning paths—as potentially helpful in addressing these challenges. However, users emphasized that AI should act as a supportive complement to, rather than a replacement for, teacher interaction. Despite these contributions, the study is limited by its focus solely on the Define phase, its use of a relatively small sample in the system trial, and the short duration of LMS interaction, which restricts conclusions about long-term effectiveness. Future research should implement the subsequent phases of the 4D model—Design, Develop, and Disseminate—and conduct large-scale, longitudinal, and experimental studies to evaluate the actual impact of the AI-based LMS on SRL development and mathematics achievement across diverse educational settings.

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