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Digital-Worksheets Based Creative Problem Solving to Support Students Mathematical Thinking for Audio-Visual Students

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Abstract

Mathematical thinking involves how individuals present, understand, and critically examine mathematical truths, considering how their relation to representation or imagination. However, students often exhibit low mathematical thinking skills. Previous research shows that digital worksheets based on creative problem-solving can foster these skills, yet the relationship between mathematical thinking and learning styles remains unexplored. This study aims to develop innovative digital worksheets based on creative problem solving, categorized as valid, practical, and effective in enhancing students' mathematical thinking with audio-visual learning styles. The study employs a development method comprising two main stages: a preliminary study (analysis and design) and a formative study (evaluation and revision). Data collection instruments include tests, observations, validation sheets, questionnaires, and interviews. The analysis integrates both quantitative and qualitative approaches. The study involved 15 audio-visual learners from 24 eighth-grade students at SMP Srijaya Negara Palembang. The results indicate that students excel in specializing and identifying problems based on given information. Their generalizing skills, including finding patterns and relationships are strong. However, their conjecturing and convincing skills require improvement, particularly in making connections and reasoning. The digital worksheets were deemed 93% valid and practical, significantly enhancing students' mathematical thinking, particularly for those with an audio-visual learning style. While students demonstrated excellent skills in specialization and good skills in generalization, there is still a need for improvement in conjecturing and convincing due to errors in mathematical reasoning.

Keywords: Audio-Visual, Creative Problem Solving, Digital-Worksheets, Formative Study, Mathematical Thinking

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INTRODUCTION

Mathematics is a scientific field that explores patterns in structure, change, and space, emphasizing substantial thinking processes that motivate pupils to follow logical norms and patterns, a process referred to as mathematical thinking (Oljayevna, 2020; Pourdavood et al., 2020). Mathematical thinking encompasses a wide range of mental activities that are crucial for understanding, processing, and analyzing information. These cognitive processes play a fundamental role in solving mathematical problems, as highlighted by several researchers (Çelik & Özdemir, 2020; Goos, 2019; Mustafa & Sari, 2019). Additionally, mathematics play a crucial role in developing essential life skills by fostering problem-solving, critical thinking, and analytical reasoning (Sharma, 2021). Mathematical thinking refers to the ability to present, comprehend, and deeply reflect on mathematical facts, as well as their connection to imagination or representation (Nasir, 2023; Susanti et al., 2019). Mathematical thinking is distinct from "doing math," which typically entails procedural tasks and some complex symbolic manipulations (Devlin, 2021). Mathematical thinking encompasses reasoning, forming mathematical arguments, developing strategies, understanding content, and communicating ideas (Sari et al., 2022).

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Mathematical thinking demonstrates the ability to solve mathematical problems by applying logical reasoning and a mathematically grounded approach (Mustafa & Sari, 2019). It represents a critical academic skill, deeply intertwined with the core process of mathematical learning and education (Khalil & Ul-Haq, 2019). Mathematics learning in schools aims to train students' thinking patterns and reasoning in concluding, developing skills in solving problems, and developing the ability to communicate ideas through writing, speaking, pictures, and so on (Laine et al., 2022; Santosa & Huda, 2023; Syaiful & Puspayanti, 2023). Four indicators are used to describe mathematical thinking ability: use examples to solve difficult problems (specializing); generalizing (using correlations and patterns as a method of problem-solving); conjecturing (making predictions about connections and outcomes); and identifying and stating the facts that support a claim (convincing) (Iswari et al., 2019).

However, TIMSS and PISA rankings indicate that Indonesian students' mathematical thinking skills are substantially below average, with nearly 70% of junior high school students struggling to solve problems requiring mathematical reasoning. Students' mathematical thinking skills remain underdeveloped (Jawad & Majeed, 2021; Susandi & Khoiriyah, 2024; Wijns et al., 2019). This limitation stems from teacher-centered instruction and individual differences in subject mastery, problem-solving abilities, baseline aptitude, and other factors. A key factor in students' success in mastering a lesson is seen from how good the teacher is in delivering the lesson (Jawad & Majeed, 2021). A contributing factor to the learning process is instructional approaches that fail to encourage the develop of mathematical thinking (Uno, 2023). Consequently, these practices hinder the advancement of students' critical thinking, problem-solving, reasoning, and mathematical communication skills. From the student perspective, mathematical thinking abilities are closely linked to their cognitive patterns in receiving, organizing, and processing problem-related information, which are further influenced by individual learning style (Ica et al., 2024; Sulistiyarini, 2016).

From a learning style perspective, audio-visual learners often make errors in problem-solving due to incomplete comprehension, lack of accuracy, and difficulty addressing unfamiliar questions (Bosman & Schulze, 2018; Ma & Ma, 2014). In contrast, errors by auditory learners often stem from limited subject comprehension and inaccuracies in final responses due to calculation errors (Malacapay, 2019; Rogowsky et al., 2020). However, no significant difference are evident in the mistakes made by children with visual and auditory learning styles (Harahap, 2021; Sulisawati et al., 2019). Students with a visual learning style, characterized by their propensity for rapid reading and problem-solving, frequently make errors when identifying patterns and drawing inferences, as reflected in an error rate exceeding 70% (Hadi et al., 2022; Ishartono et al., 2021). Additionally, students with an auditory learning style, who tend to focus on a single step in formula discovery and exhibit limited effort, have a 70% error rate categorized as high for pattern recognition. Furthermore, 80% of their conclusions fall into the extremely high error category (Hadi et al., 2022). Students with an audio-visual learning style have not yet reached the stage of reviewing the solutions they obtained (Firman et al., 2024). This indicates that students with an audio-visual learning style still struggle with mathematical thinking.

The issues mentioned above can be addressed by implementing a learning approach that incorporates cognitive processes and creative ideas tailored to students' learning styles and interests. The use of interactive teaching materials and software, equipped with video, animation, and audio, enriches the learning experience and serves as a stimulus that can be adapted to students' needs (Firman et al., 2024). Previous research indicates that digital worksheets are effective interactive teaching materials for learning (Putu et al., 2023) .Digital worksheets can engage students actively with the material, and students gain direct experience rather than limiting their learning to mere knowledge (Aisyah & Solfitri, 2022; Subekti & Prahmana, 2021; Utaminingsih et al., 2024).

An alternative instructional method that utilizes information and communication technology is the use of digital worksheets, which encourage students to share their work and enhance teacher-student interaction. In investigations, interactive digital teaching can engage students in high-level thinking by guiding them to observe and answer a series of questions (Shatri & Shala, 2022). The rapid advancement of information technology encourages the education sector to integrate various media into digital teaching materials. Digital worksheets not only provide textual information but also include images, graphics, videos, and audio to enhance student understanding. Additionally, the use of digital worksheets helps teachers increase students' attention levels (Sari et al., 2022). Digital worksheets can be easily accessed via smartphone or laptop. The questions, accompanied by pictures and videos, capture students' interest, and the results can be sent directly to the teacher's email (Chofifah & Wintarti, 2023; Juliana et al., 2024).

Additionally, it is important for students to develop problem-solving skills through mathematical thinking (Fauzi et al., 2023; Pambudi et al., 2020). One effective stimulus for fostering mathematical thinking skills, tailored to students' learning styles, is creative problem solving (Partika, 2024). Problem solving skills are crucial in mathematics education, influenced by various factors, including students' diverse learning styles (Firmansyah et al, 2023; Mattoliang et al., 2024). Moreover, the use of learning media can support different student learning styles (Fajari et al., 2020). There are 3 types of learning styles, each corresponding to learning modes: visual learning (learning by seeing), auditory learning (learning by hearing), and kinesthetic learning (learning by moving and trying). The integration of character values from various learning styles into the learning process can be facilitated through learning media that engage students by meeting their learning preferences, enhancing both enjoyment and interest in learning (Shirvani, 2016).

However, previous studies have conducted limited research on mathematical thinking skills using digital worksheets, particularly for students with audio-visual learning styles (Harahap, 2021). Implementing digital worksheets to enhance mathematical thinking skills requires the adoption of appropriate teaching methods (Putu et al., 2023; Utaminingsih et al., 2024). The low ability of students to solve mathematical problems stems from a learning process that does not encourage creative thinking. Implementing the Creative Problem-Solving method in learning can enhance student's mathematical thinking, while also improving teacher engagement, student participation, attitudes, and skills in each cycle (Iswari et al., 2019; Susanti et al., 2019). Based on the description above, this research aims to develop innovative teaching materials in the form of digital worksheets based on the Creative Problem Solving (CPS) method. These worksheets are designed to be valid, practical, and effective in enhancing the mathematical thinking abilities of audio-visual learners.

METHODS

Subject

The subjects of this research consisted of 15 eighth-grade students with audio-visual learning styles, selected from a total of 24 students at SMP Srijaya Negara Palembang, enrolled in the odd semester of the 2023/2024 academic year. The subjects comprised six male and nine female students, selected based on the results of a learning style questionnaire administered prior to the research. Participants were required to have access to adequate digital facilities, such as a smartphone or laptop, to support digital learning activities. The developed digital worksheets will be categorized based on aspects of content, layout, and support as in Table 1.

Table 1. Indicators of content, layout, and support

Aspect	Indicator
Content	Accordance to Phase D
	By learning purpose
	The material is arranged from easy to difficult and systematically
	Contains correct facts, concepts, and principles
	Accordance to Creative Problem Solving
	The problem is interesting and challenging
	Accordance to students' learning styles
Layout	Contains title, identity, learning purpose, and steps
	Accuracy and consistency of font types
	Layout settings
	Colour and design
Support	Visual illustrations either images or videos
	Narrator's Voice
	Easy to use

Research Procedure

This research employs development methods, following a procedure that generally consists of two main stages: a preliminary study and a formative study (Nieveen & Folmer, 2013). The preliminary study includes the analysis and design phases, while the formative study involves evaluation and revision. At the analysis stage, an evaluation of the current curriculum, specifically the *Kurikulum Merdeka* (Independent Curriculum), is conducted. Additionally, this stage involves identifying the abilities, skills, and mathematical concepts suitable for students with auditory-visual learning style. The subsequent stage is the design phase, which comprises two steps: the development of a paper-based concept and layout design, followed by the creation of a computer-based digital worksheet design.

The formative evaluation stage begins with the validating of the computer-based digital worksheet prototype. Feedback from the validators is utilized to revise the prototype. After the revisions, the prototype is tested with a group of students identify its weaknesses, particularly when used by students with visual-auditory learning style. Any shortcomings discovered during one-to-one, small group, and field tests are used as the basis for further evaluation and refinement of the digital worksheet.

Data Collection

The instruments for data collection included tests, observation, validation forms, questionnaires, and interviews. Tests were utilized to assess students' mathematical thinking abilities. Observations were conducted to gather data on how students interacted with the digital worksheet, the challenges they encountered, and their potential responses. Validation forms were employed to obtain feedback from validators regarding the content, construct, and linguistic validity of the digital worksheet under development. The instruments used included a learning style questionnaire and a practicality questionnaire. The learning style questionnaire was administered prior to the learning process to identify students' learning styles. The practicality questionnaire was utilized in small group settings to evaluate the usability of the digital worksheets. Semi-structured interviews were conducted to explore students' perceptions of the digital worksheets and their application in the learning process (Widayanti et al., 2019).

Data Analysis

Data analysis employed a combination of quantitative and qualitative descriptive techniques. The test results were analyzed quantitatively and presented in tables with categorized as excellent, good, sufficient, poor, and very poor in Table 2 category table. These quantitative findings were subsequently described qualitatively.

Table 2. Category table

Interval	Category
$80 < x \leq 100$	Excellent
$60 < x \leq 80$	Good
$40 < x \leq 60$	Enough
$20 < x \leq 40$	Less
$0 < x \leq 20$	Poor

Observation findings are described based on the phenomena observed in the field, such as students' interactions, engagement levels, and responses to instructional strategies. These observations provide valuable insights into the practical dynamics of the learning process, enriching the interpretation of the quantitative results. Validation data is presented in diagrammatic form, including charts or graphs, to highlight key trends and is then discussed qualitatively to connect visual patterns to meaningful conclusions. The results of the learning style questionnaire were analyzed by calculating the most dominant responses, which indicate the students' preferred learning styles and offer guidance for tailoring instructional methods. Interview data is transcribed and subsequently analyzed qualitatively, uncovering nuanced perspectives, and capturing students' experiences and reflections in their own words.

RESULTS AND DISCUSSION

Analysis Results

The analysis stage included curriculum analysis and an examination of student characteristics. The initial step in this research involves analyzing the Kurikulum Merdeka (Independent Curriculum). The curriculum analysis reveals that mathematics learning outcomes in phase D consist of several elements: numbers, algebra, measurement, geometry, as well as data and opportunity analysis. In this research, the number elements were selected, specifically focusing on number patterns, as they are fundamental to developing students' logical reasoning and problem-solving skills. The material analysis indicates that students with an audio-visual learning style can identify patterns effectively by paying attention to video illustrations while listening to sound-based explanations, which combine visual and auditory stimuli to enhance understanding and retention. This alignment ensures that the teaching materials are accessible and engaging for diverse learners.

The analysis of student characteristics revealed that students with visual learning styles tend to focus on video illustrations in finding problem-solving patterns. Conversely, students with audio learning styles prefer listening to the explanation and engaging in discussion to share ideas with friends. This aligns with previous research, which found that students with visual learning styles generally understand by looking at pictures, diagrams, demonstrations, or videos. Students with auditory learning styles process information more effectively when engage in discussions, both inside and outside the classroom, verbally sharing ideas with friends, and taking notes on lesson material. Therefore, the mathematical abilities, skills and ideas presented in digital worksheets must also be suitable for students with auditory-visual learning styles. Optimizing the use of photos, videos, and audios is the main key characteristic of this digital worksheet.

Design Results

This stage consists of two design stages: paper-based concept and layout design, followed by the computer-based digital worksheet design. The paper-based design stage begins with sketching on paper to conceptualize the forms and components that will be displayed on the digital worksheet, identify students' activities, and determine the necessary supporting elements such as visual aids, instructions, and interactive features. This initial step helps ensure that the design aligns with the learning objectives and provides a clear framework for the subsequent digital development process. Figure 1 illustrates the results of the paper-based concept design.

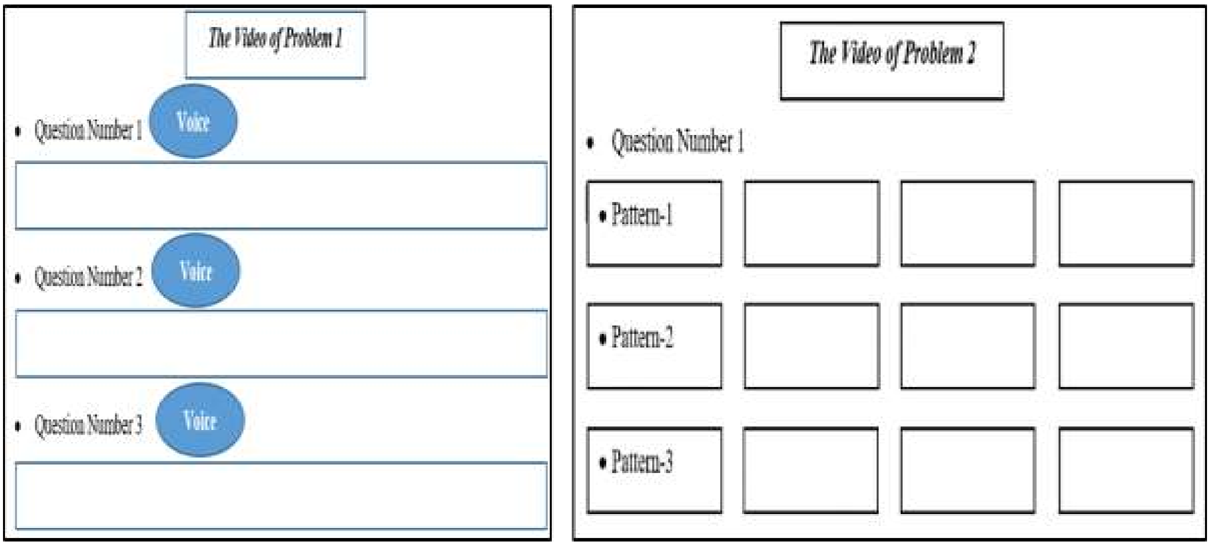


Figure 1. Paper based design

Figure 1 illustrates a written concept designed for implementation in the digital worksheet. The idea starts with the arrangement and flow of steps that will be used, starting with a thought-provoking video, followed by written and audio-based questions. After that, there is a space for students to directly respond to the questions in order to correspond with the stages of thought that are desired. The paper-based concepts were then transformed into a computer-based version using The Wizer.Me application. The initial prototype of the digital worksheet developed in the Wizer.Me application focuses on three characteristics: content, support, and layout. Apart from that, the problems presented in the digital worksheet are designed to align with the Creative Problem Solving (CPS) approach. From a layout perspective, this digital worksheet incorporates attractive images and colors, as well as videos designed to enhance students' understanding. The computer-based design for the first and second meetings can be depicted in figure 2.

Figure 2. Computer-based paper design

Figure 2 shows that the student worksheet begins with a learning video, created and uploaded to YouTube and linked in the digital worksheet. This is followed by several questions based on the Creative Problem Solving (CPS) learning syntax, presented in both written and audio format. Below each question, a designated place is provided for students to respond based on the instructions in the worksheet. Students can submit their answers not only by typing, but also through audio, images, and photos uploading.

Validation Results

The formative evaluation stage begins with validation of the computer-based digital worksheet prototype. Three validators participated in this research: SA, AOL, & SHZA. The analysis of the validation data revealed that the digital worksheet achieved validity at 93%. Based on these results, it can be concluded that the digital worksheet is categorized as 'good' in terms of its content, layout, and support aspects. Figure 3 presents the validation results.

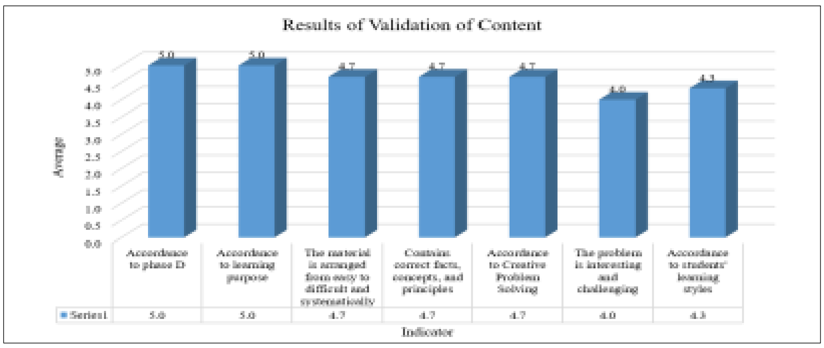


Figure 3. Content validation results

Figure 3 illustrates validation results in the content aspect. It shows that the developed digital worksheet is valid and aligns with the applicable curriculum. However, while the questions presented are quite interesting but not yet challenging to solve. Figure 4 were the validation result of layout and support.

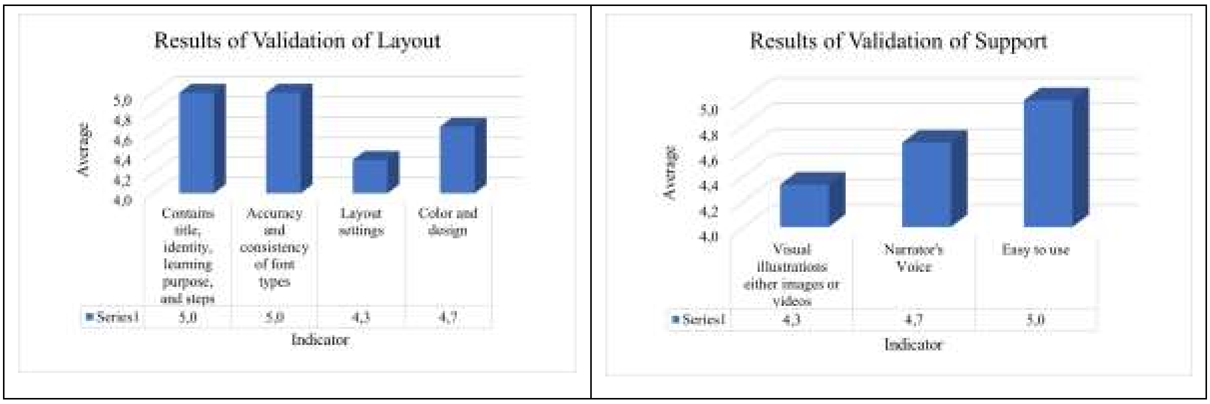


Figure 4. Layout and support validation results

Figure 4 depicts of the results of the validation of the layout and support aspects. From the layout and support aspects, it was found that the developed digital worksheet was also good. However, in terms of layout settings, it remains not optimal. Although the validation findings are considered good, the validator has made several comments and recommendations to enhance the digital worksheet. Table 3 contains comments and suggestions from validators.

Table 3. The validators' comments

No	Comments
1	Each video's questions are too long, making it challenging for pupils to understand them
2	Prior to the table that leads to the pattern in activity 2
3	Similar to Activity 1, Activity 2 includes questions that enable students to identify patterns on their own
4	Find out which patterns are the simplest
5	To make things easier for pupils, each question is assigned a sequential number.
6	Activity 2 contains pictures, but it would be easier for kids if you just used the table feature.

Based on Table 3, several comments were given by the validator regarding the difficulty level of the questions, the features to be used, or other aspects that required improvement. For instance, the validator suggested simplifying long questions in the videos to make them more understandable for pupils and using tables instead of pictures to enhance clarity in Activity 2. Additionally, sequential numbering of questions was recommended to provide better organization and ease of navigation for students. Following these suggestions, the digital worksheet was immediately corrected and then continued to the next stage.

One-to-One and Small Group

After revisions were made, the digital worksheet prototype was tested on a group of students in order to identify any potential issues, particularly among those who learn best visually and auditorily. Some of the feedbacks provided by the kids throughout the trial includes: (1) students prefer math lessons with illustrations rather than those that only include formulas; (2) this digital worksheet's design is appealing, with colors that are not too flashy; (3) the inclusion of videos and explanations helps students understand the material; (4) the explanation and video should be concise, as students tend to forget the first information; (5) adding music would help prevent boredom when answering the questions; (6) a "voice" would be helpful to avoid fatigue from writing the response; additionally, (7) some students found it challenging to upload photos due to the size of their fingers.

This stage concludes with the administration of a questionnaire to evaluate the practicality of the digital worksheets used during the lesson. The questionnaire consists of 15 questions, covering cognitive, affective, and conative aspects to provide a comprehensive assessment of the worksheet's usability and effectiveness. The results, which highlight students' perceptions and experiences, are presented in Figure 5.

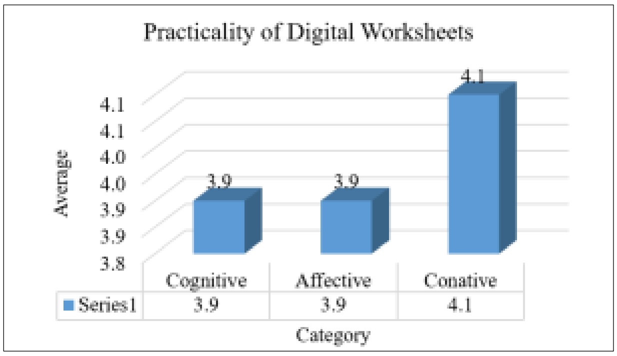


Figure 5. Practicality of Digital Worksheets

Figure 5 illustrates the practicality results of the developed digital worksheet, evaluated across cognitive, affective, and conative aspects. Based on the practicality questionnaire, the developed digital worksheet was categorized as good. Students found the digital worksheets easy to understand, which is influenced by the clarity of the directions, the presentation of the material, and the appealing of the design. Digital worksheets are also able to motivate students engage enthusiastically in solving the given problems. This digital worksheet also encourages students to actively ask questions or respond during learning. This aligns with the research by Sinuraya & Frisnoiry (2023), which found that learning supported by ICT through digital worksheets containing digital-based work steps and are arranged according to students' needs, with an appealing appearance using videos, images, text and engaging activities which enhances the effectiveness of learning.

Field Test Results

The next stage is field testing, where the research subjects engage in learning using digital worksheets. Two digital worksheets are provided for students during the learning process. At the beginning of the activity, students are directed to watch a short video introducing the problem they will solve. The video gradually guides students in identifying patterns in the series they are discussing. The digital worksheet contains several questions designed to lead students in finding solutions. These questions refer to the videos students have watched previously. In the final section, students are encouraged to find regularities and patterns based on videos and scaffolding questions, ultimately leading them to derive a general form for the nth arrangement.

During the field test stage, two learning activities were conducted using digital worksheets based on creative problem solving. Each student can use a handphone or laptop to access the material and work on the problems contained in the digital worksheets. In the first digital worksheet, students are shown a video illustrating the number pattern arrangement using several wooden sticks of the same size, providing a visual and contextual introduction to the concept. They are then asked to determine how to calculate the number of sticks in the nth arrangement, encouraging analytical thinking and fostering a deeper understanding of pattern recognition. Figure 6 below shows the digital worksheet that was tested during the field test stage.

Figure 6. The digital worksheet activity 1

Figure 6 shows the interface of the digital worksheet for Activity 1, which includes the steps of Creative Problem Solving described as follows. In working on this digital worksheet, students are guided through four learning steps based on the Creative Problem Solving (CPS) learning model.

First step is problem classification. In this step, students are directed to find any information from the activity 1 problem, which they obtained after watching the provided video. As shown in Figure 7, students are able to note the information presented in the video illustration. They reported that, based on the video, they discovered that there were three sticks in the first arrangement, five in the second, seven in the third, and nine in the fourth, with two sticks separating each arrangement. Furthermore, through this information, students can write down the problem to be solved: determining the pattern for calculating the number of sticks in the nth arrangement. The results of students' responses at the problem classification stage are shown in Figure 7.

Figure 7. Student answers in problem classification step

Figure 7 illustrates students' answers at the problem classification step, where in number 1 students are asked to determine what information they have obtained and in number 2 students are asked to find out what problems they need to solve. After completing the problem identification step, students proceed to activities in the expression of opinion step. At the stage of expressing opinions, students are directed to express their ideas to find patterns that can be used to solve problems. Figure 8 indicates that students are able to find patterns and relationships, specifically that there will be an increase of 2 sticks in each order of arrangement. The results of students' answers at the opinion expression stage are shown in Figure 8.

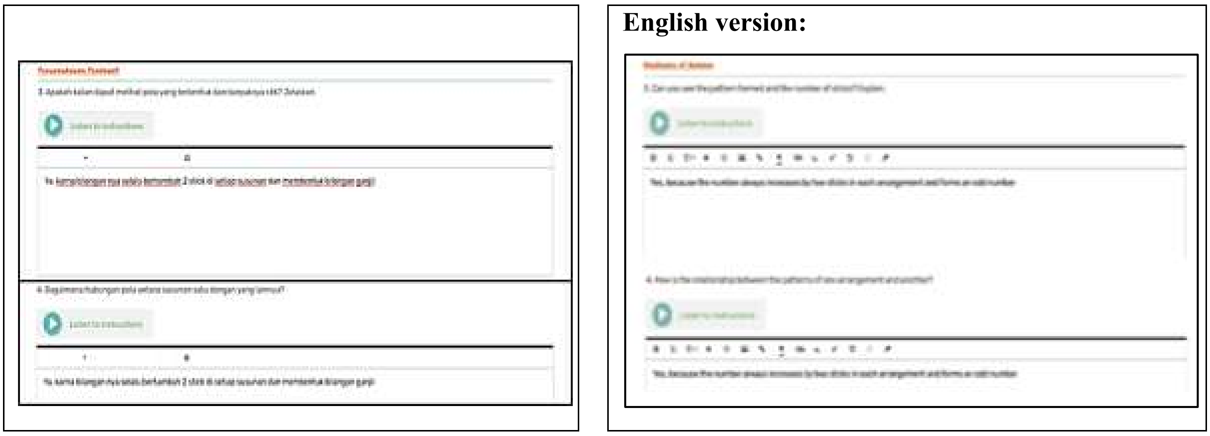


Figure 8. Student answers in expression of opinion step

Figure 8 illustrates students' answers at the opinion expression step where in number 3 students are asked to explain whether they found a pattern and in number 4 students are asked to explain the relationship between the arrangement patterns that they have found. After did the expression of opinion step, students continued to evaluation and selection step. At the evaluation and selection step, students are directed to find a general formula for finding the number of sticks in the nth arrangement. Figure 9 shows that students can get a general formula to find the number of sticks in the nth arrangement using the formula $(n\ x\ 2) + 1$. The results of students' answers at the evaluation and selection step are shown in Figure 9.

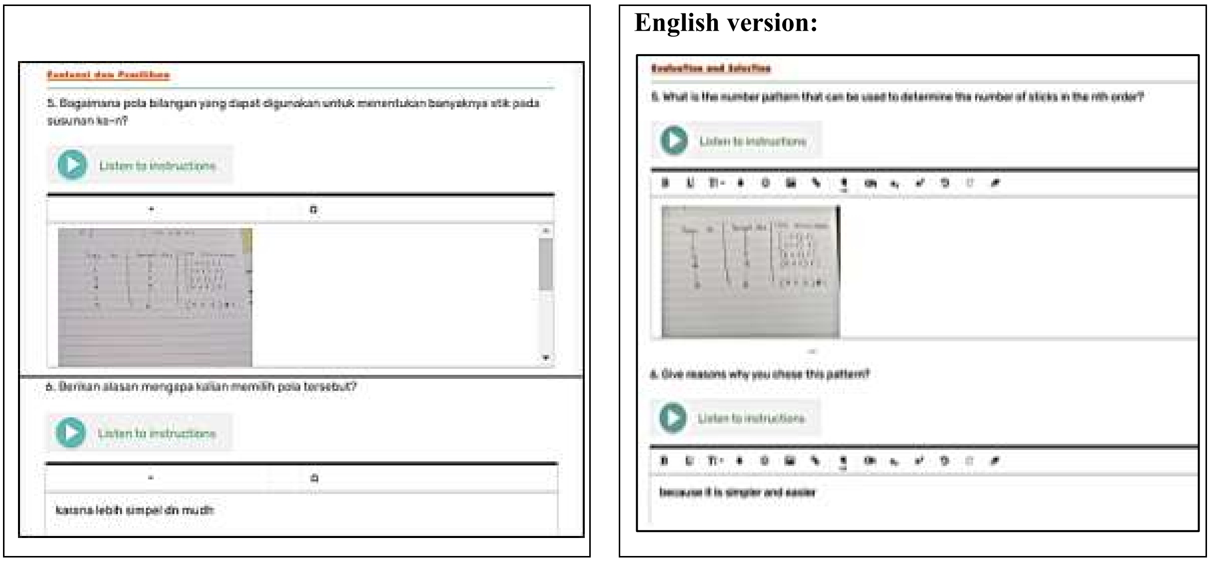


Figure 9. Student answers in evaluation and selection step

Figure 9 depicts students' answers at the evaluation and selection stage, where in number 5 students are asked to show the pattern of the nth arrangement. While in number 6, students are asked to explain the reasons for choosing this pattern. After they did evaluation and selection step, the final step is implementation. In this step, students are directed to implement the obtained ideas. Figure 10 shows that students were able to implement the general formula they obtained by entering $n = 100$ the formula $(n\ x\ 2) + 1$, resulting in $100\ x\ 2 + 1 = 201$. The results of students' answers at the implementation stage are shown in Figure 10.

Figure 10. Student answer in implementation step

Figure 10 demonstrates students' answers at the implementation stage where in number 7 students are asked to implement the results of the number patterns they have found. Here students are also asked to determine the number of sticks in the 100th arrangement using the found pattern.

After the learning activities, students are asked to complete the mathematical thinking test. The test consists of three essay questions. The results of tests conducted by audio-visual students after learning through four stages of creative problem solving using digital worksheets reveals that students are able to solve the given problems in the 'enough' category. This aligns with research by Hadi et al.

(2022) which stated that students with an audio-visual learning style tend to make mistakes in hasty situations, such as hasty reading and being lazy in making conclusion which leads to a high error rate in solving problems, especially in finding patterns and concluding results. The average score of the audio-visual students are shown in Table 4.

Table 4. Average Student Score

Interval	Frequency	Percentage	Category
81-100	0	0	Excellent
61-80	8	53.3%	Good
41-60	5	33.3%	Enough
21-40	1	6.7%	Less
0-20	1	6.7%	Poor
Number	15		
Average	55		
Category	Enough		

Apart from that, the researchers also conducted interviews with students to understand their thinking processes in solving problems. Students' mathematical thinking was observed through four key aspects: specializing, which refers to the ability to focus on the important elements of a problem; generalizing, which involves connecting concepts or patterns from one situation to another; conjecturing, which refers to the ability to make guesses or hypotheses based on observed patterns; and convincing, which includes the ability to provide reasoning or evidence to support the decisions made during the problem-solving process. Figure 11 shows 3 student responses in solving the test question given.

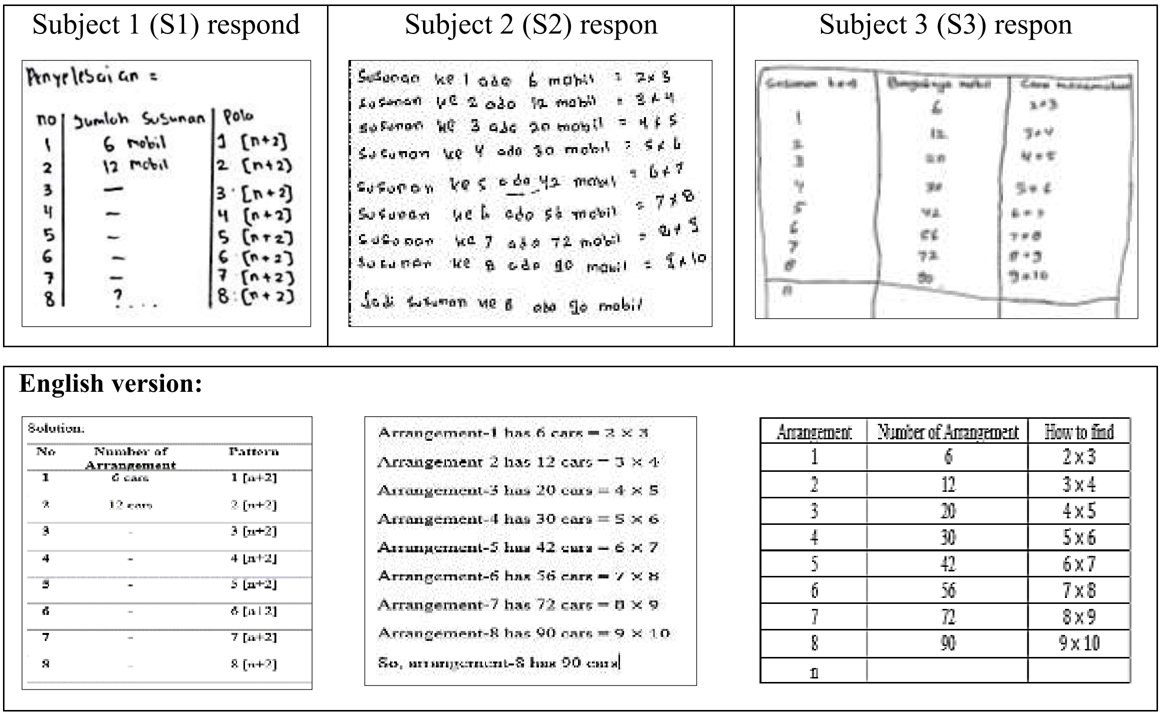


Figure 11. Answers of Subject 1, Subject 2, and Subject 3 for question number 1

Based on Figure 11, by documenting the known information and addressing question number 1, S1 demonstrates the ability to recognize and evaluate issues, enabling specialization and generalization. To identify patterns and relationships and make informed judgment about solving the problem, S1 created a table outlining various arrangements and patterns. However, while S1 applied the identified pattern to sequentially record each arrangement up to the eighth, the pattern and solution remained incorrect. By listing the arrangements sequentially up to the eighth arrangement, S2 demonstrates the ability to identify patterns and relationships in object configurations, enabling specialization and generalization. S2's observation that the object arrangement forms a rectangle connects the idea of multiplication to the calculation of a rectangle's area. The concept of S3 is nearly identical to that of S2. After attempting multiplication, which provided the number of toy cars in the first and second arrangements, S3 was able to explain the discovered patterns and relationships. This approach created the impressions that the numbers in the multiplication were sequential and progressed one after the other until the eighth arrangement. In contrast to the preceding subjects, S4 and S5 struggled to generate conjectural ideas from the identified patterns, resulting in the formula $(n+1)\ x\ (n+2)$. Interviews conducted by researchers with several students also showed that they had engaged in a mathematical thinking process while solving problems.

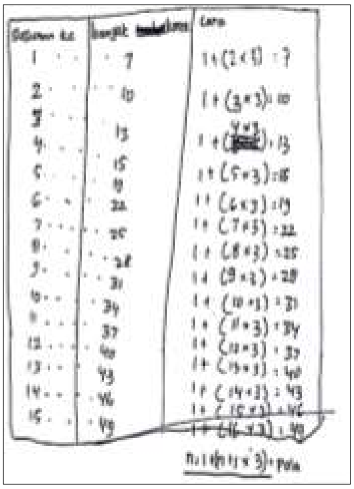
P : *"Where did you get 2 × 3, 3 × 4?"*

S3 : *"Looking from the side ma'am, there are 2, 3 (while pointing to the picture in the question) from the top and bottom."*

P : *"Why do you think it is multiplied by the top and bottom?"*

S3 : *"Because from the shape ma'am it looks like a rectangle so use the rectangle formula."*

S3 also meets the convincing indicator. This is shown from the interview results where S3 was able to test the alleged answer until it was proven correct by trial and error during the interview.

Subject 1 (S1) respond	Subject 3 (S3) respon	Subject 5 (S5) respon
		

English version:

Information = tower-1 = 7 matches

tower-2 = 10 matches

Asked = Tower-15 = ?

From the first match (7) plus 3 until it reaches 10, then so on…

1) 7

2) 7+3 = 10

Each tower to get tower-15 is separated by 3 until

10 + 3^{12} or 10 + 36 = 46 matches

So, the number for tower-15 is 46 matches

Arrangement	The Number of Matches	Method
1	7	1 + (2 x 3) = 7
2	10	1 + (3 x 3) = 10
3	13	1 + (4 x 3 = 13)
4	15	1 + (5 x 3) = 16
5	19	1 + (6 x 3) = 19
6	22	1 + (7 x 3) = 22
7	25	1 + (8 x 3 = 25)
8	28	1 + (9 x 3) = 28
9	31	1 + (10 x 3) = 31
10	34	1 + (11 x 3) = 34
11	37	1 + (12 x 3) = 37
12	40	1 + (13 x 3) = 40
13	43	1 + (14 x 3) = 43
14	46	1 + (15 x 3 = 46)
15	49	1 + (16 x 3) = 49
		n = 1 + (n + 1 x 3) = pattern

It known that tower-1 has 7 matches
Tower-2 has 10 matches
Tower-3 has 13 matches
Tower-4 has 16 matches
Tower-5 has 19 matches
Tower-6 has 22 matches
Tower-7 has 25 matches
Tower-8 has 28 matches
Tower-9 has 31 matches
Tower-10 has 34 matches
Tower-11 has 37 matches
Tower-12 has 40 matches
Tower-13 has 43 matches
Tower-14 has 46 matches
Tower-15 has 49 matches
So the number of matches in tower-15

Figure 12. Answers of Subject 1, Subject 3, and Subject 5 for question number 2

The ability to specialize and generalize is present in S1, S5, and S3. S1 recorded the pattern's relationship by noting that the first arrangement contained seven matches and subsequently added three more matches for each subsequent arrangement. By adding three matches to the number of matches in the previous tower, S2 can observe the pattern and relationship of object configurations by registering the towers one by one till the fifteenth tower. Additionally, S3 demonstrates the ability to conjecture, generalize, and specialize. Through a systematic thought process, S3 identified relationships and patterns while exploring potential solutions to the issue. To arrive at a solution, specifically solving problem using the formula $1 + ((n + 1)\ x\ 3)$, S3 first created a table to record the pattern used to determine the number of matches in each tower configuration. Nonetheless, S3's writing was careless, as evidenced by the absence of brackets to divide $((n + 1)\ x\ 3)$,. S4's approaches to problem-solving are nearly identical to those of S2. S4 began his concept by sketching the tower. Interviews conducted by researchers with several students further revealed that they engaged a mathematical thinking process in solving problems.

P : *"Where did the additional matchsticks come from?"*

S5 : *"I see from here ma'am (while pointing to the tower picture that was given), if you compare the two towers, there is an additional square picture that requires 3 matchsticks ma'am."*

P : *"So how many matchsticks are added?"*

S5 : *"There are 3."*

P : *"Can you show me which 3 matchsticks were added?"*

S5 : *"This one ma'am, the bottom square ma'am has an additional square that contains 3 matchsticks."*

This also indicates that S5 is also able to test the assumptions with verbal explanations and illustrated during the interview.

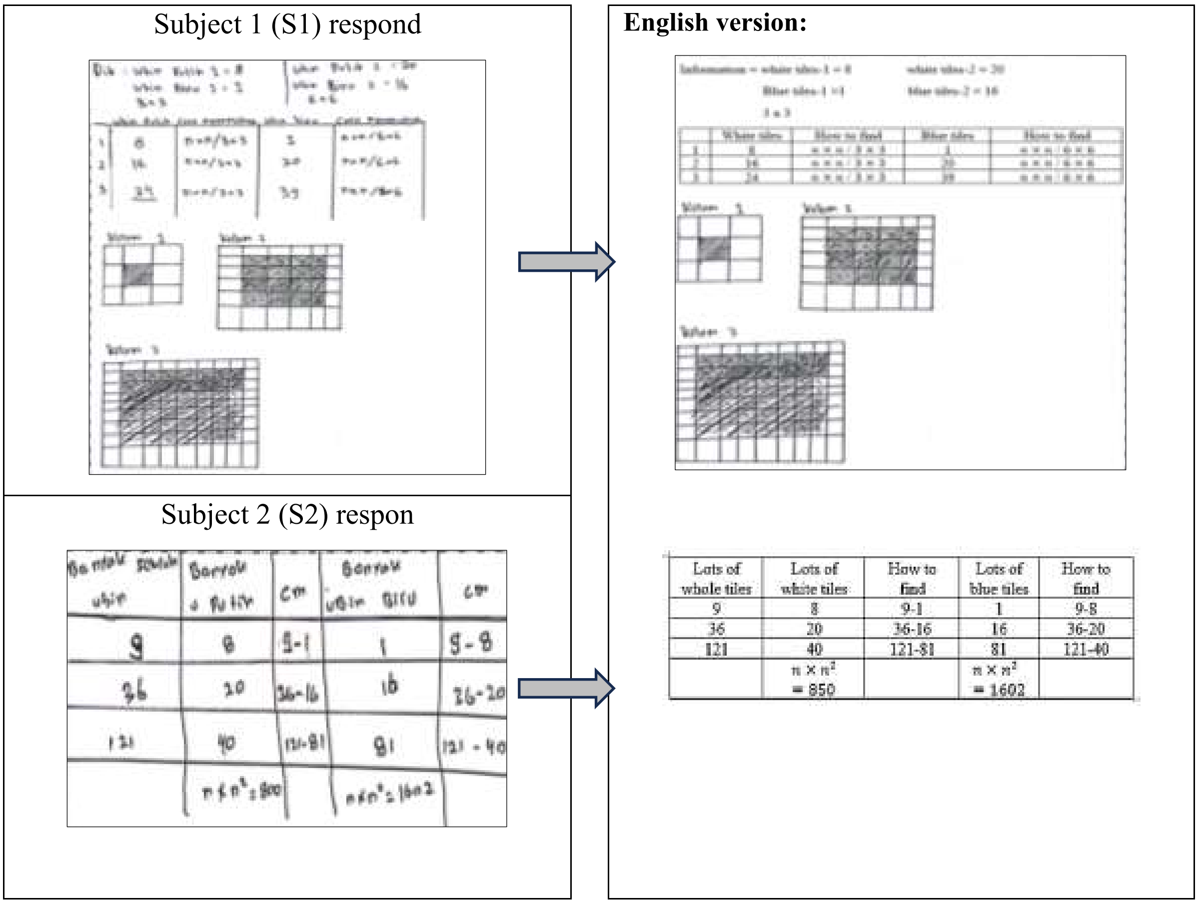


Figure 13. Answers of Subject 1 and Subject 2 for the last question

In Figure 13, S1 demonstrates the ability of specialization, generalization, conjecture, and persuasion. For the second column sketch, S1 noted that the number of blue tiles growing by 19 and the number of white tiles increasing by 8 tiles. However, S1 made errors in identifying the relationship and predicting the pattern in this case. This assumption was corrected through a sketch of the third pool, which provided clarity. In contrast, S2 did not document the information provided in the problem. However, during the interview, when asked about identifying the information provided and analyzing the problem to be solved, S2 said "What you will look for is the number of blue and white tiles." To figure out how to locate pools 1 and 2 in sketching, S1 created a table with the number of tiles and how to calculate them. S2 used this information to think through the problem, looking for patterns and linkages, as well as making educated guesses about how to solve it. The student's response is accurate, yet there are still errors that prevent movement on to the next sketch. The formula $n\ x\ n^2$ may be used to solve this problem, as S2 suspected, but this assumption remained incorrect. S4's responses and concepts closely resembles those of S1, with minor differences. Similarly, S3 and S4's concepts and responses are almost identical to those of S2. Interviews conducted by researchers with several students further revealed that they engaged in a mathematical thinking process in solving problems.

P : *"How can you answer like this?"*

S1 : *"I counted the white tiles and blue tiles in pool 1 and pool 2, then I wrote them in a table and drew them."*

P : *"Then what did you get?"*

S1 : *"From comparing the two pools, it looks like they have the same shape, which is a square, for pool 1 the sides are 3, for pool 2 the sides are 6, then the white tiles are in the edge squares of the square and the blue tiles are in the middle."*

P : *"How can you determine pool 3?"*

S1 : *"By looking at the sides, there are 3 more, so for pool 3 there are 3 more than the previous sketch so the side of the square is 9."*

P : *"Why is it not written in the table as 9 × 9."*

S1 : *"Yes ma'am, earlier I was still confused about how to write it and was in a hurry."*

The results show that Students' ability to specialize, generalize, speculate, and persuade are enhanced by the instructional materials. However, only S1 demonstrate four mathematical thinking markers while S3 is unable to demonstrate generalizing or persuasion. S3 did not provide evidence to support his claims during the interview, stating that he was unable to conduct convicting due to time constraints. It is evident from the test question results that S2 and S5 failed to establish their purported response and failed to develop a broad pattern. Based on the interviews, they completed the problems right away without creating a pattern because they were having trouble and lacked understanding of the proper procedure. Because there was a little adequate time to work on it and there was a confusion in determining conjectures in general formulation for the patterns obtained, S4 was only able to specialize and generalize in the test and interview results. However, S4 was able to demonstrate how to find the pattern by providing a verbal explanation and through pictures.

Apart from that, based on the interview results, it was also concluded that visual-auditory students watched the video repeatedly. This habit aligns with the characteristics of visual-auditory learners, who tend to prefer learning through a combination of listening and observing visually appealing materials (Rogowsky et al., 2020). These materials often include video illustrations, animations, or dynamic digital worksheets that enhance engagement and understanding (Irawati et al., 2021). By repeatedly watching the videos, visual-auditory students attempt to identify patterns, relationships, and key elements of the problems being studied, which helps them process and internalize the information effectively. This finding align with the Chofifah & Wintarti (2023) that stated the learning strategy reflects their strong inclination towards integrating auditory and visual stimuli for better comprehension and retention.

Furthermore, visual-auditory learning style students demonstrate advanced cognitive abilities such as specializing, generalizing, conjecturing, and convincing. These skills are essential in mathematics, as they allow students to move fluidly between specific examples and general principles while formulating and verifying mathematical hypotheses. These results are also in line with the findings of Harahap (2021) that found when solving test questions, visual-auditory learners typically engage in a structured approach by carefully reading the problem. They often mark or highlight key parts of the question to maintain focus but do not necessarily read the problem aloud, which aligns with their tendency to process information internally through a combination of visual and auditory cues.

Despite their strengths, one notable challenge faced by visual-auditory learners is their occasional lack of precision during calculations. While they often have accurate initial ideas and can conceptualize solutions effectively, minor errors in computation or procedural steps may occur (Alkhasawneh, 2018). This indicates the need for these learners to develop greater attentiveness to detail during problem-solving tasks. Interestingly, many visual-auditory learners exhibit the ability to construct and apply mathematical models to solve problems. They can provide formal solutions and derive formulas based on their understanding of the underlying concepts (Dewi et al., 2022). This capacity to translate abstract mathematical ideas into concrete models highlights their analytical and representational skills, which are essential for tackling complex problems. Additionally, their repeated engagement with videos and other multimedia tools reinforces their ability to connect theoretical knowledge with practical applications, fostering deeper learning and critical thinking.

To support visual-auditory learners more effectively, educators can incorporate teaching strategies that leverage their strengths. These strategies might include integrating interactive videos, dynamic simulations, and well-designed digital worksheets into the curriculum. Providing opportunities for collaborative problem-solving and discussions can also help these learners articulate their ideas and refine their understanding further. By catering to their preferred learning styles and addressing potential challenges like calculation errors, educators can create a more inclusive and effective learning environment.

CONCLUSION

This study demonstrates that the digital worksheet effectively enhances students' mathematical thinking, particularly in specialization and generalization. The developed worksheet is valid, with a 93% validity rate, and categorized as 'good' in terms of practicality. It has a sufficient impact on improving students' mathematical thinking skills. Data analysis revealed that students with an audio-visual learning style showed 'very good' abilities in specialization, as they were able to identify problems based on the given information. In generalization, students performed 'good' by identifying patterns and relationships within various arrangements. However, their skills in conjecturing and convincing were 'not yet good' due to frequent errors in making connections and mathematical reasoning when solving problems. Future research could explore the impact of digital worksheets on other learning styles, such as kinesthetic or auditory, and examine their long-term effects on mathematical thinking. Additionally, studies could investigate strategies to improve conjecturing and convincing skills, compare digital learning with traditional methods, and assess the effectiveness of digital worksheets for students with varying levels of mathematical ability.

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