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The effect of scaffolding-based digital instructional media on higher-order thinking skills

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Abstract

Higher-order thinking skills (HOTS) are widely recognized as an essential for addressing the challenges of modern life. As a result, numerous educational systems prioritize the development of students' HOTS. While previous studies have explored the impact of scaffolding on HOTS through either paper-based methods or gamified approaches, this experimental study seeks to examine the effects of scaffolding-based digital instructional media delivered via web-based instruction—specifically, the platform Madmatics—on students' HOTS. The participants in this study consisted of 64 junior high school students, with 32 students utilizing the scaffolding-based digital media for mathematics learning, while the remaining 32 students engaged in traditional paper-and-pencil exercises in a regular classroom setting. The findings reveal that students exposed to scaffolding-based digital instructional media demonstrated significantly greater improvements in HOTS compared to those in the conventional learning environment. Three key factors may explain this enhancement: the scaffolding guided students through problem-solving tasks, the media provided immediate feedback and explanations to facilitate learning, and the digital platform increased student engagement and motivation to solve mathematical problems.

Keywords: Digital, Higher Order Thinking Skills, Instructional Media, Scaffolding, Web-Based

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Numerous studies and policies have emphasized that in the modern era, possessing more than just conceptual and procedural knowledge is imperative. The ability to apply knowledge effectively is deemed more valuable than simply mastering it conceptually, as it represents a critical competency necessary for addressing real-life challenges (OECD, 2003; 2013; 2019). This competency encompasses a wide array of cognitive skills, including reasoning, mathematical representation, critical thinking, and problem-solving (OECD, 2003; 2013; Ozkale & Erdogan, 2022). As modern life becomes increasingly complex, the range of required competencies continues to expand and evolve. Beyond the ability to apply knowledge, other lifelong learning skills—such as functional skills, learning strategies, and critical thinking—are equally essential for navigating the dynamic and ever-changing demands of contemporary society (Ananiadou & Claro, 2009). These competencies are closely aligned with the concept of 21st-century skills (Ananiadou & Claro, 2009; Larson & Miller, 2011; van Laar et al., 2017).

The Assessment and Teaching of 21st Century Skills (ATC21S) project identified four critical domains necessary for addressing the complex demands of the modern era: ways of thinking, ways of working, tools for working, and living in the world (Griffin & Care, 2015). "Ways of thinking" refers to the capacity for higher-order cognitive processes, including creativity, innovation, critical thinking, decision-making, problem-solving, learning to learn, and metacognition. "Ways of working" pertains to how individuals collaborate and communicate effectively. "Tools for working" involve competencies in information literacy and ICT literacy. "Living in the world" encompasses skills related to citizenship, life and career management, as well as personal and social responsibility. Excluding affective components such as citizenship and responsibility, these 21st-century skills, along with mathematical literacy, can broadly be understood as components of higher-order thinking skills.

Miri et al. (2007) describe Higher-Order Thinking Skills (HOTS) as a mode of thinking that is non-algorithmic and complex, often yielding multiple solutions. Traditionally, HOTS have been associated with Bloom's Taxonomy, where skills such as analyzing, evaluating, synthesizing, and creating are classified as higher-order cognitive processes (Lee & Choi, 2017; Lewis & Smith, 1993; Lombardi, 2023; Miri et al., 2007). However, a broader interpretation of HOTS extends beyond Bloom's framework. Schraw and Robinson (2011) proposed four key components of HOTS: reasoning (inductive and deductive), argumentation (the generation and evaluation of evidence and arguments), metacognition (reflecting on and regulating one’s thinking), and critical thinking in problem-solving contexts. Similarly, Yen and Halili (2015) view HOTS as an umbrella term encompassing various forms of reflective thinking, including creative thinking, problem-solving, decision-making, and metacognitive processes. HOTS are also linked to skills such as problem posing, systematic thinking, and complex reasoning (Myelnawan & Setyaningrum, 2023; Zohar & Dori, 2003; Zoller, 2002). In light of these diverse definitions, this study conceptualizes HOTS as encompassing analytical thinking, evaluative thinking, problem-solving, and problem-posing abilities.

The development of students' HOTS has garnered significant attention from researchers. Studies on fostering HOTS range from exploring instructional methods (e.g., Apino & Retnawati, 2017; Sa'dijah et al., 2021) to examining assessment approaches (e.g., Azid et al., 2022). In their work, Apino and Retnawati (2017) developed instructional activities aimed at enhancing HOTS by integrating non-routine problem-solving tasks and promoting students' active construction of knowledge. In a survey, Sa'dijah et al. (2021) found that most teachers employed decision-making strategies, which involved presenting problems, prompting students to solve them, checking their work, and generating new ideas to facilitate HOTS development. From an assessment perspective, Azid et al. (2022) demonstrated that integrating HOTS into school-based assessments positively influenced students' mathematics achievement. Beyond general teaching strategies, scaffolding—an instructional technique widely used in education—has also been extensively studied for its role in improving students' mathematics performance, including HOTS. A decade ago, Bakker et al. (2015) reviewed 243 articles published in high-quality journals that explored the use of scaffolding to support student learning.

Scaffolding refers to the support provided to students to help them achieve learning objectives that are initially beyond their independent capabilities, by guiding them in coordinating and applying their existing knowledge (Wood et al., 1976). This support can take various forms, including instructional tools, assignments, guiding questions, and instructions, all of which aim to direct, broaden, or enhance students' abilities throughout the learning process. Tropper et al. (2015) emphasize that scaffolding involves three key stages. The first stage is 'contingency,' which involves providing responsive and adaptive support tailored to the student's progress. The second stage, 'fading,' refers to the gradual withdrawal of this support as students demonstrate improved performance. The final stage, 'transfer of responsibility,' entails shifting the responsibility for learning from the teacher to the students, enabling them to take ownership of their learning process. Consequently, scaffolding is designed to be temporary, with the support decreasing as students gain competence (Azevedo et al., 2004, 2005; Bakker et al., 2015). A fundamental principle of scaffolding is the dynamic interaction between the teacher and students, ensuring that assistance is proportionally reduced as students' progress towards independence (Baxter & Williams, 2010). Over-reliance on scaffolding can lead to excessive dependence on the teacher and hinder the development of students' HOTS. Therefore, scaffolding should be gradually reduced as students' learning improves. As highlighted by Muhonen et al. (2016) and van de Pol et al. (2010), once scaffolding is removed, students are expected to regulate and manage their learning autonomously, fostering the development of their cognitive processes.

Baxter and Williams (2010) identified two main types of scaffolding: social scaffolding and analytic scaffolding. Social scaffolding aims to help students collaborate effectively, often involving activities where students explain their thinking and attempt to comprehend the perspectives of others. This type of scaffolding supports peer interaction and the development of communication skills. Analytic scaffolding, on the other hand, refers to the support provided by teachers or instructional media to enhance students' understanding of mathematical tasks. This includes the use of manipulatives, models, representations, explanations, or justifications that facilitate comprehension.

Another distinction in scaffolding types is between fixed and adaptive scaffolding (Azevedo et al., 2004; Chang et al., 2001). Fixed scaffolding is a static form of support that does not change in response to individual students' abilities or learning needs. In contrast, adaptive scaffolding is dynamic, adjusting to align with students' varying levels of understanding and learning requirements. To provide effective adaptive scaffolding, teachers must continuously assess and diagnose students' progress and difficulties, ensuring that the support they offer is tailored to meet evolving learning needs.

In addition to the previously mentioned types of scaffolding, Bakker et al. (2015) analyzed 21 studies and identified a range of scaffolding techniques used in mathematics classrooms, such as dialogic instruction, scaffolded conversations with manipulatives, the use of meta-language frameworks, collective argumentation, and ICT-supported scaffolding. Their study highlighted that scaffolding is no longer solely dependent on the teacher's role; instead, it has evolved through the integration of technology. The use of digital tools not only enhances engagement with visually appealing and interactive features, which can motivate students to learn, but also provides immediate feedback that helps students correct mistakes and track their progress. Puspitaningrum and Wijaya (2023) emphasized that such immediate feedback from digital media enables students to promptly address errors and observe improvements in their learning process.

Digital technology has become a widely adopted tool for supporting students' learning through scaffolding. Sun et al. (2011) developed digital scaffolds embedded within games to guide students' problem-solving behaviors. Their study found that implementing "frustration control" in these games helped reduce feelings of being stuck, enhancing the students' comfort and perseverance. Similarly, Chang and Yang (2023) explored the effects of integrating scaffolding into digital game-based learning environments. They discovered significant interactive effects between scaffolding and students' cognitive styles on learning outcomes, emotional engagement, and cognitive load. However, Chang and Yang (2023) also underscored the importance of considering students' individual learning styles when selecting and applying various scaffolding techniques in digital game-based learning environments.

As previously mentioned, technology offers immediate feedback and enhances students' comfort in the learning process. Given the potential of digital scaffolding in education, this study aims to investigate the effects of scaffolding-based instructional media on students' higher-order thinking skills

(HOTS). Unlike previous studies that utilized game-based scaffolding (e.g., Chang & Yang, 2023; Sun et al., 2011) or mathematics applications presenting problems in a single mode—either offline or online (Dove & Hollenbrands, 2014)—this research employs a web-based instructional media designed for scaffolding, which can be used in both online and hybrid learning environments.

This study implements fixed scaffolding at multiple levels. At the initial level, scaffolding is provided in the form of guiding questions that decompose complex problems into simpler, more manageable tasks, making them easier for students to solve. By addressing these simpler questions, students engage in the necessary steps to tackle more complex problems, deepening their understanding simultaneously. To prevent over-reliance on guiding questions, which could impede the development of HOTS, subsequent scaffolding levels gradually reduce the number of guiding questions. This approach follows the principles outlined by Muhonen et al. (2016) and van de Pol et al. (2010), who advocated for fade-out scaffolding to promote students' independent learning. A detailed description of the technology-supported scaffolding developed and implemented in this study can be found in the method section, specifically in the intervention program.

METHODS

Research Design

This study utilized a quasi-experimental approach with a posttest-only nonequivalent groups design. The posttest-only control group design was selected as the participants belonged to groups with comparable mathematics performance, as determined by their scores in regular assessments administered by teachers. Additionally, employing a posttest-only design helped eliminate the potential influence of testing effects, where students' performance on a test may improve simply due to prior exposure to similar assessments. The research design comprised two groups: a control group and an experimental group.

All students across both groups were instructed by the same teacher and were provided with identical learning materials and mathematics problems. The learning activities for both groups included discussions of the learning material, completion of exercises, and quizzes for assessment purposes. The primary distinction between the groups was that students in the experimental group utilized the Madmatics platform, whereas those in the control group did not (see Figure 1). A detailed explanation of the intervention program is provided in the sub-section titled "Intervention Activity."

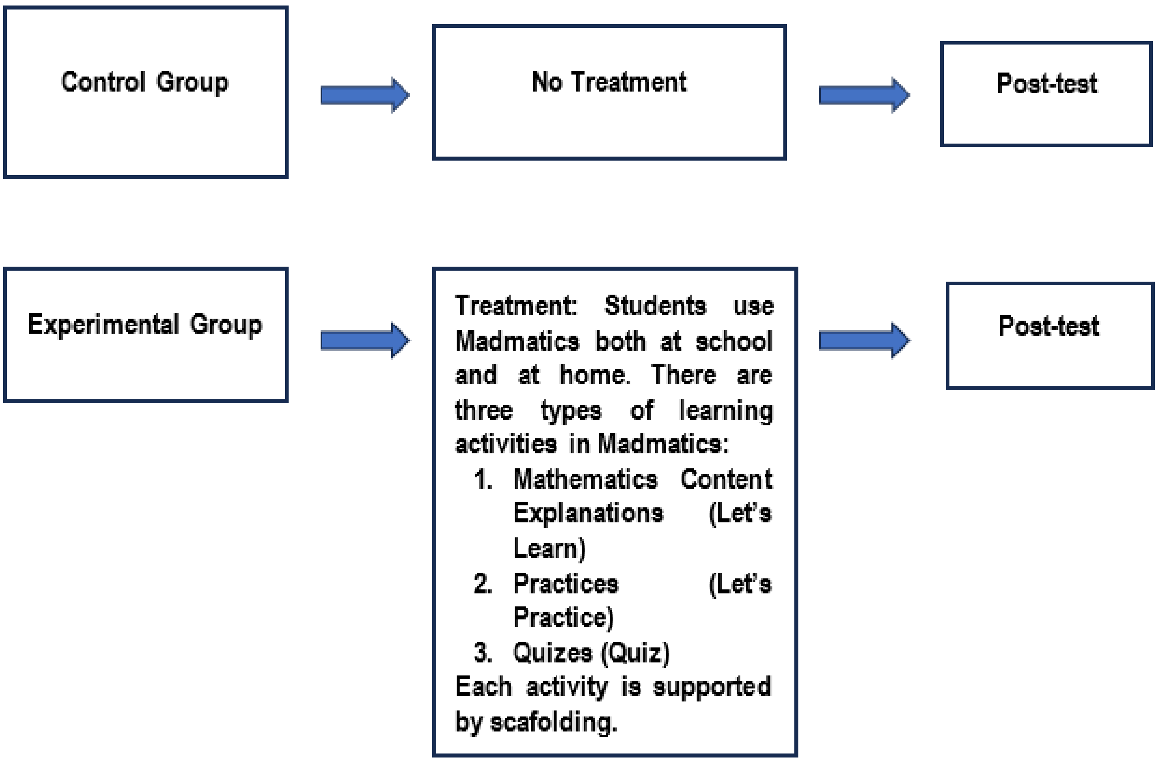

Figure 1. Research design

Participants

The study was intentionally conducted in an urban area, chosen for its access to essential facilities such as a computer laboratory and reliable internet connectivity. Additionally, this location was selected because a majority of the students demonstrated mid-level digital skills, thereby representing a spectrum of low to high proficiency. A school was randomly chosen from this area, which was classified as having a medium level of student performance in mathematics. Within the school, there were 250 eighth-grade students (approximately 14 years old) distributed across eight classes. From these classes, two were randomly selected to participate in the study, with each class consisting of 32 students. One class was designated as the experimental group, while the other served as the control group.

Intervention Activity

The intervention activity for the experimental group involved a scaffolding-based instructional media named 'Madmatics,' specifically designed for this study. The integration of Madmatics into the learning activities allowed students to access educational materials and engage with exercises through a web-based application (see Figure 2). This digital format was selected because paper-based scaffolding, which breaks down tasks into sets of guiding questions, proved to be neither effective nor practical. By utilizing a web-based scaffolding approach, the types of support provided could be automatically tailored to meet each student's individual needs and learning progress. Additionally, Madmatics offers a repository for storing students' work, making it suitable for homework assignments while also enabling the tracking of students' learning progress over time.

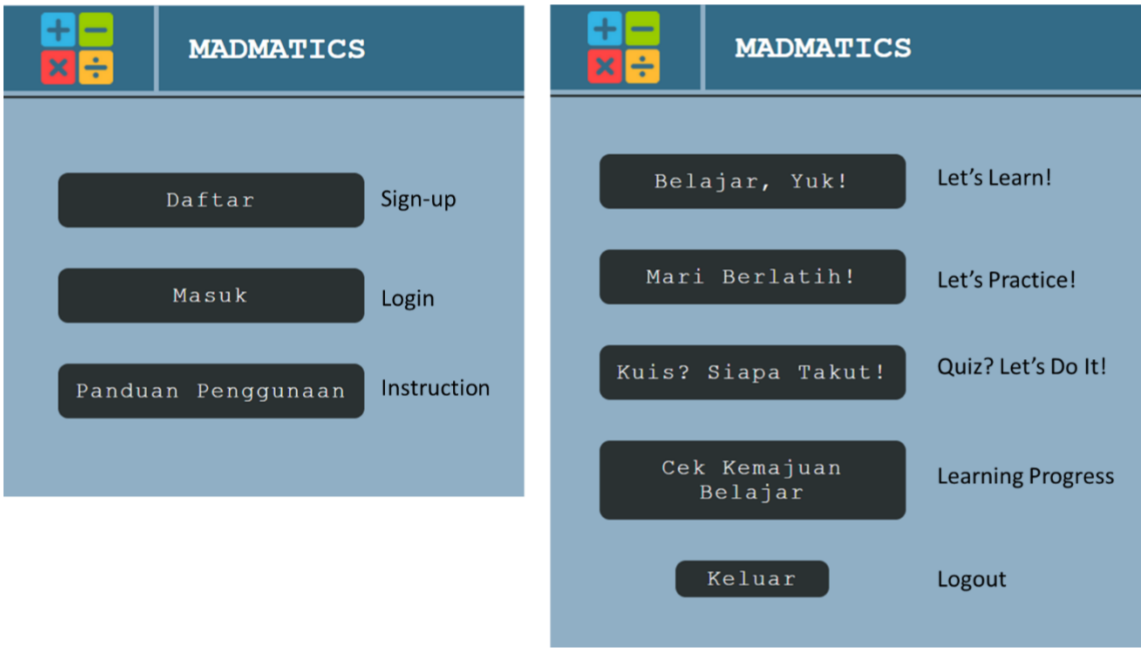

Figure 2. Homepage (left) and scaffolding options (right)

To utilize Madmatics, students first need to register an account by clicking "Daftar" (Sign-up). Once they have created their accounts, they can log into the system by selecting "Masuk" (Login). After logging in, students can choose from three levels of scaffolding: 1. Belajar, Yuk! (Let's Learn!); 2. Mari Berlatih! (Let's Practice!); and 3. Kuis? Siapa Takut! (Quiz? Let's Do It!).

Madmatics is designed to foster students' independent learning, with scaffolding seamlessly integrated into the platform. The support is offered in the form of guiding questions. To prevent students from becoming overly reliant on this scaffolding, three distinct levels are provided, each varying in the amount of guidance offered. The characteristics of these scaffolding levels are summarized in Table 1.

Table 1. Differences between each scaffolding levels

Features	"Let's Learn!"	"Let's Practice!"	"Quiz? Let's Do It"
Number of guiding questions	Maximum	Medium	Minimum
Guiding questions type	Direct questions about the steps required to solve the tasks	Hints and reflective questions that need further thinking	Only serve as a trigger
Correct answer and its explanation	Always	Only provided when students give incorrect answer	Only correct answer without an explanation

The first level, "Let's Learn!", is designed to give students the opportunity to explore the learning materials in depth. At this level, students can access instructional content, enhancing their understanding of the subject matter. Additionally, they can learn problem-solving techniques by reviewing worked examples, which serve as models for tackling similar challenges (see Figure 3). This foundational level aims to build students' comprehension and confidence as they begin their learning journey.

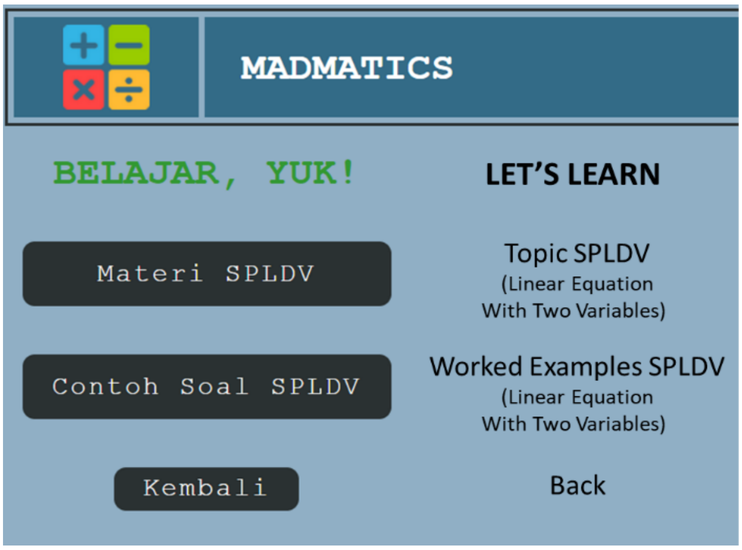

Figure 3. Main menu in "Let's Learn!"

The "Let's Learn!" level features a range of problems that vary in complexity, from easy to challenging. This level incorporates the most extensive scaffolding compared to the other two levels, as its primary goal is to help students establish a solid foundation of knowledge. The guiding questions provided at this stage are structured as direct instructions, aimed at facilitating students' understanding and engagement with the material (see Figure 4). By offering substantial support, this level encourages students to actively construct their knowledge and enhances their readiness for subsequent learning activities.

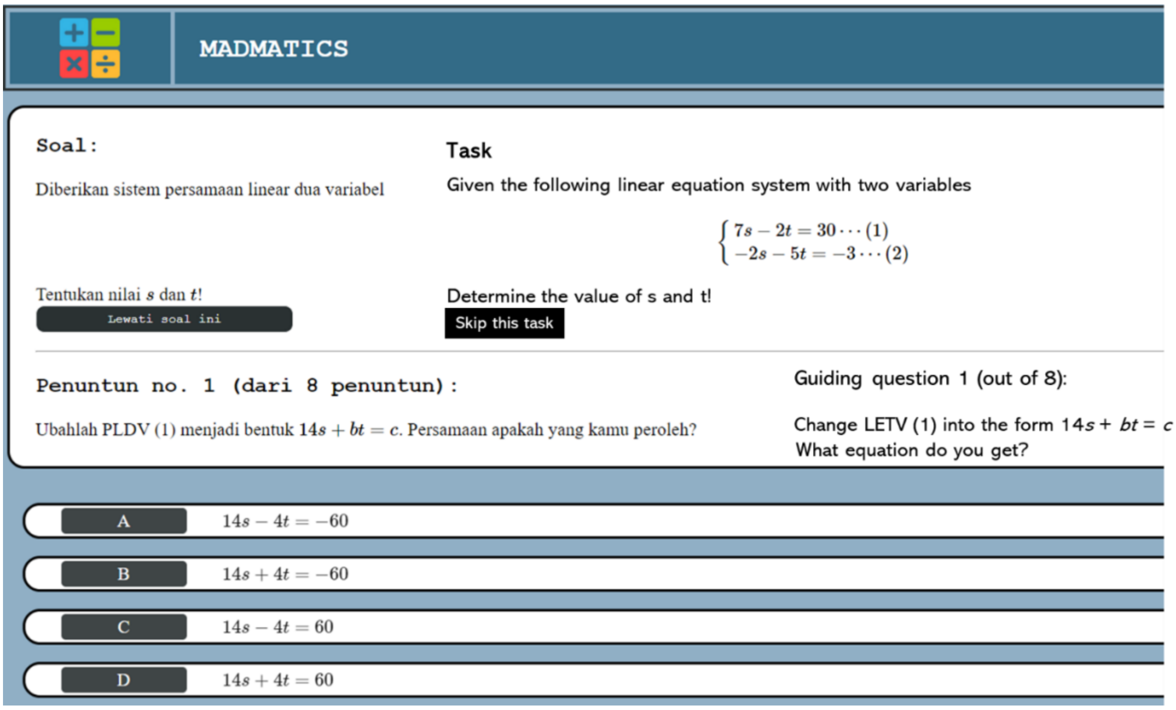

Figure 4. Scaffolding in "Let's Learn!"

The "Let's Practice!" level serves as an opportunity for students to engage in exercises following their learning of the material. In this stage, the support provided to students is intentionally reduced to foster greater independence. While guiding questions remain available, they are less detailed compared to those in the previous level. Instead of direct questions, the guidance consists of hints and reflective prompts that encourage deeper thinking and reasoning (see Figure 5). This approach aims to challenge students to apply their knowledge more autonomously, enhancing their problem-solving skills and critical thinking abilities.

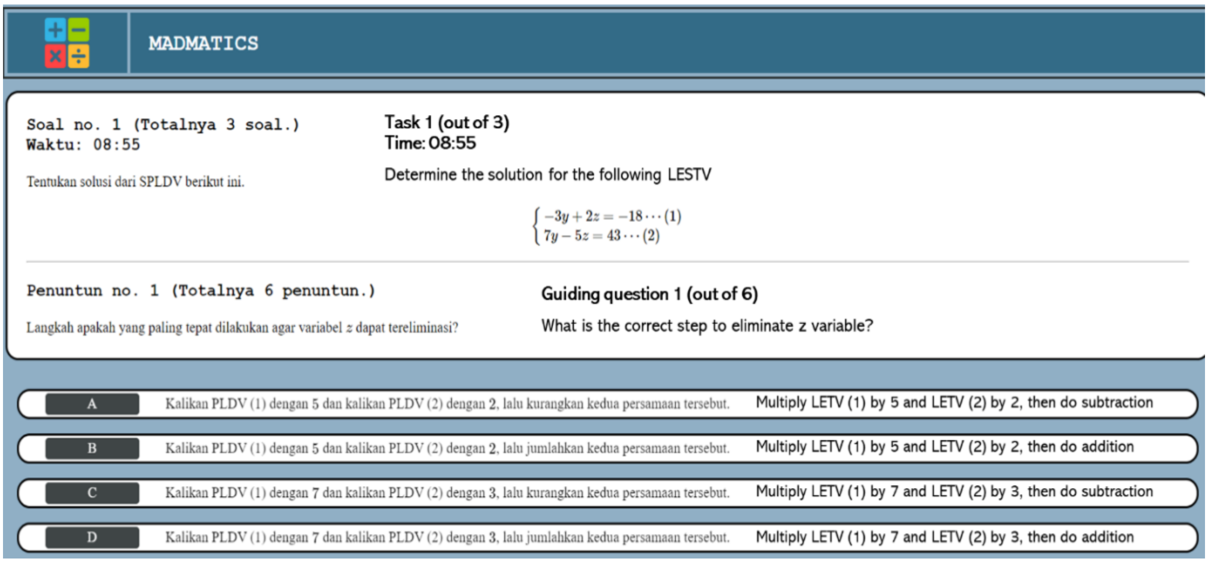

Figure 5. Scaffolding in “Let’s Practice!”

When engaging with the guiding questions, students are required to evaluate the choices presented to them. This type of questioning not only assists students in identifying mistakes in their work but also aids in recalling and remembering the necessary steps involved in problem-solving. Such activities are instrumental in developing students' analytical skills, which is a crucial component of HOTS. If a student answers a task incorrectly, they receive feedback that includes the correct answer along with a detailed explanation before proceeding to the next task (see Figure 6). These comprehensive explanations are designed to enhance students' learning experiences, enabling them to recognize their errors and understand the strategies needed to rectify them.

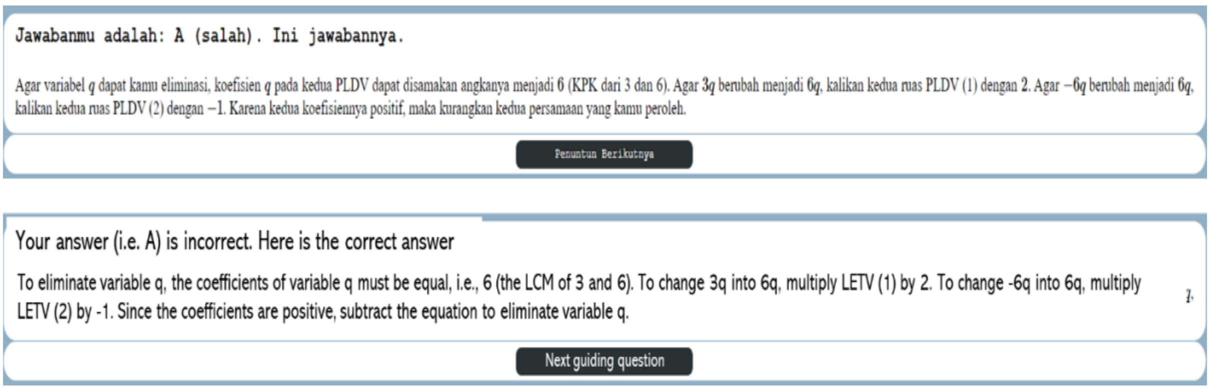

Figure 6. Feedback in “Let’s Practice!”

There are notable differences between these two levels of scaffolding, particularly in terms of the quantity of guiding questions and the nature of feedback provided. In the "Quiz? Let’s Do It!" level, students do not receive hints; instead, the guiding questions serve merely as directions for tackling problems that require higher-order thinking skills (HOTS). Through their engagement with these HOTS questions in the preceding levels, students should cultivate the ability to independently ponder guiding questions.

Regarding feedback, there is a distinct contrast between the levels. In "Let's Practice," when a student answers incorrectly, they receive detailed explanations to aid their understanding. Conversely, in "Quiz? Let's Do It!" only the correct answer is provided (see Figure 7). This approach is intentionally designed to encourage students to engage in self-reflection and critical thinking, prompting them to contemplate the methods and reasoning necessary to arrive at the correct answers independently.

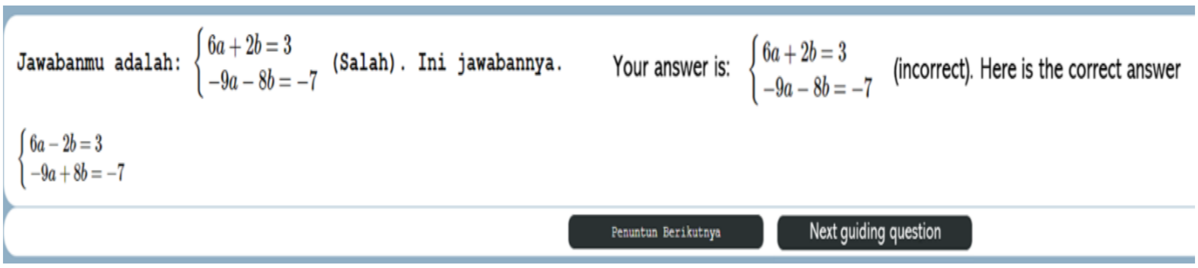

Figure 7. Feedback in "Quiz? Let's Do It!"

The primary component of Madmatics that enhances students' HOTS is the strategic use of scaffolding in question design. This scaffolding is implemented through guiding questions that decompose complex HOTS problems into smaller, more manageable components at each level. To effectively train students in HOTS—particularly in the domains of analysis and evaluation—Madmatics encourages them to approach problems incrementally, focusing first on breaking down the questions rather than attempting to solve them in their entirety.

By facilitating this process, students are trained to sift through relevant information and apply it effectively to address the problems presented. The ability to identify and analyze the different parts of a problem not only aids students in grasping what is being asked in a HOTS question but also equips them with the necessary skills to tackle the questions more effectively. This approach fosters a deeper understanding and enhances their problem-solving capabilities, ultimately leading to improved outcomes in HOTS assessments.

Data Collection Instruments

The primary objective of this study was to examine the impact of scaffolding-based digital instructional media, specifically Madmatics, on students' HOTS. To achieve this, a post-test consisting of six HOTS problems was administered to assess students' proficiency in these skills. The test items were aligned with the upper three levels of Bloom's Taxonomy (Lee & Choi, 2017), which include the cognitive processes of analysis, evaluation, and creation. Each of these levels was represented by two test items, ensuring a comprehensive evaluation of students' HOTS capabilities. Table 2 provides a summary of the indicators for HOTS along with the corresponding test items utilized in the assessment.

The quality of the assessment instrument was evaluated through its validity and reliability. Validity was measured using the Scale Level Content Validity Index (S-CVI), which yielded a score of 0.83, indicating that the instrument was considered valid (Yusoff, 2019). Regarding reliability, the instrument demonstrated a satisfactory level of reliability, with a Cronbach's Alpha score of 0.78 (Kaplan et al., 1984). These metrics confirm that the instrument is both valid and reliable for assessing students' higher-order thinking skills.

Table 2. Description of test items

Cognitive Level	Description of Level	Description of Test item
Analyze	Breaking down information into smaller parts and finding evidence to support generalization	The test item provided an example of an incorrect solution to a linear equation system with two variables. Students were asked to identify and analyze the mistake made in the given solution. Furthermore, students were asked to revise the given solution into the correct solution.
	Identifying and examining correct information	The test item provided a situation which contained correct and incorrect information. Students were asked to identify the incorrect information.
Evaluate	Justifying a decision with reasonable argument	The test item provided a linear equation system with two variables. Students were asked to determine the appropriate method – i.e. elimination, substitution, or mixed – to solve the linear equation system. Students were also asked to justify their choice.
	Evaluating whether a contextual problem can be modelled mathematically	The test item provided a contextual problem and students were asked to evaluate whether the problem could be solved by using linear equation with two variables.
Create	Producing new or original work	The test item was in the form of problem posing, i.e. students were asked to generate a word problem which suited certain criteria.
	Devising a plan to solve open-ended problems	The test item provided a number of game situations. Students were asked to devise a plan to win the game

Hypothesis and Data Analysis

The hypothesis of this research posits that the use of Madmatics positively influences students' HOTS. The data collected from the study were analyzed quantitatively. Initially, students' responses were scored, and descriptive statistics were employed to provide a comprehensive overview of their HOTS performance. To evaluate the effect of Madmatics on students' HOTS, the Mann-Whitney U-test was utilized, as the data did not conform to a normal distribution. This non-parametric test is appropriate for comparing the medians of two independent groups, allowing for an assessment of the effectiveness of the scaffolding-based instructional media on students' cognitive abilities.

RESULTS AND DISCUSSION

During the intervention period, students in the experimental group utilized Madmatics primarily for three activities: practice exercises, homework assignments, and quizzes. In contrast, the control group did not engage with Madmatics during their learning activities. However, the tasks assigned to both groups were comparable in terms of type and complexity. One significant advantage of using Madmatics was the immediate feedback mechanism, which allowed students to verify their answers for both guiding and main questions. The importance of learning from mistakes is well-documented (Cherepinsky, 2011; Henderson & Harper, 2009; Yerushalmi & Polingher, 2006), and timely feedback is crucial for students to identify their weaknesses and address them effectively (Borkowski et al., 1990; Zimmerman, 1990).

As previously mentioned, Madmatics features three levels of scaffolding, with the amount of guidance decreasing as students' progress to higher levels. This design enables students to transition from lower to higher levels of scaffolding as they develop sufficient skills and understanding. Consequently, this gradual reduction in support fosters students' independence in problem-solving, ultimately enhancing their HOTS.

The post-test results indicate a notable difference in HOTS performance between students in the experimental group and those in the control group. Specifically, students in the experimental group demonstrated superior overall performance in HOTS compared to their control group counterparts. However, an analysis of the results according to the levels of Bloom's Taxonomy revealed distinct patterns.

For the experimental group, the mean score for the "evaluate" level was the lowest, while the scores for the "analyze" and "create" levels were relatively similar. Conversely, students in the control group achieved the highest scores at the "evaluate" level, with comparable scores for the "analyze" and "create" levels. Despite these variations, both groups exhibited relatively similar scores in their evaluation abilities. Notably, students in the experimental group outperformed those in the control group in the "analyze" and "create" levels. Table 3 provides a summary of the descriptive statistics for the test results.

Table 3. Description of test items

Measures	Experimental Group	Control Group
Mean overall score	66.23	54.96
SD	22.48	18.64
Mean score for 'analyze' level	11.55	8.55
SD	3.64	4.59
Mean score for 'evaluate' level	9.69	10.35
SD	5.14	4.10
Mean score for 'create' level	11.88	8.58
SD	6.60	5.46

To draw a general conclusion regarding the impact of the scaffolding-based digital instructional media "Madmatics" on students' higher-order thinking skills (HOTS), a Mann-Whitney U-Test was conducted, given that the distribution of students' test scores was not normal. This inferential statistical test validated the findings from the descriptive statistics. The overall post-test results revealed that students utilizing Madmatics exhibited significantly better HOTS than their peers who learned mathematics without the use of Madmatics, with a test statistic of $z = -2.05$ and a significance level of $p < .050$.

The better performance of the experimental group compared to the control group can be attributed to the characteristics of the scaffolding-based digital instructional media "Madmatics," which positively influenced all dimensions of HOTS: analyze, evaluate, and create. In this study, the ability to "analyze" was assessed from two perspectives, such as breaking down information into smaller components and finding evidence to support generalizations and identifying and examining correct information.

With regard to the first perspective, students' analytical skills improved after engaging in activities across the three levels of Madmatics, where they were encouraged to decompose mathematical problems into smaller, manageable parts through guiding questions (see Figure 7). This method fosters students' capacity to view complex problems as compositions of simpler ones. This approach aligns with the brick-wall metaphor proposed by Silver (1990), which suggests that simplifying complex problems into smaller, more digestible components enhances students' overall understanding of mathematics.

Moreover, Madmatics incorporated guiding questions prompting students to determine the appropriate strategy for solving specific problems (see Figure 5). This feature contributed to the development of their skills in identifying and evaluating correct information and strategies. According to Payne et al. (1993), the ability to select effective strategies—termed the "selection process"—can be enhanced through the application of meta-strategies, enabling learners to make informed and conscious decisions while solving problems.

The second dimension of HOTS is "evaluate," which encompasses two critical aspects, namely justifying decisions with sound reasoning and assessing whether a contextual problem can be mathematically modeled. In terms of justifying decisions, many tasks within the Madmatics platform required students to make judgments and substantiate their choices. For instance, one task prompts students to determine whether a given amount of money is sufficient to purchase certain snacks (see Figure 8). This scenario encourages students to evaluate the situation and justify their conclusions based on the prices of the snacks and the available funds.

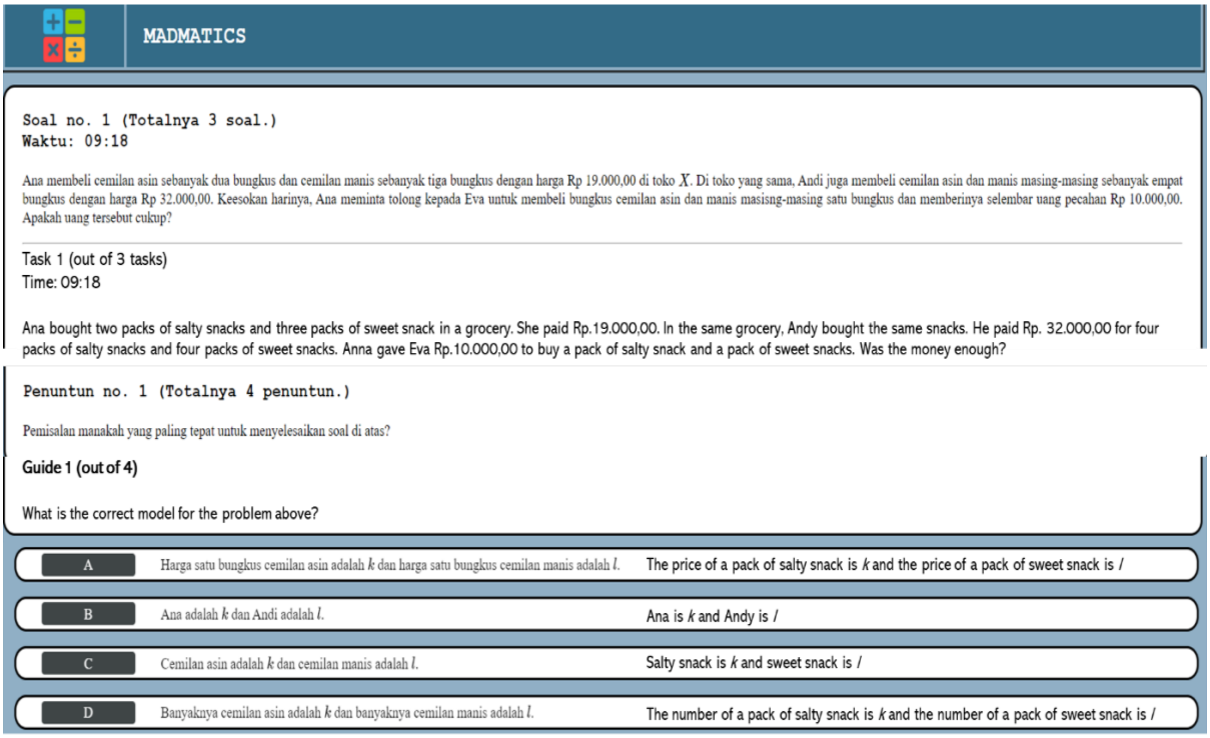

Figure 8. A guiding question that leads to making mathematical model

Moreover, the development of students' evaluative skills is not solely achieved through the tasks themselves; it is significantly enhanced by the accompanying guiding questions integrated into the Madmatics platform. These guiding questions prompt students to assess and establish the appropriate mathematical model for a particular situation (see Figure 8). Engaging in such activities fosters students' ability to critically evaluate whether a contextual problem is amenable to mathematical modeling, thereby enriching their understanding and application of mathematical concepts in real-world contexts.

The final aspect of HOTS assessed in this study was the ability to create, which was evaluated from two perspectives: generating new or original work and formulating a plan to tackle open-ended problems. While Madmatics did not specifically offer exercises that required students to create contextual problems—due to the platform's limitations, which only supported multiple-choice questions and numerical inputs for open-ended tasks—the usage of the platform still fostered skills relevant to this aspect of HOTS.

Students who engaged with Madmatics became accustomed to transforming contextual scenarios into mathematical models. This practice is essential for developing modeling competence, which is a foundational skill for creating contextual problems in the future.

Regarding the formulation of a plan, students' abilities were cultivated through systematically provided guiding questions. For example, the price-related problem depicted in Figure 8 was accompanied by a series of guiding questions designed as a step-by-step framework to navigate the problem-solving process. The initial guiding question prompts students to identify the correct mathematical model (see Figure 9). This structured approach not only assists students in devising solutions but also encourages them to think critically about the steps required to approach complex, open-ended problems, ultimately enhancing their creative capabilities in mathematics.

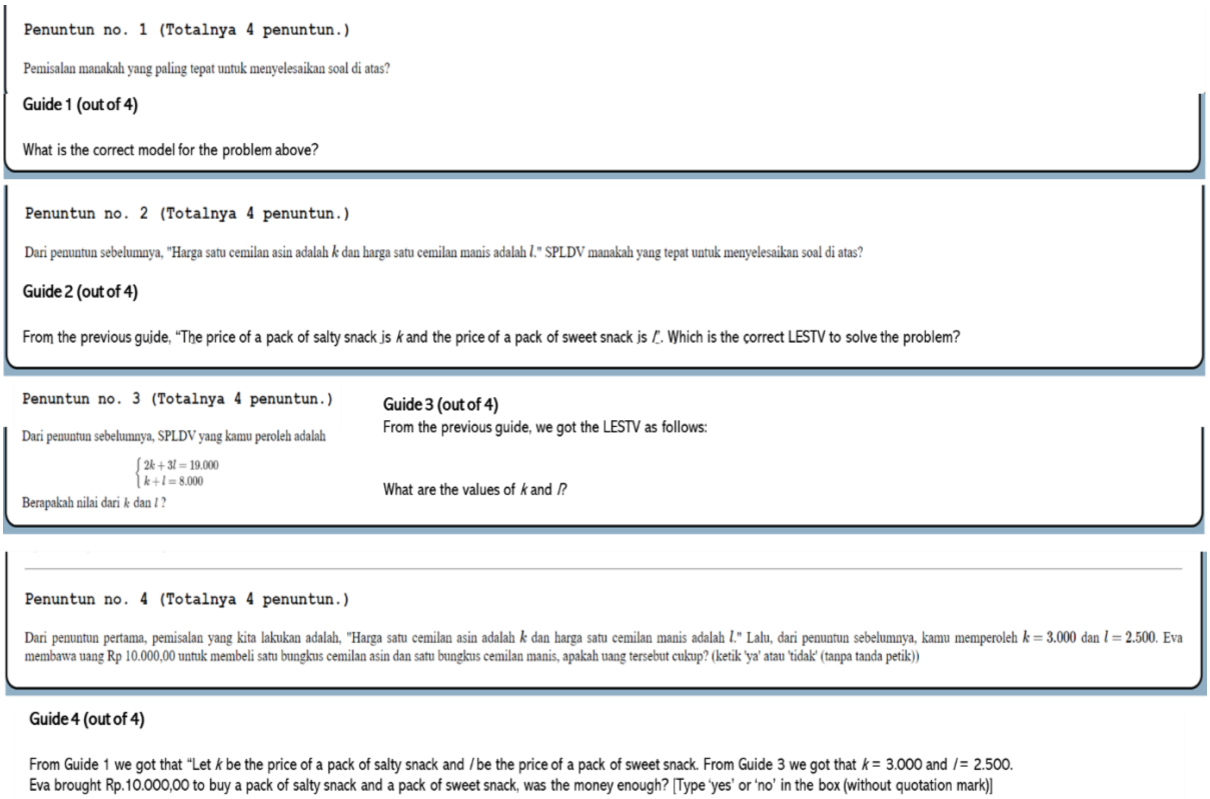

Figure 9. A guiding question that leads to making mathematical model

CONCLUSION

The findings from this study indicate that the implementation of scaffolding-based digital instructional media, specifically Madmatics, significantly enhances students' higher-order thinking skills (HOTS). The thoughtfully designed scaffolding features within Madmatics facilitate a deeper understanding of tasks by providing structured assistance through guiding questions. These questions encourage students to analyze the given tasks, enabling them to decompose complex problems into more manageable components, thereby enhancing their analytical abilities—an essential indicator of HOTS.

In addition to promoting analysis, the guiding questions in Madmatics also lead students to evaluate situations and justify their reasoning. This reflective practice fosters students' evaluative skills, allowing them to assess their decision-making processes critically. Regarding the ability to create, the guiding questions help students grasp the problem-solving flow more effectively, encouraging them to construct mathematical models from word problems. This practice ultimately supports students in formulating contextual problems and devising strategies to address them. The study also underscores the importance of not only exposing students to HOTS problems through repetitive practice but also nurturing their cognitive processes in a structured manner via guiding questions. Such scaffolding should be designed to gradually diminish, allowing students to develop both their HOTS and self-directed learning capabilities over time.

While this study yielded positive outcomes regarding the effectiveness of Madmatics in enhancing students' higher-order thinking skills (HOTS), several limitations must be acknowledged. Firstly, although the highest level of HOTS is the 'create' level, technical constraints within Madmatics hinder students' ability to articulate their thoughts through extended explanations. The platform lacks features that allow students to create or pose contextual problems representing specific mathematical models, which is an essential aspect of the post-test assessment. Additionally, another limitation pertains to the use of Madmatics for homework assignments. The platform does not possess any mechanisms to ensure that students complete their homework independently, raising concerns about the integrity of the assessment process.

Moreover, this study employed fixed scaffolding; thus, future research could benefit from the development of digital instructional media that integrates adaptive scaffolding features. Such an approach would tailor support based on individual student needs and incorporate functionalities that promote independent homework completion. By addressing these limitations, subsequent studies could further investigate the potential of scaffolding-based digital tools to foster HOTS in diverse educational contexts.

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Declarations

Author Contribution : WS: Conceptualization, data curation, writing-original draft, writing-review & editing, methodology, and supervision.

FMP: Investigating, software, formal analysis, writing-original draft, writing-review & editing.

KF: Resources, programming and validation.

CYY: Visualization, resources, Writing - review & editing.

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