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Research paper

MathDifi: A Differentiated Interactive Learning Application to Optimize Students' Creative Thinking Skills on Integer Concepts

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ABSTRACT

The low level of students' mathematical creative thinking skills in understanding the concept of integers is one of the problems in mathematics learning in schools. Therefore, this study aims to optimize the competency through the development and implementation of the *MathDifi* application based on differentiated instruction. The research design used was research and development with the ADDIE model. The participants were 441 people (420 students, 18 teachers, and 3 lecturers) in Jambi City, Indonesia. The instruments used were a mathematical creative thinking ability test, a questionnaire of student and teacher responses about the application, and an instrument validation sheet. Data analysis used descriptive and inferential statistical data analysis. The results of the study revealed that the factor causing students' low mathematical creative thinking skills was that learning in schools tended not to use interactive learning media that were appropriate to students' characteristics or needs. The *MathDifi* application was then systematically developed and designed to be able to facilitate students' learning preferences. The implementation of the application then indicated that it had the potential for a positive impact on the development of students' mathematical creative thinking skills. This was because the application facilitated students' use of various interactive media, such as ion cards, to help them understand the concept and operation of integers. Because the application was not yet able to optimally store student responses, this study recommended that future research facilitate the learning application so that the learning application used could store student responses, thus simplifying the learning assessment process.

Keywords: differentiated instruction, integers, Mathdifi, mathematical creative thinking skills

Integers are a crucial concept in mathematics (Luca et al., 2014). They play a significant role not only in other mathematical concepts (Johnson, 2018; Munagi & de Vega, 2023), but also in everyday life (Neri & Schneider, 2023). Nearly all mathematical concepts involve integer operations (Wibowo et al., 2021). In fact, the concept of integers is the most frequently used mathematical concept in social interactions (Avcil & Artemenko, 2025). For example, sellers and buyers are not separated from integer operations when conducting transactions.

Given the importance of the concept of integers, ideally, students should master this concept well. However, the facts reveal that learning the concept of integers is one of the many challenges in mathematics learning (Hawthorne et al., 2022; Romero & Llinares, 2019). Students tend to struggle to solve non-routine problems involving these concepts (Sulastri, 2019). Furthermore, students also tend to be unable to optimize the use of mathematical creative thinking skills (MCTS) when solving problems involving integer concepts (Hilmi et al., 2021; Umam et al., 2025). This ability is one of several 21st-century competencies that students must master (Kholid et al., 2024).

Several studies examine MCTS in the context of integer concepts (Hastuti et al., 2025; Hendriana & Fadhillah, 2019; Yaniawati et al., 2020), but few examine how to optimize these competencies comprehensively. Furthermore, research on interactive learning media tailored to students' needs and characteristics tends to be lacking. This media, however, provides students with more opportunities to explore or use new ideas when solving problems (Pasani & Amelia, 2025). Essentially, several previously described studies focus on examining MCTS and the use of interactive learning media in mathematics. However, these studies do not specifically optimize MCTS through the integration of differentiated learning based on interactive learning applications, resulting in limited learning. Therefore, this research is quite important because it addresses challenges related to the development of 21st-century skills, both in local and global contexts.

Therefore, this study aims to optimize students' MCTS on the concept of integers by developing interactive learning media based on differentiated instruction. The learning media developed in this study is *MathDifi*. Theoretically, this research is expected to contribute to expanding the objects of study related to differentiated learning, especially the use of technology-based and multimodal approaches as integration aspects in optimizing MCTS on the concept of integers. To achieve these research objectives, the researcher formulates several research questions, including:

RQ1: What are the results of the learning needs analysis prior to application development?
RQ2: What is the *MathDifi a*pplication design to optimize MCTS?
RQ3: What is the format of the developed *MathDifi* application?
RQ4: How is the implementation process of the *MathDifi* application described in learning?
RQ5: What are the evaluation results of the development and implementation of the *MathDifi a*pplication in schools?

METHOD

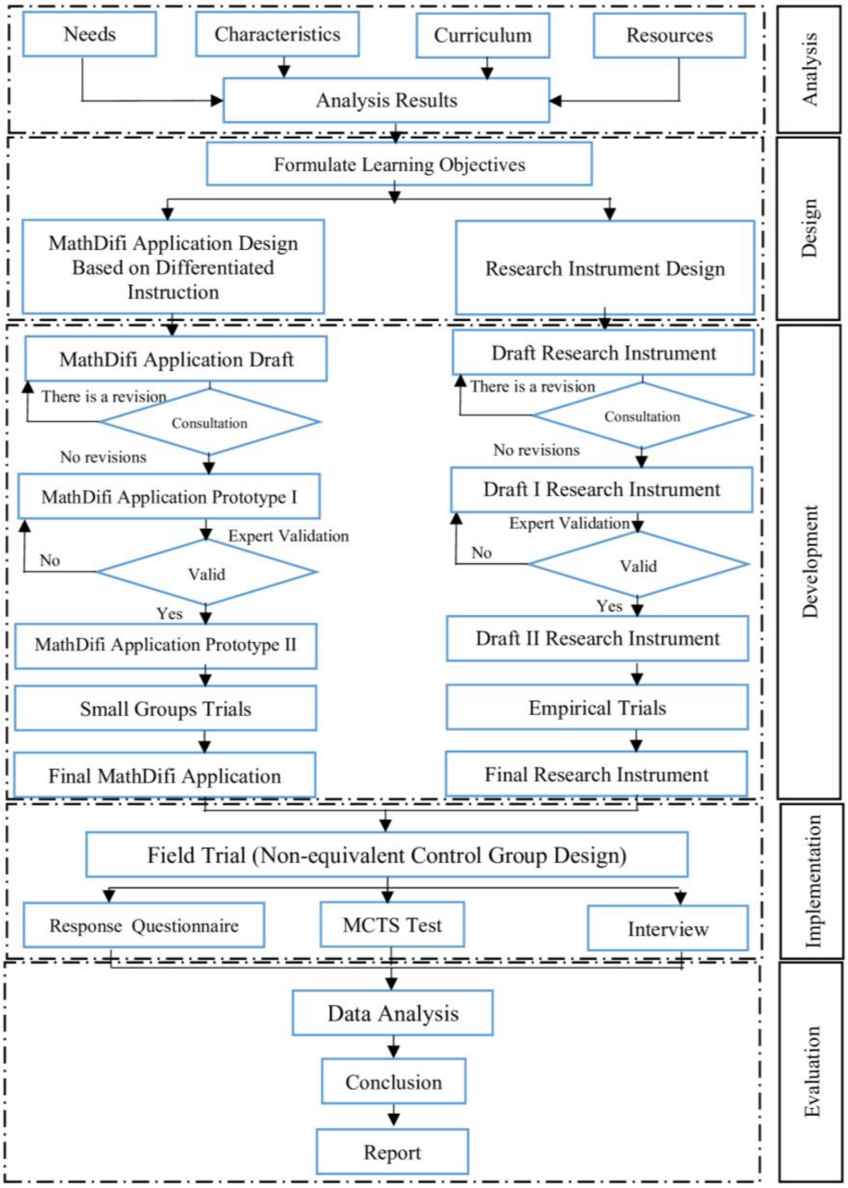
Research design

This research design was research and development. This design was used because the objectives of this study were quite relevant to the characteristics of this design: to design, develop, and test the validity, effectiveness, and practicality of the *MathDifi* application in learning integer concepts (Rahmah et al., 2022). The research and development design model used was the ADDIE model. This model was used because it was systematic, structured, and adaptive, making it easier for researchers to develop interactive and adaptive learning (Andrianingrum & Suparman, 2019), such as the *MathDifi* application itself. The software used to develop *MathDifi* was Smart Apps Creator (SAC). SAC was chosen because it required no coding skills, was easy to use, could be used offline, and supported various interactive learning menus, such as quizzes and animations (Wihardjo et al., 2025). The SAC used was the educational version of SAC 3.7.

This research procedure followed the ADDIE model steps: analysis, design, development, implementation, and evaluation (Addo, 2025; Pakaya & Machmud, 2021). In the analysis stage, the researcher conducted a needs analysis, including an analysis of the curriculum, student characteristics, and resources, which served as the basis for designing and developing the *MathDifi* application. After analyzing the needs, the researcher designed the application in the form of a systematic flowchart storyboard to align with the learning objectives, student characteristics, and the principles of differentiated instruction. The researcher then developed the *MathDifi* application based on the previous design (Prototype I). At this stage, the researcher also developed several additional instruments as needed. The researcher also conducted expert validation of the *MathDifi* application and instruments, which then led to revisions to the application and instruments (Prototype II). At this stage, the researcher also conducted a small group trial to obtain information on challenges and initial responses to the application's appearance, accessibility, material presentation, and language used. The researcher then revised the application based on the challenges encountered and the initial responses (Prototype III).

The next stage was implementation. In this stage, the researcher implemented the *MathDifi* application (Prototype III) in integer learning. In this step, a quasi-experimental research design with two nonequivalent groups was used to obtain results regarding the effectiveness of the implemented learning. The researchers used two classes as implementation targets (experimental and control). The researchers did not perform random assignment in this step because the two classes had already formed naturally. This decision then impacted the selection of the experimental and control classes, which used naturally existing classes. Each class was given a pre-test and post-test. Finally, the researchers conducted a formative evaluation of all previous research stages and a summative evaluation to determine the effectiveness and practicality of the *MathDifi* application. A brief overview of the research procedures could be seen in **Figure 1**.

Figure 1
Research procedure



Participants

There were several groups of participants in this study. First, 363 people participated in the analysis stage (15 mathematics teachers, 314 students who had not yet learned the concept of integers, 32 students who had already learned the concept of integers, 1 vice principal for curriculum, and 1 vice principal for facilities and infrastructure). Second, 11 people participated in the small-group trial (10 students who had not yet learned the concept of integers and 1 mathematics education lecturer as an observer). Third, 64 students as a sample (32 students in the experimental class and 32 students in the control class), 1 model teacher, and 2 observers participated in the implementation stage. This research was conducted at a school in Jambi City, Indonesia. The school was chosen because some students were indicated to be experiencing problems in learning the concept of integers. Students' initial abilities were used as an additional control in this study through pre-test results. This measure was intended to strengthen the research findings that the differences in results in the analysis were truly due to the instruction provided by the researcher. Therefore, the total number of participants involved in this study was 441 people.

Research instruments

This study used several instruments to obtain data from participants. First, there were several types of instrument validation sheets: the *MathDifi* application validation sheet, the teaching module validation sheet, the mathematical creative thinking ability test validation sheet, the student response questionnaire validation sheet, and the teacher response questionnaire validation sheet. Each validation sheet was structured using a Likert scale of 1–4. Second, a mathematical creative thinking ability test consisting of five questions was used to identify all indicators of mathematical creative thinking ability, such as fluency (question 1), flexibility (question 2), novelty (question 3), and elaboration (questions 4a and 4b). The expert validation results for this test item were categorized as high with a V value of 0,89. The results of the empirical validity test indicated that all items were statistically significant ($p < 0{,}001$), so it could be concluded that all instrument items were valid. The values obtained ranged from 0,000 to 0,0003 for instrument items. Meanwhile, the reliability estimate showed a high category with a Cronbach's alpha value of 0,75. Third, the student questionnaire responses were categorized as high (V = 0,84), and the teacher questionnaire responses were categorized as high (V = 0,84).

Data analysis

The validation data were analyzed using Aiken's V, with the instrument being considered high when the V value was in the range of 0,80 to 1,00. The practicality data were analyzed using the practicality p value, with the criterion being practical when the p value was in the range of 61 to 80 and very practical when the p value was in the range of 81 to 100 (Aiken, 1980, 1985). The mathematical creative thinking ability data were analyzed using the average value category, with the category being high when the average value was greater than 16,6; and inferential statistical tests were used. The inferential statistical tests used were the paired-samples t-test (when the data were normally distributed) and the Wilcoxon signed-rank test (when the data were not normally distributed). The test criteria used were when the significance value was less than 0,05; then there was a significant difference between the experimental and control classes (C. Park et al., 2020; Thakkar, 2025). In addition, this study also used Cohen's d effect size to test the impact of the *MathDifi* application implementation on students' MCTS in learning integer concepts. The criteria used were that the MathDifi application had a large effect when the d value was greater than or equal to 0,80 or $|r|$ was greater than or equal to 0,50 (Gülkesen et al., 2022). The N-gain test was also used to determine the effectiveness of each learning. The criteria used were high learning effectiveness when the g value was greater than or equal to 0,70 (Prayogo et al., 2022).

Finally, the Mann-Whitney U test was used to determine the average increase in mathematical creative thinking skills between students learning using *MathDifi* and those learning using the conventional approach. When the significance value of the results was less than 0,05; it could be concluded that there was a significant difference in effectiveness between the two groups. The paired-sample t-test and Wilcoxon signed-rank test were used in this study to analyze the improvement in pre-test and post-test scores within the same class. The Mann-Whitney U test was used to compare changes in MCTS between the experimental and control classes.

RESULTS AND DISCUSSION

Results

What are the results of the learning needs analysis prior to application development?

Based on the analysis, it was found that mathematics learning conditions before the development of the *MathDifi* app tended to be conventional, with teachers using lecture methods. Furthermore, the questions used tended to be routine, and students and teachers tended to use government textbooks as learning resources and rarely integrated technology into their learning (teachers were limited to sharing learning video links via WhatsApp groups). More specifically, the analysis revealed that approximately 85% of students and 93% of teachers used government textbooks as learning resources, and only approximately 3% of students and 7% of teachers used interactive learning media as a supplementary learning resource. This study further revealed that interactive learning media tended to be underutilized by students and teachers in mathematics learning at school.

Following up on the low percentage of interactive learning media use, the researchers then identified that approximately 96% of students and 100% of teachers considered the use of interactive learning media in mathematics learning. Furthermore, the concept of integers was considered a difficult topic that required the use of interactive learning media. It was found that 52% of students found the concept of integers difficult, 20% the concept of rational numbers, 13% the concept of algebra, 7% the concept of ratios, and 7% the concept of similarity. The results of this study further revealed the need for the use of interactive learning media, particularly for learning the concept of integers.

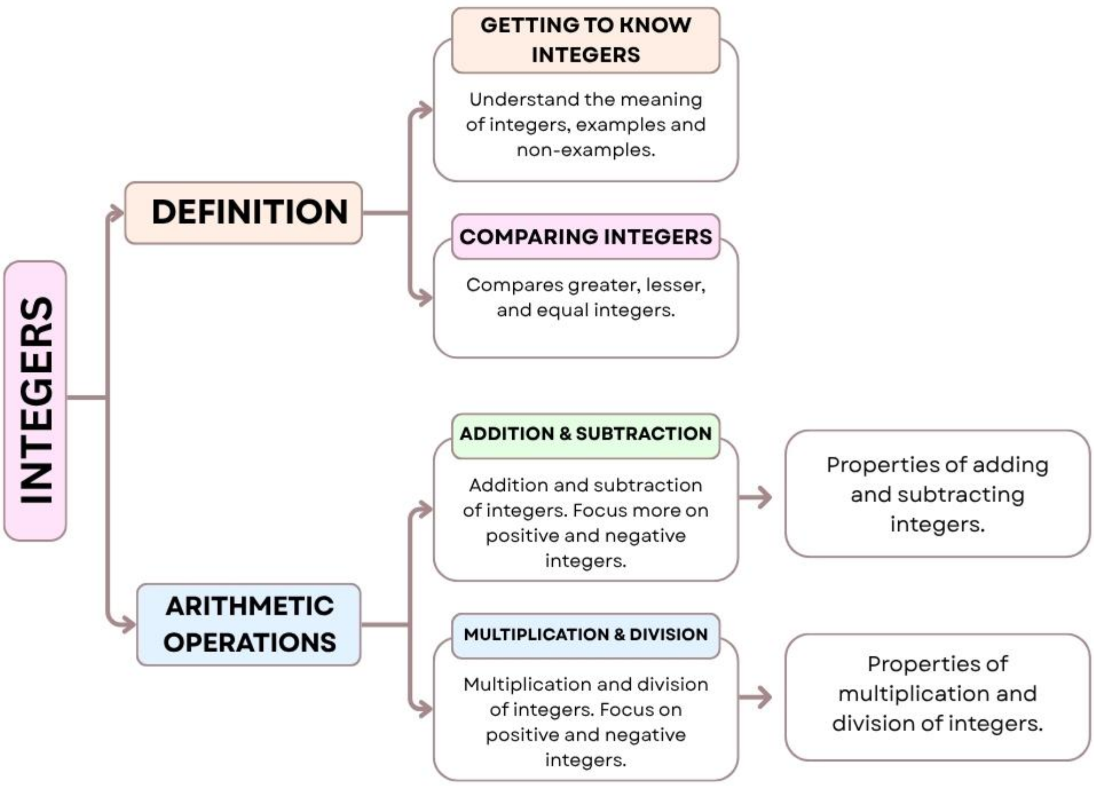
Regarding MCTS, the analysis revealed that most students were not optimally utilizing these thinking skills. The average student score for the fluency indicator was 41,30; the flexibility indicator was 54,38; the novelty indicator was 55,00; and the elaboration indicators were 33,10 and 36,25. These results indicated the importance of innovation in learning to optimize these thinking skills. These findings then motivated the researchers to develop interactive learning media in the form of the *MathDifi* application to optimize students' MCTS.

The results of the curriculum analysis revealed that the recommended learning characteristic was differentiated instruction. Differentiated instruction in this context referred to student-centered learning that used student characteristics as a guideline in developing lessons. The learning provided was tailored to the student's needs, thus fostering teaching at the right level (TaRL). Based on this, the *MathDifi* application developed had to be differentiated to suit the student's needs and circumstances.The results of the resource analysis also supported the development of the *MathDifi* application. The school had three computer labs with a capacity of 102 active computers that students could use during lessons using the *MathDifi* application. Furthermore, there were four LCD projectors and a stable internet connection (100 Mbps) to support the application's use. The students' basic experience with digital devices was also undeniable. Fifty-nine students were already familiar with using laptops, smartphones, and other interactive learning media. This analysis indicated that the students and the school were at least somewhat ready to use interactive learning media, such as *MathDifi*.

What is the MathDifi application design to optimize MCTS?

Before designing the *MathDifi* application, learning objectives were first formulated. Regarding the concept of integers, the researchers formulated several learning objectives allocated to seven learning sessions based on a previously created concept map. A brief overview of the integer concept map could be seen in **Figure 2**.

Figure 2
Integer concept map



After formulating the learning objectives, the researchers first developed a learning design that would be integrated into the *MathDifi* application. This study integrated differentiated instruction using the discovery learning model. The syntax of the discovery learning model used was stimulation, problem statement, data collection, data processing, verification, and generalization. In this context, student activities were tailored to their learning preferences. In the context of this research, this approach was defined as students' learning preferences facilitated through various multimodal accesses, rather than as a fixed category inherent to the student. These preferences referred to visual, auditory, and kinesthetic aspects. For example, in the data collection step, students with a visual learning style gathered information through visual observation, such as example problems with various graphical displays in the *MathDifi* application; auditory learners gathered information using audio descriptions, discussions, and narration; while kinesthetic learners utilized information through the use of visual aids, simulations, or exploration of the application's interactive features.

After all activities were designed, the researchers designed the *MathDifi* application navigation flow, as shown in **Figure 3**. **Figure 3** showed all the interrelated instructions from the initial screen to the final screen in the *MathDifi* application. The researchers then designed a storyboard after the navigation flow was complete. The *MathDifi* application storyboard could be seen in **Figure 4**. **Figure 4** showed a more interactive navigation flow with several screenshots of the application. During the design stage, the researchers also compiled an asset plan that included the asset name, type, learning function, visual characteristics, and format used.

Figure 3
MathDifi application navigation flow

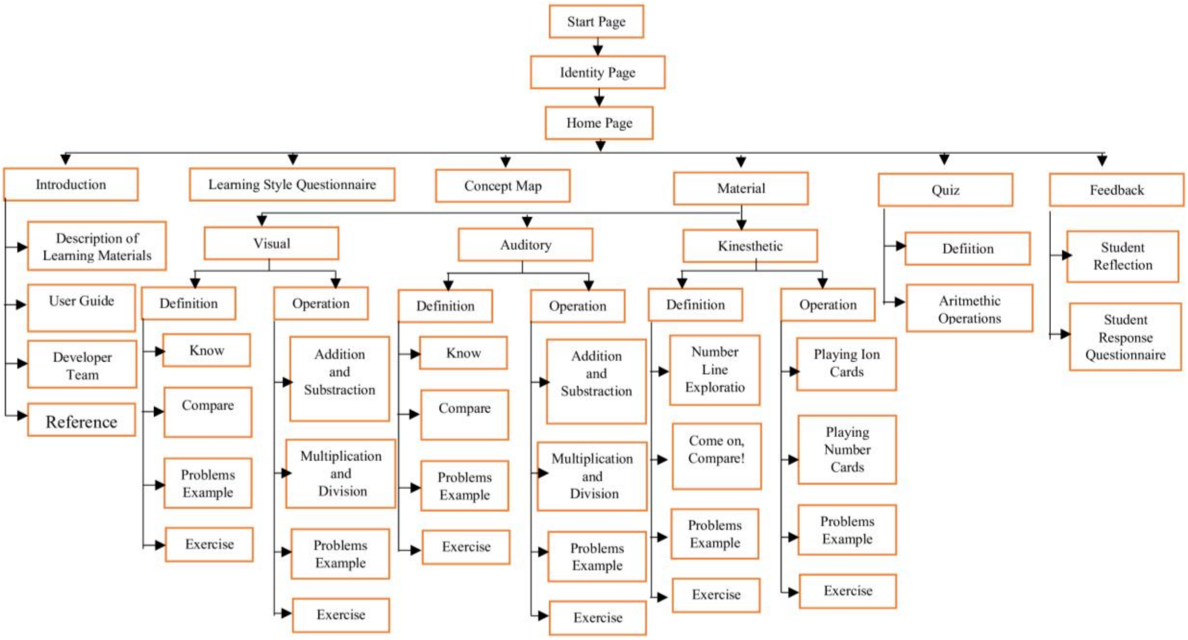


Figure 4
MathDifi application storyboard snapshot

What is the format of the developed MathDifi application?

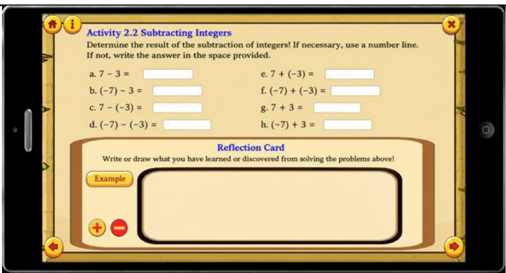
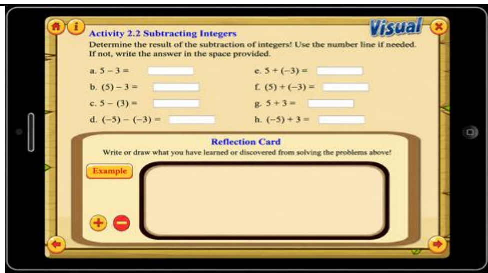
Before developing the *MathDifi* application, a teaching module was first developed to guide students in using the application. This teaching module was structured based on previously designed learning objectives and activities. The teaching module contained general information, core components, and appendices. The general information consisted of the module's identity, initial competencies, Pancasila student profiles, facilities and infrastructure, learning models, and target students. The core components included learning outcomes, meaningful understanding, provocative questions, learning activities, assessments, and criteria for achieving learning objectives. The appendices contained assessment sheets, teacher and student reading materials, a glossary, and a bibliography. The learning activities in the teaching module were divided into three stages: introduction, core, and conclusion, with stages following the syntax of differentiated instruction using the discovery learning model, as described in the previous section.

After the development of the teaching module was completed, the researchers installed the SAC 3.7 educational version of the software to prepare the assets and materials to be used in developing the *MathDifi* application. Asset creation was carried out using three applications: *Canva, Coologo,* and *Clipchamp.* After the assets were completed, the researchers created a new project in SAC 3.7, specifying the device type, screen size, display orientation, and initial application settings. They then created a Start Page, set the page background, structured the page flow, integrated multimedia assets, configured the interactivity of menu and navigation buttons, and configured the interactivity of interactive features. They also conducted functional testing and published the product.

After successful product publication, the researchers conducted expert validation of the developed *MathDifi* application. A comparison of the application's display before and after the validation revisions could be seen in **Table 1**. **Table 1** showed that several expert validations were significant, impacting the clarity of module navigation. The language used was simplified, and the display was more engaging and aligned with the principles of differentiated learning. For example, the validator recommended that apps use larger font sizes, clear menu labels, and more consistent navigation button positions.

Table 1

Comparison of the MathDifi application before and after expert validation

<table>
<tr><th>Number</th><th>Before</th><th>After</th></tr>
<tr><td>1</td><td>
</td><td>
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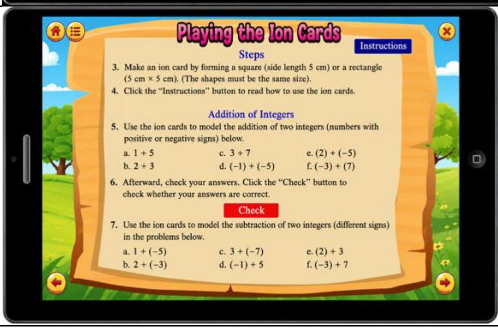
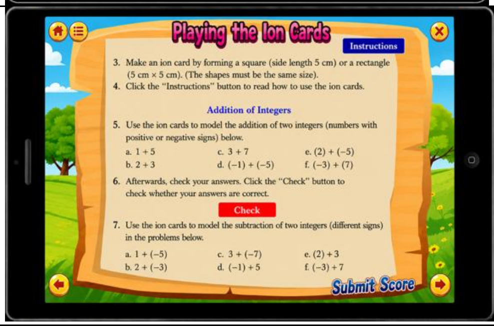
<tr><td>2</td><td>
</td><td>
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How is the implementation process of the MathDifi application described in learning?

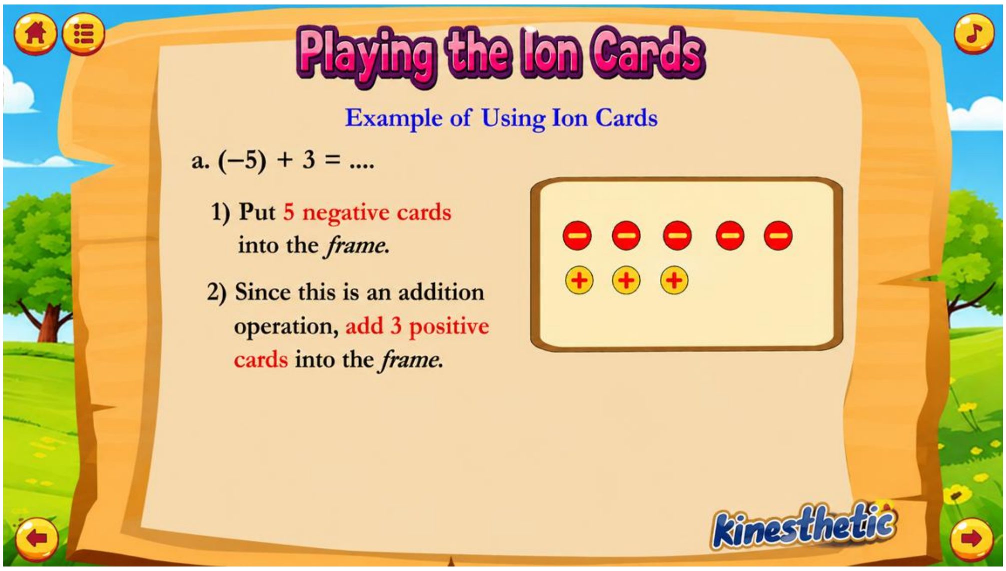
As described in the previous section, the *MathDifi a*pplication was implemented in seven sessions. However, this section described the implementation of *MathDifi* on the concept of addition and subtraction of integers. During these sessions, students were asked to study using the *MathDifi* application in groups. Students were grouped based on their learning preferences. In the context of this research, grouping was used as a basis for student learning preferences. This was intended to facilitate access to learning materials and not to serve as a permanent or fixed grouping of students. Students first clicked on "Materials" to display three learning preferences. While students were waiting to choose their learning style, the *MathDifi* application provided audio and visual descriptions of the benefits of integers in using a thermometer. The following was an example of an activity carried out by students with a visual learning style.

After the student group selected their learning style, they clicked on "Integer Arithmetic Operations." This displayed the material being studied, sample problems, and practice problems. Students were directed to select the material they would like to study. During this session, students selected the "Addition and Subtraction" menu. This was followed by an exploration activity. In this exploration activity, students were shown animated videos explaining the use of integers in everyday life, for example, air temperature at the beach, during rain, and in snowy areas. In this section, students also answered prompt questions about operations that applied when the air temperature rose or fell.

The exploration activity continued with information on how to explore ion cards. Ion cards were a tool students used to learn the concept of adding and subtracting positive and negative integers, or vice versa. Once students understood how to use ion cards, they selected the sub-topic menu they were studying. Several problems then appeared that they had to solve using ion cards. Students dragged and dropped each ion card according to the problem they were facing. Students repeated this activity several times for different problems. Excerpts of student answers could be seen in **Figure 5**.

Figure 5

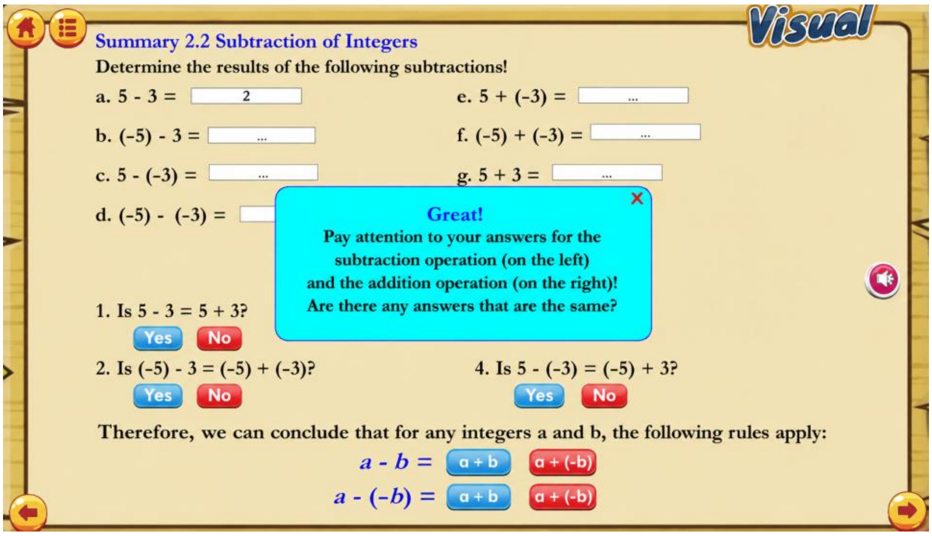
Excerpts of student answers using ion cards



After completing this activity, students filled in their answers in the provided fields. Students automatically received feedback on whether their answers were correct or incorrect. Excerpts of the feedback provided could be seen in **Figure 6**.

Figure 6

Excerpts of feedback in the Mathdifi application



The previous activity then led students to deduce the general formula for subtracting two integers. After that, students studied the other sub-topics until the activity was complete. After all activities were completed, students were asked to reflect on the learning session. Students were then directed to complete a Google Form about learning activities they considered difficult and enjoyable, their commitment to improving their learning outcomes, and their rating of the course. In this activity, the majority of students gave a rating of 4 out of 5. The analysis of the implementation results could then be seen in the next section, which divided the analysis into three stages: descriptive analysis, testing the effectiveness of learning for each group, and testing differences in treatment between groups. The descriptions were as follows.

What are the evaluation results of the development and implementation of the MathDifi application in schools?

The formative evaluation results for the analysis stage confirmed that learning problems had been clearly identified and warranted further action by developing interactive learning media tailored to student characteristics, such as the *MathDifi* application, which was based on differentiated instruction. The design stage evaluation revealed that constructive feedback from experts helped refine the navigation flow, storyboard, and multimedia asset design, making it ready for development. The development stage evaluation confirmed that module and application development, along with small group trials, resulted in a *MathDifi* application ready for implementation. Meanwhile, the formative evaluation for the implementation stage revealed that the *MathDifi* application implementation proceeded systematically and smoothly, with a very high level of learning activity implementation. In other words, planning and implementation were well aligned. However, one obstacle encountered was the *MathDifi* application's inability to fully record student responses for each learning activity within the application.

The analysis of teacher responses to the implementation of the *MathDifi* application in the classroom revealed that the application's practicality criteria were very practical, with a practicality index of 98%. The analysis of student responses revealed that approximately 79% of students considered the *MathDifi* application practical. The results of the descriptive statistical analysis of the application's effectiveness on MCTS revealed that approximately 78% of students achieved learning mastery in terms of MCTS after implementing the application. Furthermore, there was an increase in scores from the pre-test to the post-test. This increase could be seen in **Table 2**. **Table 2** showed a greater increase in scores for the *MathDifi* class compared to the conventional class. This increase was evident in the higher average post-test scores for the *MathDifi* class compared to the conventional class, as well as the larger difference in score increases before inferential statistical analysis. **Table 2** also showed that the pre-test scores of the two classes tended to be insignificant before treatment.

Table 2

Comparison of descriptive statistics of MathDifi and conventional classes

Descriptive Statistics	*MathDifi*		Conventional	
	Pre-Test	Post-Test	Pre-Test	Post-Test
Mean	5,47	16,88	6,75	9,19
Median	4,05	16,50	6,50	9,00
Mode	1,00	16,00	0,00	12,00
Standard Deviation	4,39	3,63	3,24	3,06
Minimum Value	0,00	9,00	1,00	4,00
Maximum Value	19,00	24,00	15,00	15,00

The descriptive statistical results were then reinforced by the following inferential statistical results. The results of the inferential statistical analysis revealed a paired-sample t-test with a value of 11,406 with a large effect size criterion, $p < 0,05$. In other words, implementing the *MathDifi* application was indicated to have been effective in optimizing students' MCTS in learning integer concepts between pre-test and post-test scores. However, these results required further analysis by comparing its effectiveness with a control class. The analysis of the magnitude of the impact also revealed a Cohen's d value of 3,10. In other words, the effect size of the *MathDifi* application on this competency was quite large. The N-gain analysis also revealed an N-gain value of 0,59, indicating a moderate increase in students' MCTS. Finally, to ensure there was a difference in effectiveness between students learning using *MathDifi* and students learning using the conventional approach, a Mann-Whitney U test was conducted. The analysis results revealed that the U value obtained was 7,5; $p < 0,05$; and $|r| = 0,842$ with the criteria of a very large effect. This result indicated that there was an increase in students' mathematical creative thinking abilities in the class using the *MathDifi* application based on differentiated learning (experimental class) higher than students who did not use the *MathDifi* application based on differentiated learning (conventional class).

DISCUSSION

The findings of this study are described using the constructivist learning theory perspective, which emphasizes that knowledge is actively constructed through the use of students' learning experiences. The constructivist theory in this study is seen in the exploration activities carried out by students, discovery learning, and reflection activities carried out by students actively when constructing mathematical concepts. The cognitive load theory perspective is also used to describe the use of ion cards as a visual medium, which is expected to help students reduce cognitive load when attempting to construct the concept of integers, which tend to be abstract. In the context of this research, the cognitive load theory is seen in the use of ion cards as a form of concrete representation to help students understand the abstract concept of integers. In the context of creativity in learning, these two perspectives are expected to be supporting factors in developing the flexibility and originality of students' thinking processes.

The research reveals that the learning methods used by teachers before the development of the *MathDifi* application tend to be conventional. Most learning sessions used by mathematics teachers tend to use the lecture method and rarely integrate technology. This is because teachers perceive that creating innovative and interactive learning media is difficult and time-consuming. These findings align with several previous studies (Fatihah et al., 2023; Pasani & Amelia, 2025; Winata et al., 2025), which reveal that one of the problems in learning integers is the tendency for teachers to use the lecture method. Students are given fewer opportunities to use prior knowledge or experience when solving mathematics problems (Kudaibergenova et al., 2024). Kim (2019) reveals that teachers face a significant administrative burden, reducing their effectiveness in developing interactive learning media. Teacher well-being is also a factor in teachers' lack of enthusiasm in developing interactive learning (Munandar et al., 2019).

The problems given by teachers are mostly routine, making them less challenging or engaging for students to solve. The results of this study align with those of (H. A. Nguyen et al., 2020), who find that mathematics problems in schools tend to be routine, thus hindering students' ability to solve non-routine problems. This is evident in the PISA scores of Indonesian students, which tend to fall below international standards for numeracy (Schleicher, 2023). These results also align with previous studies (Aziz et al., 2023; Yildiz & Karadeniz, 2016), which find a significant number of routine problems in school mathematics textbooks.

The use of lecture methods and routine problems is directly proportional to students' MCTS. Students in this study tend to have low MCTS. These research findings align with those of (Umam et al., 2025), who reveal that students' MCTS in schools have not developed optimally. This is because students are not given the opportunity to use ideas flexibly during learning (Isyrofinnisak et al., 2020). Furthermore, the problems presented are mostly routine, making students less accustomed to solving non-routine problems (Shaw et al., 2020). The use of conventional methods during mathematics learning also impacts students' suboptimal mathematical competence (Bishara, 2018) because students are not provided with contextual experiences, such as hands-on activities in constructing mathematical concepts (Magrone et al., 2019).

Addressing several issues in mathematics learning before the development of the *MathDifi* application, this study also reveals that differentiated instruction is one of the recommended learning methods. Differentiated instruction is learning tailored to student characteristics or needs (Inman & Roberts, 2022; Pəniyeva, 2025). The integration of the *MathDifi* application also tends to be relevant to the STEAM approach because it combines technology in mathematics learning and encourages students to solve problems creatively. Operationally, differentiated instruction can be implemented by adapting learning to suit students' learning preferences (Hati et al., 2025). Furthermore, differentiated instruction is one of the learning recommendations in the Independent Curriculum in Indonesia (Somnam et al., 2025). These research findings align with those of Rijal et al. (2025), who state that differentiated instruction is one solution expected to optimize students' mathematical competence in schools. This is because learning is structured and implemented according to student characteristics or needs, such as learning preferences (Marlina et al., 2024).

The research also reveals that resource readiness, such as supporting facilities and infrastructure, is a crucial aspect before implementing interactive learning media. These findings align with those of Sinaj and Xhabafti (2025), who state that the availability of supporting devices, such as laptops, smartphones, or a good internet connection, is a determining factor in the successful integration of technology into learning. This is because without these devices, technology-assisted or -based learning will not be effective (Hidayat & Firmanti, 2024; Katz, 2026; Pabilario, 2025; Sies et al., 2025). In fact, during the implementation of technology-assisted learning, the availability of technological devices is a mandatory component that must be present before learning begins (Anisa et al., 2025; Cullen et al., 2020; Wardani et al., 2025; Sultan et al., 2025).

After identifying the learning conditions, a concept map of the integers to be taught is formulated. Learning begins by introducing the concept of integers, followed by integer operations. Recognizing and comparing integers become two subconcepts learned initially. After that, it continues with addition and subtraction of integers containing the properties of addition and subtraction, then ends with multiplication and division of integers, including their inherent properties. The preparation of this concept map is based on several previous studies (Nur et al., 2022; Shanty, 2016), which study the concept of integers first before studying integer operations in the local instructional trajectory. This is because once students understand the meaning of integers, they will easily compare several integers (Sukiyanto et al., 2023). After students understand the concept of integers well, students are then directed to perform integer operations preceded by addition and subtraction operations before learning multiplication and division (Liebert, 2022). This is because the concepts of multiplication and division are the concepts of multiplication and division (Darmadi & Wihardjo, 2019; Simon et al., 2018).

The discovery learning model is then integrated into each learning session on integer concepts. This model is used because it is closely related to differentiated instruction (Hammer & Gunstone, 2015). The discovery learning model facilitates students' exploration of concepts, utilizing prior competencies and experiences, including learning style characteristics, to explore these concepts (Wada et al., 2019). Process differentiation is implemented for almost all syntaxes of the discovery learning model. The results of this study align with those of (Marlina et al., 2024), who state that the discovery learning model is classified as an example of differentiated instruction. This is because in some syntaxes of discovery learning, various content and process differentiations can be integrated into the learning (Hammer & Gunstone, 2015).

Furthermore, the results of this study reveal that navigation flow and storyboard design are key steps in determining the success of the *MathDifi* application development. Furthermore, the results of this study reveal that comprehensive asset design is quite helpful in application development. The results of this study align with several previous studies (Castillo et al., 2025; Mudaly & Fletcher, 2019; Utami et al., 2024), which reveal that creating a navigation flow, a good storyboard, and comprehensive asset design significantly influence the success of developing a learning application. This is because these three aspects are integral to the planning process when developing an application (Outhwaite et al., 2023).

After the design is complete, a teaching module is then developed as a learning guide for students. The teaching module in this study contains several pieces of information, such as general information, core components, and appendices. The teaching module is developed based on the Merdeka Curriculum, the current educational curriculum in Indonesia. These research findings align with those of Prastowo and Elvi (2023), who state that teaching modules in the Merdeka Curriculum contain at least three main components: general information, core components, and appendices. The general information section contains information about the module's identity, initial competencies, Pancasila student profile, resources and equipment, learning model, and target students. This general information helps anyone reading the module understand what to prepare and what to target in the learning process (Amali et al., 2025). The core component includes all activities used during the learning process. Core activities typically include the complete learning activities and the assessments used to assess that learning. The appendices, meanwhile, contain several supporting components, such as reading materials that students can use as supplementary learning resources (Siregar et al., 2023). This is based on previous research (Kemmerlin & Wilkins, 2020; Rickford, 2019), which finds that providing references to other reading materials provides students with a more comprehensive variety of learning resources.

This study uses the educational version of SAC 3.7 to develop the *MathDifi* application. This application is used because it does not require coding skills for developers, is easy to use (self-study), can be used offline (without internet access), and supports various menus for interactive learning (Person et al., 2018; Wihardjo et al., 2025). For example, the software offers several animations and interactive quizzes (Mustikaningsih et al., 2025). The use of this application is based on recommendations from several previous studies (Alam & Dubé, 2022; Outhwaite et al., 2023; Seftiana et al., 2024), which find that SAC tends to be quite effective and efficient when developing learning applications, including mathematics.

Furthermore, *Canva, Coologo,* and *Clipchamp* are used to create assets in this study. These applications are chosen because they are free to access, attractive, and easy to use. Kurniasari et al. (2022) find that using *Canva* significantly assists teachers in developing interactive and engaging teaching materials. Furthermore, Canva offers a wide variety of pre-made asset templates that can be tailored to meet the needs of math teachers (Miranda & Enciso, 2023). Jun and Lee (2020), also note that using an attractive logo can attract students' interest. Vegh and Udvaros (2020), also reveal that using short animations can motivate students to learn using a learning app.

The results of this study reveal that students engage in group learning. This is intended to provide students with discussion partners when solving problems or other learning activities. These findings are supported by Retnowati et al. (2018), who find that group learning has a more positive impact than individual learning. This is because students in groups can share responsibilities for solving problems, thereby simplifying them. Furthermore, the diversity of group members' knowledge is an important factor when students solve problems (Tang & Liao, 2023). Grouping students based on learning preferences also has a positive impact because the activities provided are more relevant to those learning preferences (Nguyen, 2023).

The analysis also reveals that the study uses instructional videos as a medium to convey messages about the benefits of integer concepts in everyday life. These findings build on several previous studies (Luzón & Letón, 2015; Tso et al., 2022), which find that the use of animated videos has a positive impact on improving students' mathematical competence. This is because animated videos can provide clear and engaging visualizations (Han & Toh, 2019). Furthermore, animated videos can provide more engaging information about the benefits of the material being studied in everyday life (Ulfah et al., 2025). By understanding these benefits, students are expected to at least attract interest or motivate them to learn specific mathematical concepts (Jawad, 2022; N. Sari et al., 2023). Presenting several contextual problem examples also makes learning more acceptable to students (Mahmuti et al., 2025). The presentation of these contextual problems is expected to enable students to explore ideas flexibly and creatively, thus impacting their creative mathematical thinking skills in school.

This study uses ion cards as a learning medium to understand the concept of addition and subtraction of integers. The results of this study are based on Recentes (2019), which reveals that the card technique has a positive impact on students' ability to operate with integers. Picture cards, including ion cards, provide engaging visualizations and conceptual understanding in a simple way when students perform integer operations (Sahat et al., 2018). Furthermore, the use of visual models, such as cards, facilitates hands-on activity for students when discovering concepts about integer operations (P. Sari et al., 2025). Students can use a variety of ion cards in different or new ways according to their understanding, thereby automatically developing students' creative mathematical thinking skills. The use of ion cards is indicated to facilitate students in making concrete representations of various integers presented in questions or problems (Junitawati & Abidin, 2024). This approach is then indicated to have an impact in terms of reducing students' cognitive load in abstracting an integer, thus facilitating the process of constructing knowledge (Muzaini et al., 2026). In addition, the implementation of the principle of differentiated learning facilitates students in accessing teaching materials through various possible paths according to their learning preferences, such as visual, auditory, and kinesthetic approaches, thus indicating an influence on students' flexibility in thinking when solving problems about integers (Herwin et al., 2026).

Furthermore, research results reveal that the *MathDifi* application provides rapid feedback when students solve problems. This feedback is expected to challenge students to try again until the answer is correct. These research findings are supported by (Bringula et al., 2017), who reveal that providing feedback on the correctness of answers increases students' motivation to solve mathematical problems. This is because students can clearly and quickly determine whether their answer is correct (Huang et al., 2024). When an answer is incorrect, students will try again with a different method to solve the problem. This repetition of activities subsequently impacts students' MCTS (Asare et al., 2025).

Students are then guided to deduce the concept of integer operations through previously implemented activities. The results of this study align with those of (Isnawan et al., 2025), who state that deducing mathematical concepts through several constructive activities tends to be highly recommended for deepening students' conceptual understanding. Deducing mathematical concepts is one aspect of validation in the theory of didactic situations (Sridana et al., 2025). This situation is one of the core situations before students can apply learned concepts to problems in different contexts or conditions (Sukarma et al., 2024). Furthermore, this activity also serves as an indicator of whether mathematics learning objectives have been achieved (Isnawan et al., 2024).

Another activity included in the implementation is reflection. This activity aims to identify weaknesses or lessons learned that can be used to improve the quality of learning in subsequent sessions. The results of this study align with those of Radović et al. (2023), who state that reflection is a key activity, especially at the end of a lesson. This is because reflection allows students to determine whether learning objectives have been achieved, whether the learning process has gone well, and to identify future learning improvement plans (Heydari & Beigzadeh, 2024; Patel, 2023). At the very least, one indicator that can be assessed in this reflection activity is students' feelings about whether the learning is enjoyable (Johnsen et al., 2023 ; McKim, 2023).

The evaluation results reveal that the development and implementation of the *MathDifi* application go well. However, there is one obstacle: students' answers cannot be saved in the *MathDifi* application. This is expected to lead to future improvements in the application. In fact, student responses stored in the application can be used as a basis for in-depth analysis or evaluation of the success of a learning process (Farley & Burbules, 2022; J. Y. Park et al., 2022). Contrary to these research findings, Annuš and Kmeť (2024), state that one aspect that should be considered when using software to develop teaching materials is the software's ability to store student responses or answers, thus making learning more personalized.

Nevertheless, the research findings reveal that the *MathDifi* application is highly practical based on teacher responses (98%) and practical based on student responses (79%). This finding is due to the application's development being based on student characteristics or needs, as well as the availability of learning support facilities and infrastructure. These research findings align with those of Outhwaite et al. (2023), who find that applications designed to meet student needs tend to be more interactive and engage students' interest in learning mathematics. This is because the features in these applications tend to be more appropriate for students' age and cognitive development levels (Divyasri et al., 2025).

Finally, the results of this study reveal that the implementation of the *MathDifi* application is indicated to have a positive impact on students' MCTS. These findings are relevant to global trends, as reported by PISA and the OECD, which reveal that creative thinking skills and digital literacy are key competencies that must be optimized in education in the 21st century. This is because the application provides students with the opportunity to use or explore ideas through existing features. In fact, the quiz feature is one of the features that is quite attractive to students because they feel like they are playing a game. These results are then in line with several previous studies (Kaźmierczak et al., 2025; Zagoto et al., 2025), which reveal that interactive learning applications tend to be favored by students during mathematics learning because they have an attractive appearance and several features or menus that attract students' interest in learning. In fact, the quiz feature is one of the favorite menus in learning applications because students feel challenged to solve or answer the questions and feel as if they are playing a game (Isnawan et al., 2025; Magadán-Díaz & Rivas-García, 2022; Rayan & Watted, 2024). The findings of this study also have implications for STEM/STEAM education and learning globally, particularly regarding the development of adaptive learning applications tailored to student needs (Islam, 2026; Webb, 2026). These findings align with the PISA and OECD reports, which highlight the importance of creative thinking skills and the use of technology in school learning.

CONCLUSION

There are several conclusions from the findings in this study. First, the tendency to use conventional learning methods, such as lecture methods and the limited use of interactive learning media, as well as routine problems, is indicated as a factor contributing to low MCTS. Second, the use of interactive learning media based on differentiated instruction is an alternative solution to optimize these competencies. Third, the *MathDifi* application based on differentiated instruction using the discovery learning model according to students' learning preferences is an interactive learning media choice to optimize student competencies. Fourth, the implementation of the *MathDifi* application has the potential to optimize MCTS. This is because the application facilitates student learning according to their learning preferences, provides students with opportunities to explore ideas using interactive media, and provides rapid feedback when students solve problems. However, further research on these results using a different, more robust design than this study is needed.

There were several limitations to this study. First, the *MathDifi* application was unable to save the responses presented by students. Second, the study was conducted in only one school, so the results may have been influenced by the quality of the mathematics teachers involved in the learning process. Third, this study used a quasi-experimental design without random assignment so that the research results needed to be interpreted more carefully. This study recommends that future researchers consider the software used before developing applications. Applications should be able to store student answers or responses without requiring redirection to Google Forms. This is intended to make it easier for teachers to assess students. In addition, the use of a more relevant research design is expected to produce findings that can be generalized.

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Ethical statement

This research obtained permission from the school and approval from students during data collection.

Competing interests

There is no competing interest in this research.

Author contributions

Peni Anggareni: research concept and design, collection and/or assembly of data, data analysis and interpretation, and writing the article. Yaya S. Kusumah: research concept and design, data analysis and interpretation, critical revision of the article, and final approval of the article. Jarnawi Afgani Dahlan: research concept and design, data analysis and interpretation, and critical revision of the article. Siti Fatimah: research concept and design, collection and/or assembly of data, and critical revision of the article. Stevi Natalia: collection and/or assembly of data and critical revision of the article. Rima Aksen Cahdriyana: collection and/or assembly of data, data analysis and interpretation, critical revision of the article, and final approval of the article. Hendra Lesmana: collection and/or assembly of data, data analysis and interpretation, and critical revision of the article.

Data availability

This research data is available upon request.

AI disclosure

The researcher did not use AI in the process of writing this article.

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