

Development of Guided Discovery-Based Mathematics Learning Devices for High School Science Students

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Abstract. This research is motivated by low student learning outcomes because they have difficulty understanding the subject matter, recalling the material that has been studied, not being active in the learning process, and low motivation to learn. Therefore, learning devices are needed that can actively increase student involvement in building their understanding of mathematical concepts. The purpose of this study is to produce learning devices in the form of guided discovery-based RPP and LKPD for class XI science students of SMAN 16 Padang that are valid, practical, and effective. This type of research is development research with the Plomp model which consists of three phases, namely preliminary research, development or prototyping phase, and assessment phase. The instruments used are interview guidelines, observation sheets, checklists, questionnaires, and learning outcomes tests. The results showed that (1) Guided discovery-based mathematics learning devices have met valid criteria, both in terms of content and construct, (2) Guided discovery-based mathematics learning devices are practical because they can be implemented and used well by teachers and students in mathematics learning, especially the limit material of algebraic functions, and (3) Guided discovery-based mathematics learning devices have been effective in small group evaluation because the percentage of classical completion has exceeded 70%.

Keywords: Learning Devices, Guided Discovery Models

INTRODUCTION

Education plays a very important role in the development of science and technology, because education is a vehicle to improve and develop human resources. In order to produce quality human resources, good quality education is needed. One of the subjects that plays an important role in improving the quality of education is mathematics (Deogratias, 2022). Mathematics has a major role in the development of science and technology (Gluchmanova, 2021; Hamad, 2022). Therefore, mathematics is widely studied from elementary school to college level.

Nasution (2018) stated that mathematics needs to be taught to students because all fields of study require mathematical skills. In addition, mathematics can also be used to present information in various ways, improve logical thinking

skills, accuracy and spatial awareness, and provide satisfaction with challenging problem solving (Chirinda, 2021). This is in accordance with the objectives of learning mathematics, namely training how to think and reason in drawing conclusions, developing activities that involve imagination, intuition, and discovery by involving divergent, original, curiosity, making predictions, and dabbling (Singh, 2016).

In order to achieve these learning objectives, it should emphasize the principles of mathematics learning. The principles of mathematics learning according to Fatimah (2018), namely (1) involving students directly in the mathematics learning process, (2) assessing students' abilities on the material that has been learned, (3) students assessing themselves, (4) providing opportunities to practice and repeat, (5) generalizing to new situations, (6) building a solid foundation of mathematical concepts and skills, (7) presenting a balanced mathematics program, and (8) an effective learning atmosphere. Teachers must be able to provide diverse learning experiences through the application of various learning strategies and learning models that are fun, contextual, effective, efficient and meaningful. One of the efforts that teachers can do is to design learning devices that can develop student creativity and make students active in the learning process.

Learning devices serve to guide the course of the learning process (Rahmi, 2017). The availability of adequate learning devices will assist teachers in carrying out the learning process so that the expected learning goals and objectives can be achieved. The syllabus is a set of learning activity plans, classroom management, and assessment of learning outcomes. The steps for presenting the syllabus completely and systematically are packaged in the form of lesson implementation plan (RPP). RPP is prepared according to the situation and conditions of the school and students. Learning activities in RPP are arranged by prioritizing the learning process in an interactive, fun, and motivating students to actively participate during the learning process (Fernandes, 2020). Student worksheet (LKPD) is one of the learning resources that can be developed by teachers as facilitators in learning activities (Riyanto, 2019). Betyka (2019)

revealed that LKPD is designed according to the conditions and situations of learning activities that will be faced. The learning process will run smoothly, if the teacher as a facilitator can direct students towards the expected learning goals so that learning objectives can be achieved optimally (Sugiarti, 2021).

The expected learning process has not yet been realized at SMAN 16 Padang. The results of observations show that teachers have tried to make students active in the learning process. However, it is constrained in implementing learning strategies because the available time is not adequate. As a result, teachers tend to use conventional learning using the lecture method, then give sample questions and do exercises. Students are less enthusiastic in participating in mathematics learning. It is because they are not directly involved or experience the process of discovering mathematical concepts themselves. Sari (2022) stated that learning will be meaningful if students are directly involved in the learning process. In addition, most student learning outcomes are below the Minimum Learning Completeness set by the school. The daily assessment value of class XI science students of SMAN 16 Padang for statistics material are shown in Table 1.

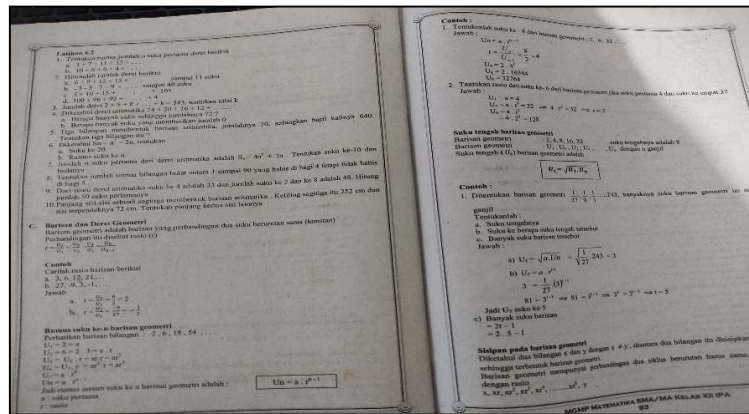
Class	Total	Complete		Incomplete	
		Total	%	Total	%
XI IPA 1	32	4	12.5	28	87.5
XI IPA 2	33	3	9.10	30	90.9
XI IPA 3	30	4	13.3	26	86.7
XI IPA 4	32	3	9.38	30	93.8

Table 1. Daily Assessment Value of Class XI Science Students of SMAN 16 Padang

The results of observations conducted at SMA Dr. H. Abdullah Ahmad PGAI Padang show the same thing. Students are not actively involved in the learning process. For example, during group discussions only high-ability students are actively involved in the discussion. This certainly has an impact on student learning outcomes. As Ayuwanti (2021) argues, in the learning process students should play more role in building their own knowledge, so that they are able to develop their intellectuals and seek learning experiences.

Lubis (2019) revealed that the discovery learning process will be more effective if supported by LKPD. LKPD in learning serves as a concise and task-rich teaching material for practice, as well as facilitating the implementation of

learning (Bhoke, 2021; Ariani, 2022). However, the LKPD used by students has not presented enough problems so that students can construct their own understanding, as in Figure 2. Student involvement in rediscovering mathematical concepts is very necessary in order to improve students' mathematical abilities (Yaiche, 2021).



or prototyping phase, and assessment phase. In each phase there is an illustrated formative evaluation, such as Figure 2.

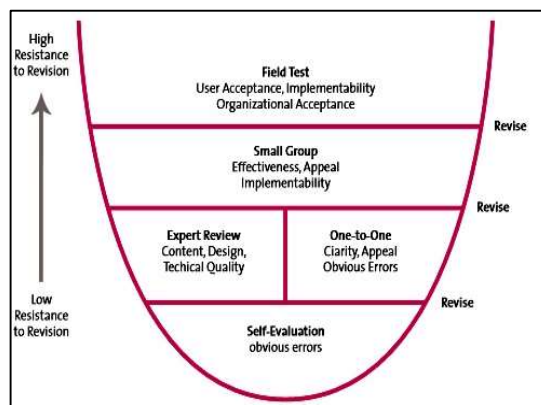


Figure 2. Layers of the Formative Evaluation of the Plomp Model

The detailed development procedure includes the following steps:

A. Preliminary Research

At this stage, identification of problems that occur in mathematics learning is carried out, so that it can be used as a reference in determining alternative solutions. Researchers obtain a provisional picture of the product specifications needed in the development of learning devices. The analysis studies carried out include needs analysis, curriculum analysis, concept analysis, student analysis, and literature review.

B. Development or Prototyping Phase

In prototype 1, the RPP and LKPD are designed based on guided findings based on the results of the preliminary research then followed by self evaluation and expert review to determine the validity of learning devices. Prototype 2 was obtained after revision based on the results of self evaluation and expert review.

The validated learning tools were tested on three students who had different abilities, namely high, medium, and low abilities. The selection of subjects one to one evaluation is carried out by discussing with the mathematics teacher concerned. The purpose of the one to one evaluation activity is to find out students' responses and opinions about the readability of learning devices, clarity of instructions, and other responses from students. The learning devices that has been revised after one to one evaluation is called Prototype 3.

Small group evaluation activities are carried out by applying learning tools to six students who are different from students in one to one evaluation. In the implementation of small group evaluation, researchers act as teachers to apply the learning devices that have been designed. To observe the implementation of learning, researchers involve an observer. Researchers also reflect on the implementation of learning that has been done. Small group evaluation activities aim to determine the practicality of guided discovery-based learning devices. The product that has been revised after a small group evaluation is called Prototype 4.

C. Assessment Phase

In the assessment phase, the effectiveness of the learning devices designed is seen, whether or not it has an effect on student learning outcomes.

The data analysis technique used is descriptive analysis to determine the level of validity, practicality, and effectiveness of guided discovery-based learning devices. A guided discovery-based learning device is said to be valid if the validity value is more than 2.40. Practicality test data was obtained from filling out observation sheets on the implementation of learning by observers, accompanied by questionnaires of teacher and student responses. Guided discovery-based learning devices are said to be practical if the practicality value is 75% to 100%. While the effectiveness test is obtained through student learning outcomes. Guided discovery-based learning devices are said to be effective when students achieve classical completeness $\geq 70\%$.

RESULTS AND DISCUSSION

1. Results of the Preliminary Research

Based on the results of interviews with teachers, information was obtained that lack of motivation to learn mathematics. It can be seen from students who are less enthusiastic in participating in mathematics learning because they are not directly involved in the learning process. Teachers have tried to keep students motivated in learning, for example by using interesting learning strategies. However, it is constrained in implementing these learning strategies because the available time is not enough to implement them. As a result, teachers tend to use

conventional learning using the lecture method, then provide examples of questions and exercises.

Based on the results of curriculum analysis, information was obtained that the learning tools used by teachers had implemented the 2013 curriculum. There are several indicators whose material order is changed to be developed. For example, indicators 3.7.3 and 4.7.1 are combined so that each indicator can be presented problems. Learning that begins with problems can train students' thinking power towards an existing problem, able to formulate problems and find their own solutions.

Based on the results of concept analysis, learning limit algebraic functions begins by telling the history of limits and the use of limits in everyday life. Next, students calculate the area of a thickly shaded part of a square, starting from a square that has an area of $\frac{1}{2}$ unit, $(\frac{1}{2} + \frac{1}{4})$ unit, and $(\frac{1}{2} + \frac{1}{4} + \frac{1}{8})$ unit. The activity of observing and calculating the amount of area can guide students in finding their own limit concept, namely the number of square parts that are thickly shaded will be close to 1 unit of area. In the next meeting, students were guided to rediscover the limit properties of algebraic functions and then determine the limit value of the function through three ways, namely the substitution method, the factoring method, and the herd multiplication method.

Based on the results of student analysis, information was obtained that low student learning outcomes were due to their difficulty understanding the material, remembering the material that had been learned, not being active in the learning process, and low student learning motivation. Therefore, learning devices in the form of guided discovery-based RPP and LKPD are needed to improve the learning outcomes of grade XI high school science students.

2. Result of the Development or Prototyping Phase

a. Prototype Design

In this phase, guided discovery-based RPP and LKPD are designed. Figure 3 shows guided discovery-based LKPD activities.

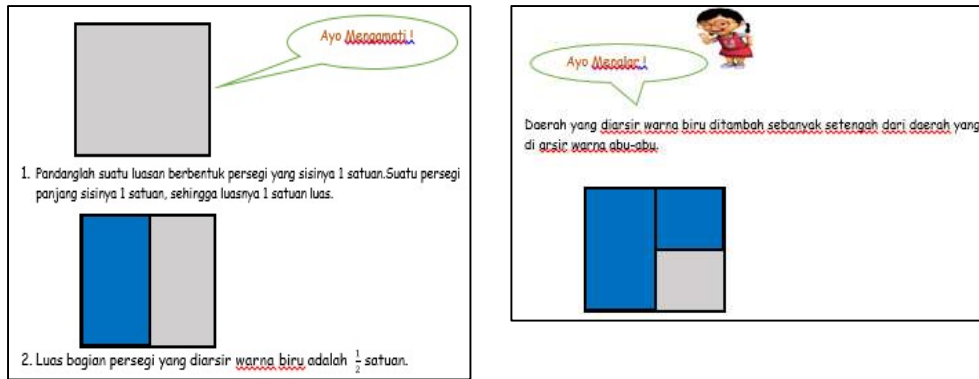
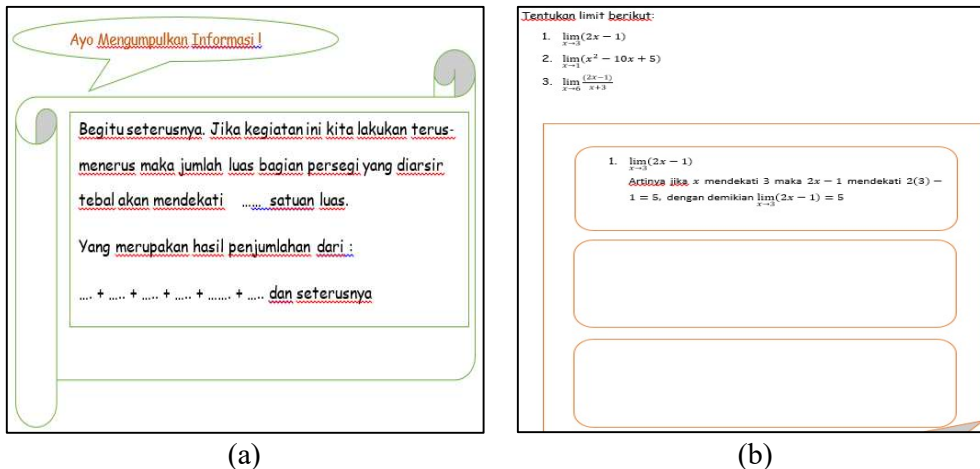


Figure 3. LKPD Activities Based on Guided Discovery

Based on Figure 3, students are first asked to observe and understand issues related to the amount of square footage. Students analyze the data provided and then answer questions in the LKPD. Next, students gather information and do exercises, as in Figure 4.



(a) (b)
 Figure 4. Information Gathering Activities (a) and Exercises (b)
 on Guided Discovery-Based LKPD

b. Formative Evaluation

1) Result of Self Evaluation

No	Component	Before Revision	After Revision
RPP			
1	Clarity of writing.	The writing is clear.	No revision.
2	Typing errors.	There are some sentences that do not use capital letters at the beginning of sentences.	Already using capital letters at the beginning of sentences.
3	Misuse of terms.	No misuse of terms.	No revision.
4	Punctuation errors.	There are some words in the RPP identity that do not use colons.	No more punctuation errors.
LKPD			
1	Clarity of writing.	There is a small font size, which is 10 in some columns.	The font size in the column has been revised to 12.
2	Typing errors.	There are some errors in writing negative signs.	No more errors in writing negative signs.
3	Misuse of terms.	There are no errors in the use of terms.	No revision.
4	Misuse of punctuation.	Do not use exclamation marks in the command sentence contained in the instructions for use of LKPD.	No more exclamation mark errors.

Table 2. Result of Self Evaluation

2) Result of Expert Review

No	Assessed Aspects	Average	Criteria
1	RPP Component.	3.50	Very Valid
2	Teaching and Learning Activities.	3.40	Very Valid
3	Language.	3.70	Very Valid
Overall Average		3.50	Very Valid

Table 3. Guided Discovery-Based RPP Validation Results

Based on Table 3, the RPP validation results for each aspect have very valid criteria. Overall, the RPP developed has a validity value of 3.50 with very valid criteria. Validator suggestions and RPP revision results can be seen in Table 4.

No	Validator Suggestions	Before Revision	After Revision
1	Add clear perceptions and motivations in each preliminary activity.	Perceptions and motivations are less clear in the preliminary activities.	Perceptions and motivations are less clear in the preliminary activities.
2	Clarify the guided discovery learning syntax for each meeting.	The syntax of guided discovery learning is not yet apparent.	The syntax of guided discovery learning has been seen.

Table 4. Validator Suggestions and Guided Discovery-Based RPP Revision Results

No	Assessed Aspects	Average	Criteria
1	Didactic Aspect.	3.60	Very Valid
2	Content Aspect.	3.40	Very Valid
3	Language Aspect.	3.70	Very Valid
Overall Average		3.60	Very Valid

Table 5. LKPD Validation Results Based on Guided Discovery

Based on Table 5, the LKPD validation results for each aspect have very valid criteria. Overall, the developed LKPD has a validity value of 3.60 with very valid criteria. It means that the LKPD designed is in accordance with the SK and KD that have been set out in the curriculum, the order of material in the LKPD is appropriate, and the steps in the LKPD are in accordance with the syntax of the guided discovery model (Revita, 2017). However, there are still validator suggestions for improving LKPD, as in Table 6.

No	Validator Suggestions	Before Revision	After Revision
1	Sync image selection with student limit and age topics.	The image on the LKPD has not been synchronized with the topic of limit and age of students.	The picture on LKPD is in accordance with the topic of limit and age of students.
2	Clarify the syntax of guided discovery learning in LKPD.	There is still a syntax of guided discovery learning that is not yet clear in LKPD.	Each activity in LKPD is in accordance with the syntax of guided discovery learning.
3	Add a bibliography.	LKPD has not been equipped with a bibliography.	LKPD has been equipped with a bibliography.
4	Facilitate students with LOTS and HOTS questions.	LKPD has not been equipped with HOTS and LOTS questions.	LKPD has been equipped with LOTS and HOTS questions.

Table 6. Validator Suggestions and Guided Discovery-Based LKPD Revision Results

3) Result of One to one Evaluation

Based on the results of individual evaluations, in general, high, medium, and low ability students can understand the problems in LKPD well. Students are asked to observe the LKPD cover, table of contents, learning objectives, and instructions for using LKPD. Then given the opportunity to ask if there are things that have not been understood. Furthermore, students work on activities in LKPD 1 regarding the concept of function limits.

In activity 1 there is a sentence that is difficult for students to understand, namely *“Look at a square area whose side is 1 unit. A rectangle has 1 side unit, so the area is 1 unit area”*. One of the students expressed doubt with the sentence *“A rectangle has 1 side unit, so the area is 1 unit area”*. Students doubt that the sentence means square or rectangular. This obstacle became a reference for students to improve the sentence, becoming *“A square that has a side length of 1 unit, then the area is 1 unit of area”*. Then another question arises, the student asks *“Why does the area of a square whose side length is 1 unit have an area of 1 unit also 1 unit of area?”*. Based on these constraints, the researcher improved activity 1 by adding the note *“Remember the square area formula”*.

The obstacles experienced by students at the second meeting regarding the properties of function limits include (1) students are still confused because the researcher only makes y in the table of approach values, if the researcher makes $f(x)$, students will be easier to understand, and (2) exercise question number 1 has too large a rank so that students have difficulty in showing the value of the $f(x)$ approach. At the third meeting, students calculate the limit value of the function by substitution and factoring. The results showed that students had difficulty in finding factorization. So the researchers added easy tips in factoring. The same also happened at the fourth meeting that students had difficulty in factoring because of its function in the form of roots. Therefore, researchers add examples of problems and tips to multiply root function by peer factors.

4) Result of Small Group Evaluation

The small group evaluation at the first meeting discusses the concept of function limits. Learning begins with saying greetings, checking attendance, conveying learning objectives, conveying apperception and motivation. Students listen to the explanation from the researcher well. Students begin to observe and analyze problems in LKPD 1 regarding the concept of function limits. In LKPD 2, students have difficulty doing HOTS questions. Some students are still confused about how to factor functions. At the time of improvement of LKPD 3, researchers have added tips on how to easily factor. However, still students must be guided how to factor.

The obstacle found at the fourth meeting was that students were still confused about how to calculate the limit value of the function with the flock factor, even though the researcher had added tips on multiplying the root function by the flock factor. The addition of tips to LKPD 4 is very helpful for students, but there must still be guidance from the teacher so that students can find the right answer. In addition, there is an answer box that does not fit to write student answers. It is because solving practice questions to calculate the limit value with a peer factor is too large so it requires a large answer box as well. Students who were shy at the first meeting to present now have the courage to present their work and other students have the courage to respond to the presentation.

In the closing activity, the teacher asked students to convey conclusions from the material that had been learned. After all meetings are completed, students and teachers fill out questionnaires to see the practicality of guided discovery-based learning devices. The results of the questionnaire on the practicality of RPP and LKPD teacher responses in small group evaluation can be seen in Table 7.

No	Assessed Aspects	Practicality Value (%)	Criteria
1	Didactic.	95%	Very Practical
2	Ease of Use.	94%	Very Practical
3	Readability.	88%	Very Practical
4	Time.	75%	Practical
Overall Average		88%	Very Practical

Table 7. Results of the Questionnaire on the Practicality of Guided Discovery-Based Learning Devices at the Small Group Evaluation Stage (Teacher Response)

Based on Table 7, the overall practicality score of the teacher's response is 88% with very practical criteria. It shows that guided discovery-based learning tools can be implemented and used well by teachers in the learning process. Furthermore, the results of the LKPD practicality questionnaire on student responses to small group evaluation can be seen in Table 8.

No	Assessed Aspects	Practicality Value (%)	Criteria
1	Didactic.	99%	Very Practical
2	Ease of Use.	85%	Very Practical
3	Readability.	100%	Very Practical
4	Time.	80%	Practical
Overall Average		90%	Very Practical

Table 8. Results of the Questionnaire on the Practicality of Guided Discovery-Based Learning Devices at the Small Group Evaluation Stage (Student Response)

Based on Table 8, the overall practicality score of student responses is 90% with very practical criteria. It shows that guided discovery-based learning tools can be implemented and used well by students in the learning process. In accordance with the findings of Susanti (2017) that the results of the LKPD practicality questionnaire based on guided findings, teacher and student responses were 82.5% and 86.15% with very practical criteria. That is, guided discovery-based LKPD can be used well in statistical learning. The same thing was also found by Ariani (2022) that the practicality value of LKPD based on guided discovery on Pythagorean material reached 85.52% (teacher response) and 82.70% (student response).

Meiliputri (2021) developed mathematics learning devices in the form of guided discovery-based RPP and LKPD to introduce cartesian coordinates to grade VIII junior high school students. The results of the questionnaire analysis

of the practicality of student responses to LKPD at the small group evaluation and field test stages reached 85.19% and 84.35%. Meanwhile, the practicality value of teacher responses to RPP and LKPD at the field test stage was 89.29% and 87.5% with very practical criteria.

Yerizon (2021) found that guided discovery-based LKPD can be used easily by students in matrix learning with a practicality value of 88.47%. Sari (2022) stated that the practicality value of guided discovery-based learning tools according to teacher responses was 98.6% and according to student responses was 87.7% with very practical criteria.

Based on the results of previous research and research that has been done, it can be concluded that guided discovery-based mathematics learning has a fairly good practical value, meaning that the learning tools are easy to understand and use during the learning process by both teachers and students. Through guided discovery-based learning, students become more active in learning because they themselves find concepts and remember longer with the material provided.

3. Result of the Assessment Phase

The effectiveness of guided discovery-based learning device is seen from the results of student learning tests at the small group evaluation stage. A recapitulation of student learning outcomes can be seen in Table 9.

No	Student	Score	Category
1	FA	95	Complete
2	OP	75	Incomplete
3	ME	80	Complete
4	AN	80	Complete
5	AR	80	Complete
6	NA	90	Complete

Tabel 9. Recapitulation of Student Learning Outcomes at the Small Group Evaluation Stage

Table 10 shows the analysis of student learning outcomes data at the small group evaluation stage.

	Completeness		Total
	Complete (≥ 80)	Incomplete (< 80)	
Total	5	1	6
Percentage	83%	17%	100%

Tabel 10. Data Analysis of Student Learning Outcomes at the Small Group Evaluation Stage

Based on Table 10, it can be seen that 5 people are complete (83%) and 1 person is incomplete (17%). Thus, it can be concluded that guided discovery-based learning tools are effective in small group evaluation because the percentage of classical completeness exceeds 70%. It is in accordance with Wanahari's (2022) findings that classical completeness reached 88.40% after students participated in guided discovery-based learning using hypercontent. The guided discovery-based learning tool developed by Wulandari (2020) is also effective in improving the analytical skills of grade X vocational students.

Susanti (2020) found the same thing that the use of guided discovery-based LKPD effectively improved problem-solving skills because 78% of students scored above the Minimum Learning Completeness. Furthermore, Kariman (2019) stated that the use of guided discovery-based modules in the Complex Analysis course can improve student learning outcomes. Based on the results of previous research and findings, it can be concluded that the use of guided discovery models effectively improves students' mathematical abilities.

CONCLUSION

Based on the results of the study, several conclusions were obtained, namely:

1. Guided discovery-based mathematics learning devices have met valid criteria, both in terms of content and construct.
2. Guided discovery-based mathematics learning devices have been practical because they can be implemented and used well by teachers and students in the learning process.

3. Guided discovery-based mathematics learning devices have been effective at the small group evaluation stage because the percentage of classical completeness exceeds 70%.

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