Research and Development in Education
(RaDEn)

Research Article

Development of metacognition-based mathematics learning devices with heuristic strategies on sequences and series

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Citation: Rosendra, N.L. Yarman, Musdi, E., Arnawa, I.M. (2025). Development of metacognition-based mathematics learning devices with heuristic strategies on sequences and series. *Research and Development in Education (RaDEn)*, *5*(1), 56-68. https://doi.org/10.22219/raden.v5i1.39056

Received: 8 January 2025
Revised: 11 February 2025
Accepted: 13 February 2025
Published: 7 March 2025

Abstract: The creation of learning tools that aren't expressly designed to help people enhance their problem-solving abilities serves as a model for creating learning tools that do just that. The goal of this research is to develop metacognition-based learning tools that employ heuristic techniques and comprise instructional modules and student workbooks that satisfy reliable, useful, and efficient standards. Enhancing pupils' capacity to resolve mathematical issues is the aim. Students in SMAN 1 Lengayang's grade X, or Phase E, participated in this study. The Ploomp model approach is used in this development research study. Respondent surveys, RPP implementation observation sheets, teaching module and Student Worksheet *(LKPD)* validation sheets, and test questions requiring mathematical problem-solving were the tools employed in the data collection process. The study's findings demonstrated the high validity of the learning devices created for *LKPD* and teaching modules, the practicality test analysis demonstrated that the *LKPD* was useful in the very useful category, and the effectiveness test results demonstrated that the learning devices were useful in the good category.

Keywords: heuristic strategy; learning tools; metacognition; problem solving skills

1. Introduction

One of the fundamental mathematical abilities that students need to acquire in secondary school is the ability to solve mathematical problems (Hedriana & Soemarmono, 2016). Effective problem-solving skills are also a crucial starting point for students to master them. These skills are linked to reading comprehension, mathematical interest and attitudes, epistemological beliefs, IQ levels, and the development of communication skills by allowing students to conduct in-depth research (Gökkurt & Soylu, 2016). Effective problem-solving skills are also a crucial starting point for students to master them. These skills are linked to reading comprehension, mathematical interest and attitudes, epistemological beliefs, IQ levels, and the development of communication skills by allowing students to conduct in-depth research.

However, most students have problem-solving skills that are not yet well developed (Firdaus et al., 2019; Yandhari et al., 2019). Furthermore, students hardly ever work on non-routine problem-solving problems; instead, they are primarily concerned with answering professors' routine questions, which prevents them from honing their mathematical problem-solving abilities (Febrianty et al., 2024; Pirmanto et al., 2020). The majority of Indonesian students struggle to solve mathematical problems, specifically because they are unable to translate the problem's keywords into mathematical sentences, understand what assumptions they must make, and determine what information is required to solve the problem (Firdaus et al., 2019; Kurnia et al., 2023; Phonapichat et al., 2014).

According to the findings of observations and early assessments carried out at SMAN 1 Lengayang and SMAN 3 Lengayang, the school's students' proficiency in solving mathematical problems is still lacking. Students' actions demonstrate this, as they typically only complete the teacher's prescribed exercises. Additionally, pupils prefer to just receive knowledge straight from the teacher and are less involved in the learning process. Reviewing the planning and execution of learning is essential since the ability to solve mathematical problems is a crucial skill and the aim of studying mathematics.

Therefore, careful planning is unquestionably required to create a learning process that can enhance students' capacity for addressing mathematical problems. Teaching modules and worksheet (*LKPD*) are two examples of how this planning might be organized into learning resources. Mathematical problem-solving skills are thought to be enhanced by the use of metacognition-based learning resources. Students' mathematical problem-solving skills and metacognitive learning are significantly correlated. The steps of metacognition outline each step of problem-solving generally and help students become more proficient in both metacognition and mathematical problem-solving (Shilo & Kramarski, 2019).

Learning competencies and understanding of an individual's capacity to regulate their thought processes in order to solve difficulties are linked to metacognition (Mitsea & Drigas, 2019; Rivas et al., 2022). Additionally, metacognition helps pupils comprehend cognitive processes in their entirety (Duque Jr. & Tan, 2018). The metacognitive approach of students can be successful in developing problem solving (Ramadhani et al., 2020; Talaumbanua et al., 2017; Stern & Hertel, 2022). Thus, it can be said that students' ability to solve mathematical problems is intimately linked to metacognition, and that this method can help students become more adept at solving mathematical problems.

A heuristic strategy, which is a specific step of the metacognitive stage, will help the metacognitive approach in this study. Students can identify and resolve issues by using a heuristic strategy in conjunction with the metacognitive approach (Hanin & Nieuwenhoven, 2018; Mulyani, 2020). The heuristic technique created by Krulik and Rudnick was selected for this investigation. This is because, in comparison to other learning approaches, the Krulik-Rudnick heuristic is superior and more appropriate for promoting the use of the metacognitive approach, where the heuristic strategy can assist each stage of the metacognitive approach in solving mathematical issues (Mulyani, 2020).

The novelty of this research is to develop an innovative learning device in mathematics lessons. The device is combined based on metacognition with heuristic strategies in mathematics lessons. The difference with previous research is that this research develops by combining two moderator variables and researchers have not seen the same thing in previous research.

This heuristic strategy aims to enable students to have the ability to think logically and creatively. With students finding solutions to a problem, it is hoped that students will have an independent attitude and not be able to depend or rely on what is explained by the teacher. The benefits of heuristic strategies are 1) solving problems. Heuristics can help find solutions that can be proven correct. 2) Making judgments Heuristics can help make direct judgments. 3) Finding important data. Heuristics can help find important data about history that is relevant to the research topic. 4) Helping to reduce cognitive load. Heuristics can help reduce cognitive load and speed up many small everyday choices. With the use of reliable and useful heuristic techniques, this study aims to develop a metacognition-based learning tool and assess its impact on high school students' capacity for solving mathematical problems. For phase E, the content is centered on sequences and series.

2. Materials and Methods

Development research using the Plomp model technique was part of the study. Additionally, the research's subjects were SMAN 1 Lengayang students enrolled in phase E for the 2024–2025 school year. The research participants were chosen based on the phases of the formative assessment that was conducted. This study focuses on metacognitive learning tools that use heuristic techniques. Preliminary research, development or prototyping, and evaluation are the phases that were completed in the creation of Plomp. Each activity is explained in full as follows.

2.1 Preliminary Stage

A number of aspects, including needs, curriculum, concepts, and student characteristics, are analyzed during the preliminary stage. The information that was evaluated came from student surveys, teacher and student interviews, and observations. As a result, a tool is required in the form of a checklist, interview protocols, and surveys on student characteristics. Obtaining significant information about the design of metacognition-based learning devices with heuristic techniques is the aim of this project.

2.2 Development Stage

The findings of the study conducted in the earlier phases serve as a guide for product development. Designing learning tools in the form of *LKPD* and instructional modules, or prototype I, is the first step in the product development process. Additionally, formative assessments, which include multiple stages including self-evaluation, expert review, one-on-one evaluation, small group evaluation, and field testing, are used to gauge the quality of prototype I (Plomp, 2013).

2.2.1 Self-Evaluation

The researcher does this assessment with the help of colleagues in order to double-check the mistakes in the developed learning tools. Only obvious problems, such typos and component completeness, are verified.

2.2.2 Expert Review

This activity is an evaluation of 3 experts, namely language experts, educational technology experts and mathematicians. The instrument used in this evaluation is a learning device validation instrument. The results of the revision of the experts' suggestions are called prototype 2. Data from this evaluation are presented in the form of a table and the average score per aspect item is calculated and the validity value is determined using the Formula 1.

$$R = \frac{\sum_{j=1}^{m} \overline{X_J}}{m} \quad (1)$$

R is the validity value of the learning device, is the average result of the validity assessment of the jth item, is $\overline{X}_J M$ many items. The results of this calculation are adjusted to the validity criteria in Table 1.

Table 1. Validity Criteria

Criteria	Interpretation
1≤ R < 1.6	Invalid
1.6 ≤ R < 2.2	Less Valid
2.2 ≤ R < 2.8	Quite Valid
2.8 ≤ R < 3.4	Valid
3.4 ≤ R ≤ 4	Very Valid

2.2.3 One-on-One Evaluation

One-on-one evaluation was conducted on 3 research subjects with low, medium and high criteria. Consideration of research subject selection through preliminary tests and discussions with mathematics teachers at the school. This evaluation aims to obtain suggestions from students regarding the *LKPD* worked on by the 3 students. The assessment of these students was obtained from interviews, so this evaluation requires an interview guide instrument. In accordance with student suggestions, the learning device was revised, called prototype 3.

2.2.4 Small Group Evaluation

In order to undertake this evaluation, learning was done in small groups using *LKPD* and teaching modules as learning instruments. Six kids, two of each with low, medium, and high ability, served as the study's subjects. Student answer questionnaires, interview instructions, and learning implementation sheets were the tools utilized in this assessment. Prototype 4 is the outcome of the learning devices' revision based on feedback from the research participants in this assessment. Additionally, a field test including instruction in a single class will be used to evaluate the learning gadgets.

2.3 Assessment Stage

The assessment phase, which involves implementing learning gadgets in one class or in large groups, includes field testing. In this assessment, the researcher is merely a spectator, joined by another observer. An observation sheet for the teaching module's execution, a questionnaire on the practicality of student responses, a questionnaire on educator responses, interview guidelines, and a test of mathematical problem-solving skills are required for the collection of data for this evaluation. Six sessions are spent learning about sequences and series under the guidance of a math teacher. A test of mathematical problem-solving skills is then administered to the students. Data from the observation sheet and practicality questionnaire were calculated to conduct a practicality test. Where this data was calculated using Formula 2.

$$P = \frac{R}{SM} \times 100\% \quad (2)$$

Description P represents the practicality value, R is the score obtained and SM is the maximum score. The results of the calculation of the practicality of this learning device are adjusted to the practicality criteria in Table 2. Where the learning device can be called practical if its practicality value is greater than 70%.

Table 2. Practicality Criteria

Achievement Rate (%)	Interpretation
25≤P≤40	Not Practical
40<P≤55	Less practical
55<P≤70	Quite Practical
70<P≤85	Practical
85<P≤100	Very Practical

Data from the mathematical problem-solving ability test were tested for effectiveness. This test was calculated using Formula 3.

$$E = \frac{Jumlah\ yang\ tuntas}{Jumlah\ Seluruh} \times 100\% \quad (3)$$

Description E in the formula is the effectiveness value or percentage of completion of the test. The results of this effectiveness calculation are adjusted to the effectiveness criteria in Table 3. Where the learning device is effective if the effectiveness value is more than 65%.

Table 3. Practicality Criteria

Effectiveness Value (%)	Criteria
80 ≤ E ≤ 100	Very well
65 ≤ E < 80	Good
55 ≤ E < 65	Enough
40 ≤ E < 55	Not enough
E < 40	Fail

3. Results

3.1 Preliminary Stage

The preparatory stage consists of four actions, the outcomes of which serve as the foundation for the product's design. Analyzing student traits, concepts, and curriculum as well as needs is what is being done. The requirements analysis's findings show that the current method of instruction is tedious and inefficient in helping pupils improve their ability to solve mathematical problems. Thus, it is essential to create educational resources such as student worksheet (*LKPD)* and instructional modules that can boost students' engagement and mathematical problem-solving skills.

The Pesisir Selatan Mathematics Subject Teachers' Conference (*MGMP*) and the outcomes of conversations with math teachers about the mathematical ideas covered in phase E or grade X of high school serve as the foundation for the guidelines for the math materials. According to the findings of the curriculum study, the information on sequences, series, and applications of single and compound interest was consolidated into a single chapter in the number element for phase E. Additionally, the learning activities are broken down into six meetings with six learning objectives based on the overall breadth of the material and the competencies in the learning outcomes. One learning objective and two measures of its accomplishment are included in each meeting. The foundation for creating teaching modules and student worksheet *(LKPD)* based on metacognition with heuristic techniques is the development of learning outcomes into learning objectives and markers of achievement. Through learning activities that align with the stages of the metacognition method with heuristic strategies, an effort is made to enhance students' mathematical problem-solving skills in the sequence and series material.

According to data gathered from the examination of student attributes, pupils' proficiency in mathematics, especially problem-solving, varies. Students over the age of eleven can think abstractly and construct their own knowledge, according to Piaget's theory of child development. Students are interested in using *LKPD* with educational content that is relevant to the local environment or culture, according to the results of the student characteristics questionnaire. Additionally, students favor instructions and problem information written in plain, understandable language. In light of the analysis's general findings, heuristic-based learning tools based on metacognition must be designed.

3.2 Development Stage

Taking into account the findings of the preliminary analysis, metacognition-based learning tools with heuristic techniques are developed. Teaching modules and student worksheet (*LKPD*), which are continuously arranged, are the learning gadgets that were designed. wherein two teaching hours—one teaching hour being equivalent to forty-five minutes—are allotted for the preparation of the teaching modules for six meetings. The elements of the metacognition-based training module using this heuristic technique are described in detail below.

(1) Cover of Teaching Module

The cover of the metacognition-based teaching module with heuristic strategies usesA4 paper designed using the Canva application. The following is the appearance of the teaching module cover in Figure 1.

(2) Identity and General Information

The identity and general information of the metacognition-based teaching module with this heuristic strategy contains the name of the compiler, target students, class/phase, material, prerequisite material/skills, facilities/infrastructure, and learning resources. It also includes information related to the learning approach, Pancasila lesson profile and general assessment forms.

Figure 1. Cover of Teaching Module

(3) Learning Outcomes
Learning outcomes used in metacognition-based teaching modules with heuristic strategies for phase E of the number elements section.

(4) Learning objectives
In accordance with learning outcomes, learning objectives are described in each meeting related to the distribution of materials. Learning objectives are also detailed into indicators of achievement of these learning objectives. And learning objectives are arranged based on the ABCD formula (Audiance, Behavior, Condition, Degree).

(5) General Glossary
The general glossary in metacognition-based teaching modules with heuristic strategies consists of rationalization, sequence of learning materials and assessment plans.

(6) Learning Activities
Learning activities in metacognition-based teaching modules with heuristic strategies begin with topics, meaningful understanding, trigger questions and Pancasila student profiles used in each meeting. Furthermore, there are stages of learning activities in the form of preliminary, core and closing activities.

(7) Reflection
This section contains questions for general learning reflection for both educators and students. Reflection for students is not only aimed at learning, but also the atmosphere of discussion through peer reflection.

(8) Glossary
Contains related important words in the entire teaching module, along with the meaning or understanding of the term. For example, metacognitive approach, sequence, series, geometric sequence, arithmetic sequence and others.

(9) Bibliography

Contains sources used in compiling the teaching module as a whole. Can be sources of mathematics lesson materials, namely sequences and series or sources of apperception materials. As well as sources of use of learning approaches or methods, problem content and others.

(10) Evaluation

Assessment in the teaching module is related to the established profile of Pancasila students, namely cooperation and independence. This assessment is assessed during the learning process (formative). In addition, summative assessment is also carried out at the end of learning and the end of the chapter. The characteristics of the LKPD developed are described as follows.

(a) Cover of student worksheet (*LKPD*) can be seen in Figure 2. The *LKPD* cover contains general information that describes the contents of the *LKPD*, in the form of a relationship with mathematics subjects and materials.

Figure 2. Student worksheet (*LKPD*) activity

(b) Sub-Material Home Page. Each initial page of the sub-material contains a column of student identity, in the form of name, class and group. This page also contains learning objectives according to the sub-material per meeting. Instructions for completing *LKPD* activities are also included at the bottom of the page.

(c) Student Activities. The following is a description of student activities according to the characteristics of *LKPD* assisted by metacognition with a heuristic strategy. Where before entering the initial stage, students are asked to read literacy related to regional culture that will be linked to the problems in the *LKPD*. In accordance with the metacognitive approach, the initial stage carried out by students in the *LKPD* is Planning. At this stage, students are asked to read and analyze problems related to the content read previously (Read & Think). Furthermore, students follow the *LKPD* instructions to write down the information obtained and determine strategies in solving problems (Explore). According to group discussions, students determine the most effective strategy (Select A strategy).

3.3 The second stage

The second stage of the metacognitive approach is monitoring, which is in accordance with the heuristic step of find and answer. Where students solve problems according to the established strategy and find answers/solutions. The Reflection stage is the last stage, where students conclude the concepts that have been found through problem solving. On the last page of the LKPD for each meeting there is an independent exercise containing 2 questions. Where the questions given are related to the sub-material at each meeting, to see students' understanding of the concept of the material that has been studied. Next, prototype 1 will be validated through 2 stages, namely self-evaluation and expert review. The Results of validation self-evaluation can be seen in Table 4.

Table 4. Results of validation of teaching modules

No	Rated aspect	Validity Index	Category
1.	Content Eligibility	3.54	Very Valid
2.	Didactic	3.44	Very Valid
3.	Language	4	Very Valid
4.	Graphics	3.2	Valid
	Average	3.54	Very Valid

Based on Table 4. it can be seen that the results of the validity test of the teaching module for the aspects of content feasibility, didactics and language are very valid, while for graphics it is valid. Overall, the developed teaching module has an average validity index of 3.54 with a very valid category. So, it can be concluded that the metacognition-based teaching module with this heuristic strategy is valid. The Results of validation expert review can be seen in Table 5.

Table 5. LKPD Validation Results

No	Rated aspect	Validity Index	Category
1.	Content Eligibility	3.7	Very Valid
2.	Didactic	3.33	Valid
3.	Language	4	Very Valid
4.	Graphics	3.2	Valid
	Average	3.56	Very Valid

Based on Table 4, it can be seen that the results of the validity test on the *LKPD* for the aspects of content and language feasibility are very valid, and for the didactic and graphic aspects are valid. Overall, the *LKPD* developed has a validity value of 3.56 with very valid criteria. So, it can be concluded that the *LKPD* assisted by metacognition with this heuristic strategy is valid.

The evaluation of the learning device is conducted in both small-group and one-on-one settings following expert validation. The total practicality value of the teaching module is 93.31% with very practical standards, based on the observation findings of the execution of the module at the small group evaluation stage. Therefore, it can be said that the teaching module that uses heuristics and metacognition is useful for small group evaluation.

This small group evaluation activity was continued by filling out a questionnaire on the practicality of the *LKPD* assisted by metacognition with heuristic strategies and interviewing student responses. The overall average result of the percentage of the *LKPD* practicality value was 82.47%, with practical criteria. Thus, the *LKPD* assisted by metacognition with heuristic strategies can be used well by students at this small group evaluation stage.

Additionally, an effectiveness test was administered at this point. The results of the effectiveness test at the small group evaluation stage demonstrated that students' mathematical problem-solving skills improved when metacognition-based learning tools were combined with heuristic strategies. The average value of the six students increased after utilizing heuristic techniques and metacognition-based learning tools, demonstrating this. The six students who took the test finished it 100% of the time, according to the test results, indicating that their scores were higher than the Minimum Completion Criteria (*KKM* = 75). Therefore, in the small group evaluation stage, students have benefited from or found the development of metacognition-based mathematics learning devices with heuristic techniques to be effective.

3.4 Assessment Stage

With the requirement that students at this level are not students at the prior stage, this field test is an extension of the small group evaluation. In phase E1 of SMAN 1 Lengayang, 36 students will participate in a restricted field test of this metacognition-based learning tool. It was discovered that the observation results for every meeting did not always improve following the field test's execution. However, as the results were still within the very realistic requirements, the drop in assessment from the prior meeting was not an issue. Using the very practical criteria, the instructional module's overall practicality value was 93.31%. Therefore, it can be said that the teaching module that uses heuristics and metacognition is already useful.

In addition to observing how the teaching module was implemented, educators who used the metacognition-based teaching module using a heuristic technique were given a practicality questionnaire. With the criteria being very practical, the educator response questionnaire on the usefulness of metacognition-based learning tools with a heuristic approach at the field test stage yielded 93.75% of the results. This indicates that the teaching module for metacognition-based mathematics learning devices with a heuristic technique was deemed practicable by educators based on their survey on the subject.

The activity was continued with the filling of the practicality questionnaire of *LKPD* assisted by metacognition with heuristic strategies by students. The overall average result of the percentage of the practicality value of the *LKPD* was 86.20%, with the criteria of very practical. Thus, *LKPD* assisted by metacognition with heuristic strategies can be used well by students.

4. Discussion

The results of interviews with educators stated that learning with metacognition-based teaching modules with heuristic strategies is easy to apply and systematic. Systematic modules can help facilitate their use, so as module designers must maintain quality (Mitsea & Drigas, 2019). And the learning is more focused with the use of interesting *LKPD* and consistent problems related to everyday life around the students' environment. It's just that there still needs to be a more detailed time adjustment in the teaching module, to make it easier for educators to apply.

During the field test phase, a problem-solving test was used to gauge the learning device's efficacy. According to the analysis's findings, 69.44% of the 36 students who took the *KKM* were successful, demonstrating the usefulness of the metacognition-based learning tool using heuristic techniques and sound standards. An implemented module can be categorized as good because it fulfills the functions of accuracy and precision with learning objectives, reliability due to minimal errors, and comprehensive (Lubis & Lubis, 2023). Additionally, as demonstrated by test results taken both before and after students used the metacognition-based learning device with heuristic strategies, the achievement for each indicator of students' mathematical problem-solving ability has increased from the overall examination. This shows that there is an increase in students' mathematical problem-solving abilities after using metacognition-based mathematics learning devices with heuristic strategies. Thus, metacognition-based learning devices with heuristic strategies can be said to be effective in improving students' problem-solving abilities.

In this study, the Ploom model was used to develop. The development process was carried out carefully at each step of its development. The first stage is the preliminary stage which is carried out by analyzing the needs of students, curriculum analysis, concepts and characteristics of students. The results of the needs analysis illustrate that the learning process carried out is monotonous and ineffective in developing students' mathematical problem-solving abilities. Therefore, it is necessary to develop learning devices in the form of teaching modules and LKPD that can increase the activity and mathematical problem-solving abilities of students. improving the quality of learning, will be more targeted if based on student problems in the classroom (Pirmanto et al., 2020).

The second stage is the development stage which consists of prototypes 1-4. Prototype 1 is designing learning devices in the form of teaching modules and *LKPD*. Prototype 2 is a review by 3 experts/scientific experts, namely linguists, educational technology experts and mathematicians. Prototype 3 is an assessment of students obtained from interviews, so this evaluation requires an interview guide instrument. Prototype 4 is a small group evaluation where suggestions from research subjects in this evaluation are used to revise learning devices. The results of this development stage are producing *LKPD* assisted by metacognition with heuristic strategies. The development of *LKPD* is adjusted to the first stage of the metacognitive approach carried out by students in *LKPD*, namely Planning. At this stage, students are asked to read and analyze problems related to the content read previously (Read & Think). Furthermore, students follow the *LKPD* instructions to write down the information obtained and determine a strategy for solving the problem (Explore). A systematic learning process that makes it easier for students to process learning activities in improving competence through adequate learning resources (Bidayati et al., 2021). According to the group discussion, students determine the most effective strategy (Select A strategy). The second stage of the metacognitive approach is monitoring, which is in accordance with the heuristic step of find and answer. Students solve problems according to the strategy that has been set and find answers/solutions.

The Reflection stage is the last stage, where students conclude the concepts that have been found through problem solving. On the last page of *LKPD* for each meeting there is an independent exercise containing 2 questions. Where the questions given are related to the sub-material at each meeting, to see students' understanding of the concept of the material that has been studied. The third stage is the assessment stage. Based on the results of this study, it was found that *LKPD* developed with the help of metacognition with a heuristic strategy is classified as very practical. This means that the developed *LKPD* is successful and practical to use for students in mathematics lessons. Giving students the opportunity to reflect on themselves after learning can be useful as a strategy to maintain the continuity of learning (Hanin & Nieuwenhoven, 2018).

The results of interviews with educators stated that learning with metacognition-based teaching modules with heuristic strategies is easy to apply and systematic. In the field test of this research, it was found that there was an increase in students' mathematical problem-solving abilities after using metacognition-based mathematics learning devices with heuristic strategies. The advantages of the resulting product are that it is easy to use and easy to understand. The resulting *LKPD* can bring positive changes to students that can be seen during the research process. Students actively participate in learning and are able to explore their abilities. The disadvantages of this product are that it still needs more detailed time adjustments in the teaching module, to make it easier for educators to apply and also the availability of human resources who are able to support the use of this *LKPD* because it requires adequate digitalization skills.

This study is in line with previous studies that also developed learning tools to improve the learning process in schools. Research conducted by Rida Nelviani and her team revealed that through the development of a learning support tool based on a metacognitive approach, it can support learning success and also be able to create a good module and meet students' learning needs (Lubis & Lubis, 2023). Metacognition indicators are declarative knowledge, procedural knowledge, and conditional knowledge. Metacognition is a thinking skill that is useful for solving problems, controlling emotions, and planning for the future. Metacognition can also help someone become an independent learner (Bidayati et al., 2021; Rivas et al., 2022).

Metacognitive-based mathematics learning encourages children to develop learning concepts. Children can understand the importance of developing problem-solving skills, train independence in learning, and enable them to identify their strengths and weaknesses. Metacognitive learning invites children to reorganize their way of thinking by looking at goals, how to achieve goals, how to overcome obstacles, and how to evaluate (Lisa, 2020; Rahmaniah & Zainuddin, 2023). Based on the results of the research and development that have been carried out, it can be concluded that the product developed in the research and development is the Metacognitive-Based Digital Mathematics Module. In the digital module there are materials and questions that can train students to think, be able to plan, control, and evaluate them (Lisa, 2020).

Research result Nugraha (2011) also metacognitive-based learning devices with humanistic with the results of the analysis that the learning devices are effective in improving students' problem-solving abilities. As well as research Hanin & Nieuwenhoven (2018) states that metacognitive programs with heuristic strategies can help students find and solve problems. Where a heuristic consists of stages of thinking that help someone solve problems, especially with a metacognitive learning approach (Mulyani, 2020). This heuristic strategy can also be interpreted as a special action carried out to achieve the goal of solving a mathematical problem, which provides direction or guidance in the form of commands or questions contained in the problem-solving steps (Ariani & Batubara, 2017).

The difference between this study and previous studies lies in the assistance of Krulick & Rudnick's heuristic strategy to metacognition. So, the steps of the metacognitive approach are: Planning, setting goals, Evaluating and monitoring the process, Developing strategies (Musyrifah & Safitri, 2019). The visible impact of the application of this learning device is to train students' thinking patterns to be more systematic in solving problems. And accustom students to be creative in solving problems

The limitation of the research on the development of metacognition-based learning devices with this heuristic strategy lies in the materials developed. The materials developed are only sequence and series materials for grade X or phase E high school students.

5. Conclusion

According to the research objectives and the results of the data analysis obtained, it was concluded that the metacognition-based learning device with the designed heuristic strategy was valid, practical and effective according to the criteria set in improving the mathematical problem-solving abilities of students in class X of SMAN. Referring to the conclusions above and the limitations experienced, it is suggested that the metacognition-based mathematics learning device with heuristic strategies for sequence and series material has been declared valid, practical, and effective so that it is suggested that it can be used by mathematics teachers as an alternative learning device for class X/Phase E. Furthermore, this metacognition-based mathematics learning device with heuristic strategies can be used as a guideline for other teachers or researchers in developing learning devices for other materials.

Authors Contribution: Nadita Lerian Rosendra; Methodology, conducting the research and writing original article, field data collection, data analysis, and revision. Yarman; Edwin Musdi; I Made Arnawa; Field data collection data analysis, and revision.

Acknowledgements: Thank you to all parties who have provided support in completing this research. Especially thank you to Universitas Negeri Padang which has become the main container and supporter of the research. Thank you to all authors who have helped the smooth running of this research.

Conflict of Interest: The authors declare no conflict of interest.

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