



## Developing Mathematic Learning Devices Oriented Problem Based Learning to improve Students' High Order Thinking Skill

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### Abstract

Students demonstrate low proficiency in answering HOTS (Higher Order Thinking Skills) questions, indicating the need for a learning model that aligns with the nature and demands of such questions. One such suitable model is Problem-Based Learning (PBL), which serves as a relevant and applicable approach for the current curriculum. This study aims to develop a mathematics learning tool based on the Problem-Based Learning (PBL) model to enhance students' higher-order thinking skills (HOTS). This research employed the 4D Model in the research and development (R&D) approach, encompassing the stage of define, design, develop, and dissemination. The sampling used a purposive sampling technique, namely 22 students of SMP Plus Darussalam Blokagung Banyuwangi. The expert validation results showed that the lesson plan (RPP) achieved an average score of 92.2%, placing it in the "highly valid" category. The learning tool's practicality earned an average of 95.4% (very practical), whereas the student worksheet's (LKS) validation yielded 90.4% (extremely viable). During the dissemination stage, the effectiveness was measured using the N-Gain method. Data were collected through test designs to measure HOTS. Using essay questions in pre-test and post-test that focused on the HOTS indicators: analysis, evaluation, and creation. The results indicated a significant improvement in students' HOTS with an average score of 0.915a (High category) for analysis, 0.675 (medium category) for evaluation, and 0.54 (low category) for creation. These findings indicated that the problem-based learning tool effectively enhances students' higher-order thinking skills (HOTS).

**Keywords:** Higher-Order Thinking Skills (HOTS); Mathematics Learning Tools; Problem-Based Learning (PBL)

### Abstrak

Kemampuan siswa dalam menyelesaikan soal soal HOTS masih sangat rendah sehingga dibutuhkan model pembelajaran yang sesuai dengan ciri ciri soal HOTS. Salah satunya adalah model pembelajaran PBL mampu menjadi pendekatan yang

relevan dan aplikatif untuk kurikulum saat ini. Penelitian ini bertujuan untuk mengembangkan Perangkat pembelajaran Matematika model *Problem-Based Learning* (PBL) dalam meningkatkan keterampilan berpikir tingkat tinggi (HOTS). Penelitian ini menggunakan Model 4D dalam pendekatan penelitian dan pengembangan (R&D) yang mencakup *define, design, develop, and dissemination*. Pengambilan sampel menggunakan teknik purposif sampling yaitu 22 siswa SMP Plus Darussalam Blokagung Banyuwangi. Hasil Validasi oleh Ahli memperoleh rata-rata RPP 92,2% (kategori sangat Valid), dan validasi LKS memperoleh 90,4% (Kategori sangat layak), sedangkan dalam kepraktisan perangkat mendapatkan rata-rata 95,4% (kategori sangat praktis). Pada tahap dissemination untuk mengukur keefektifitasnya menggunakan metode N-Gain. Data dikumpulkan menggunakan tes yang mengukur HOTS. Menggunakan soal esai dalam pre-test dan post-test, indikator HOTS—analisis, evaluasi, dan kreasi. Menghasilkan peningkatan yang signifikan dalam HOTS siswa dengan skor rata-rata 0,915 (menganalisis) kategori tinggi, 0,675 (mengevaluasi) kategori menengah, dan 0,54 (mengkreasikan) kategori rendah, sehingga menunjukkan bahwa perangkat pembelajaran berbasis problem based learning yang dihasilkan secara efektif meningkatkan kemampuan berfikir tingkat tinggi siswa (HOTS).

**Kata Kunci:** *High Order thinking Skill; Perangkat Pembelajaran Matematika; Problem Based Learning*

## Introduction

The effectiveness of Problem-Based Learning (PBL) models integrated into mathematics learning tools for enhancing students' higher-order thinking skills (HOTS) is increasingly supported by educational research. PBL fosters deeper learning by engaging students in solving complex, real-world problems that require critical thinking, analysis, and creative problem-solving (Moustafa & Al-Rashaida, 2024; Williamson, 2023).

PBL has been found to significantly improve HOTS among students through its focus on inquiry and collaborative learning strategies (Dewi et al., 2021; Lu et al., 2021). Afikah et al. (2022) conducted a systematic review of innovative learning approaches and found that PBL significantly enhances students' higher-order thinking capabilities, a finding supported by Kwangmuang et al. (2021). This is corroborated by Simanjuntak et al., who noted that PBL encourages students to engage with contextual problems, thereby enhancing their higher-order thinking skills (Anderson, 1994; Simanjuntak et al., 2021). These findings indicate that the real-world applications of PBL are critical for fostering effective learning environments in which HOTS can thrive.

In a comparative study, Palinussa et al. investigated the impact of Problem-Based Learning (PBL) versus Discovery Learning on students' mathematical critical thinking skills. Their research indicated that PBL offered greater opportunities for students to develop self-efficacy and critical thinking skills through active problem-solving tasks (Saepuloh et al., 2021). Additionally, Kwangmuang et al. emphasized

that integrating problem-solving principles within PBL frameworks enables students to engage in structured problem analysis, using multimedia tools to collaborate and derive solutions (Kwangmuang et al., 2021). This practical engagement is essential for developing skills that go beyond fostering rote learning to higher-level analysis and application of mathematical concepts.

The effectiveness of PBL is also evident in its ability to accommodate various learning styles and preferences. The adaptability of PBL enables students from diverse backgrounds to develop their critical thinking and analytical skills (Song et al., 2024; Yu & Zin, 2023). For instance, research shows that PBL approaches enhance mathematical literacy and support independent learning pathways (Maslihah et al., 2021; Sudianto et al., 2023). Furthermore, PBL fosters an environment in which students not only learn to solve mathematical problems but also reflect on their thought processes, thus promoting metacognition – another crucial component of HOTS (Izzati, 2021; Qohar, 2024).

While the benefits of PBL are substantial, careful consideration is essential when implementing it. Instructors must be adequately trained in PBL methodologies to effectively facilitate student discussions and sustain an active learning environment (Alqasa & Afaneh, 2022; Kusmaryono, 2023). Students must also understand the problem-solving processes to maximize the impact of PBL on their higher-order thinking skills. Moreover, students must fully grasp problem-solving processes to enhance the effectiveness of PBL in developing higher-order thinking skills.

Existing research on the effectiveness of Problem-Based Learning (PBL) models in enhancing students' higher-order thinking skills (HOTS) in mathematics education reveals several gaps that warrant further exploration. While studies such as those by Hendriana and Fadhillah (2019) and Suratno and Waliyanti (2023) demonstrate improvements in problem-solving abilities and creative thinking through PBL, they often lack longitudinal assessments to determine the sustained impact of these interventions. Furthermore, research often emphasizes qualitative outcomes without adequately addressing how varying educational contexts—such as diverse student backgrounds and learning environments—affect the efficacy of PBL. In addition, many studies have yet to thoroughly examine the essential teacher training and support needed for the effective implementation of PBL, which is vital, as the success of this teaching approach depends heavily on educators' ability to deliver it proficiently. The integration of technological tools, such as *GeoGebra*, into PBL has been discussed primarily in terms of its potential benefits; however, comprehensive studies focusing on the interactive capabilities of such tools to support HOTS remain limited. Finally, although some research indicates a positive

correlation between PBL and student engagement, systematic investigations into how students' perceptions and emotional responses to PBL influence their learning outcomes remain limited. Addressing these gaps in future research can significantly enhance our understanding of PBL's role and effectiveness in promoting higher-order thinking in mathematics education.

Ideally, mathematics learning should not only aim for achieving cognitive results but also foster students' critical thinking, problem-solving, and mathematical communication skills. However, in practice shows that the mathematics learning tools used in schools remain conventional and teacher-centered. Most teachers have yet to utilize learning tools that support students' exploration, collaboration, and independent problem-solving activities (Mulyasa, 2013; Widodo & Jasmani, 2008). This has resulted in students' limited ability to solve contextual and non-routine problems that require higher-order thinking skills (Trianto, 2010).

One approach considered relevant for addressing this challenge is Problem-Based Learning (PBL). PBL is a learning model that emphasizes solving contextual problems as a means to learn concepts and principles (Hmelo-Silver, 2004; Savery, 2006). PBL encourages students to actively seek information, participate in discussions, and collaboratively develop solutions. Several studies have shown that PBL enhances students' problem-solving abilities, mathematical communication, and critical thinking skills (Arends, 2012; Rusman, 2011). However, the PBL model also has several challenges. Implementing PBL requires teachers to possess skills in classroom management, designing meaningful problems, and guiding student discussions in a structured manner. Without systematic learning support tools, teachers often struggle to implement PBL effectively (Savery, 2006). Moreover, students with low abilities may become passive or fall behind if PBL is not designed inclusively (Hmelo-Silver, 2004).

Therefore, it is necessary to develop PBL-based mathematics learning tools that are both content-valid and practical for teachers to implement, while also being adaptable to the students' diverse abilities. Several developments of PBL-based mathematics learning tools have been carried out previously, for example, by Wardono (2018), who integrated the Realistic Mathematics Education (RME) approach into PBL. Another study by Nasution et al. (2019) emphasized the importance of tool validity and practicality through formative evaluation. However, most of the developed tools have not fully integrated formative assessment and scaffolding strategies to support the success of all students in PBL learning. In addition, documentation on how these tools were tested in real contexts (e.g., at the MTs or SMP level) remains limited. Based on the above explanation, there is an urgent need to develop a valid, practical, and effective Problem-Based Learning

(PBL) mathematics teaching tool that addresses the limitations of previous PBL implementations. The devices developed in this study will include Lesson Plans (RPP), Student Activity Sheets (LAS), and assessment instruments that comprehensively support the PBL process, including aspects of formative assessment and instructional differentiation.

Based on the urgency described above, the research problems are formulated as follows: (1) How can valid PBL-based mathematics learning tools be designed to enhance students' higher-order thinking skills? (2) How effective are these learning tools in improving students' higher-order thinking skills?. This development is expected to provide a practical solution for teachers implementing PBL while also addressing the challenges of learning in the digital era, which demands the enhancement of mathematical HOTS and 21st-century skills.

## Method

This study employed a research and development (R&D) approach aimed at producing educational products and evaluating their effectiveness (Sugiyono, 2017). The 4D model—Define, Design, Develop, and Disseminate—is used as the foundation for the development process (Thiagarajan, 1974). 1) Define: Researchers analyzed the requirements for the development of learning tools on the circle material, including front-end analysis, learner analysis, task analysis, concept analysis, and specifying instructional objectives. 2) Design: researchers prepared a design of learning devices to be developed, including media selection and format selection. 3) Develop: At this stage, the activities included developing and modifying the learning tools. These activities involved instrument validation, product validation (covering the lesson plan format, content, compatibility with PBL, language, time allocation, and presentation methods), and conducting a field trial. 4) Disseminate: This stage involves distributing the developed products on a wider scale. Expert validation of the lesson plans yielded an average score of 92.2%, meeting the valid criteria. Validation of the LKS resulted in an average of 90.4%, also meeting the valid criteria. In terms of practical validity, the learning tools achieved an average score of 95.4%, classifying them as practical.

In the disseminate phase, the study participants consisted of 22 eighth-grade students from MTsN 2 Banyuwangi selected through a purposive sampling model. The effectiveness of the PBL model was evaluated based on students' scientific process skills, measured through pre-test and post-test assessments. Before and after participating in PBL-based learning activities related to additives and addictive substances, students completed a scientific process skills test. Improvements in test scores serve as an indicator of the success of the guided PBL model. The

effectiveness was analyzed using the N-Gain technique, with data collected through structured tests. To analyze the results, the N-Gain score was calculated using the following equation:

$$(N - \text{gain}) = \frac{\text{posttest score} - \text{pretest score}}{\text{ideal score} - \text{pretest score}}$$

Based on the above calculation, it is then interpreted into the effectiveness category with the following N-Gain (Sari et al., 2022).

Tabel 1. Interprets N-Gain

N-Gain Score	Category
N-Gain $\geq 0,70$	High
$0,30 \leq$ N-Gain $< 0,70$	Middle
N-Gain $< 0,30$	Low

The N-Gain interpretation in Table 1 was used to measure the extent to which the students' higher-order thinking skills improved from the previous condition. The N-Gain value provided insight into the effectiveness of the learning tools that have been developed. A high N-Gain value indicated that the developed learning tools provided significant improvement, while a low value indicated the need for revision or adjustment to achieve the desired results. To evaluate the effectiveness of this PBL Model, a Paired Sample T Test was also conducted.

Data from expert validation were analyzed both descriptively and quantitatively using a Likert scale. Each aspect was evaluated by experts, then summed and averaged.

Formula: Average =  $\frac{\sum \text{Validation score}}{n}$

n = number of statements x number of validators

Next, the average score results are converted into model feasibility level categories using the following criteria:

Table 2. The average score results

Average Score	Prosentase	Eligibility Category
<b>4.20 - 5.00</b>	84% - 100%	Very Eligible / Very Practical
<b>3.40 - 4.19</b>	68% - 83.9%	Eligible / Practical
<b>2.60 - 3.39</b>	52% - 67.9%	Fairly Adequate/ Fairly Practical
<b>1.80 - 2.59</b>	36% - 51.9%	Less Suitable / Less Practical
<b>1.00 - 1.79</b>	20% - 35.9%	Not Eligible / Not Practical

## Results

There are five steps in the defining phase: namely, analyzing the front end, students, concepts, tasks, and setting learning objectives (Herowati & Azizah, 2022). Front-end analysis revealed that Mathematics teachers in junior high schools have difficulty adapting to the independent curriculum, particularly in developing the components of learning tools, which are now called teaching Modules. This issue was also experienced by mathematics teachers at SMP Plus Darussalam Blokagung Banyuwangi. The transition from the 2013 Curriculum to the Independent Curriculum is currently in progress. Mathematics teachers reported that they have not yet fully developed their learning tools in alignment with the demands of the new curriculum. They primarily rely on pre-existing learning tools and continue to use resources available on the independent learning platform through cellphones or computers (teaching modules, student worksheets, and handouts) that have been provided. A similar situation was encountered by mathematics teachers at MTs Al Amiriyyah Banyuwangi. To ensure effective learning, it is important to select appropriate teaching approaches and models to achieve instructional goals. In the process of learning, Mathematics is often related to thinking and problem-solving; students need approaches that guide them toward deeper understanding.

Students at SMP Plus Darussalam Blokagung and MTs Al Amiriyyah Banyuwangi demonstrated a wide range of learning abilities, from high to low levels, based on an analysis of their aptitudes. Students find it challenging to solve story-based problems, and they frequently make errors when attempting to translate them into mathematical form. According to Phase D learning outcomes, derived from the concept and learning outcomes analyses, students are expected to possess the ability to translate contextual problems into mathematical problems and, conversely, apply mathematical problems to real-life contexts. The main conceptual material to be taught is based on this foundation. Task analysis serves as the basis for identifying indicators. Planning learning objectives is motivated by the desire to identify learning targets by reviewing material reviews, task reviews, and learning target reviews. These elements are aligned with the progressive learning achievements outlined in Phase D of the junior high school mathematics curriculum under the independent learning framework.

The design consists of three key processes, which prepare the learning device prototype: (a) selecting media appropriate to the learning targets, (b) choosing a format, and (c) initiating the basic design. Digital media, specifically a projector to display the content larger than a computer screen, was selected for this development. After determining the format of teaching modules, student worksheets, and learning outcome assessments that adhere to the principles and characteristics of the problem-based learning model, the first design was completed.

During the development phase, the customized learning device was created with input from practitioners (one math teacher at MTs Al Amiriyah) and experts (two educational experts at Jember University), along with data from trials. The main criterion for determining the usability of the learning device is the validation results provided by experts or specialists. The expert review included several minor suggestions for improvement. The initial version of the learning tool (Draft I) was validated by both experts and practitioners. Based on their feedback, Draft II was revised and subsequently tested at SMP Plus Darussalam Blokagung. The trial results demonstrated the effectiveness of the developed product.

To revise the learning tools, the validators—subject matter experts and practitioners—provide notes before providing their assessment on the validation sheet. Table 2 below provides an overview of the validators' revision notes:

Table 2. Product revision notes

Expert Review Revision Notes	Practitioner Revision Notes
1. The purpose of the teaching module follows the ABCD (Audience, Behavior, Condition, Degree) rule.	1. The layout in the student worksheets would be better aligned with the arrangement in the Teaching Module.
2. Learning materials are presented in the form of facts, concepts, principles, and procedures.	2. Student worksheets was made more colorful and images were added.

The validated learning device was assessed based on language, presentation, and content components. The learning device received an average score of 92.2% from both practitioners and subject matter experts, placing it in the highly valid category. The student worksheets earned an average score of 90.4%, also indicating they were highly feasible. Additionally, the practicality analysis conducted over two sessions showed an average percentage score of 95.4%, classifying the learning devices as highly practical.

The presented material was in line with the learning objectives in the independent curriculum at Phase D from the standpoint of content feasibility. Effective teaching and meaningful learning are predicated on content validity, or the material's relevance and appropriateness (Report, 2012). They had fulfilled the required standards in terms of the way the content was presented, the design of the educational resources, and their conformity to the problem-based learning paradigm and scientific method. This comprises the device's component integration, logical learning flow, and clear directions. According to Gagne (1985), the learning process should proceed methodically, beginning with capturing students' attention and culminating in knowledge transfer and retention. These

phases ensure that the instructions are comprehensible and that the learning devices' structure is properly incorporated. Language appropriateness also plays a crucial role, as the use of clear and simple language helps middle school students grasp the material. Ausubel (1960) emphasized the importance of advance organizers, which assist students in connecting new content with prior knowledge. Clear language and well-organized visual aids act as advance organizers to improve students' comprehension and retention of the subject matter.

The results of the students' learning achievement assessments indicated the effectiveness of the developed product. To improve higher-order thinking skills, the learning outcome test was administered both before and after the implementation of problem-based learning. The test assessed eighth-grade students' proficiency in answering HOTS (Higher-Order Thinking Skills) questions. The test results were conducted at MTsN 2 Banyuwangi before and after students participated in learning activities focused on flat shapes, particularly circles. This study also examined students' application of the scientific method and problem-solving skills, including their ability to formulate problems, develop hypotheses, design and conduct experiments, collect and analyze data, and draw conclusions. Table 3 displays the learning achievement exam results for the pupils.

Table 3, The result of pretest and post-test

No	Student	Value		Score	N-Gain Category
		Pretest	Post-test		
1	A	50	80	0.6	Middle
2	B	45	90	0.82	High
3	C	55	90	0.78	High
4	D	55	100	0.98	High
5	E	50	100	0.9	High
6	F	35	70	0.54	Middle
7	G	45	60	0.27	Low
8	H	65	100	0.86	High
9	I	55	90	0.78	High
10	J	25	50	0.33	Middle
11	K	65	100	0.86	High
12	L	50	80	0.6	Middle
13	M	70	100	0.97	High
14	N	65	100	0.94	High
15	O	35	70	0.54	Middle
16	P	50	80	0.6	Middle
17	Q	45	80	0.64	Middle
18	R	45	80	0.64	Middle
19	S	25	60	0.47	Middle
20	T	45	70	0.45	Middle

21	U	65	90	0.71	High
22	V	45	80	0.64	Middle
		Average		0.68	Middle

Based on the evaluation results from the pre-test and post-test circular material, the N-Gain calculation was utilized to assess progress in higher-order thinking skills. According to Table 2, students in this area were categorized as moderate with an average N-Gain score of 0.68. The problem-based learning strategy facilitated students' transition from a less proficient group to a higher one in terms of higher-order thinking skills (Indriati, 2022). Furthermore, worksheets and tests based on higher-order thinking skill indicators have been shown to enhance methods to improve these abilities (Qohar, 2017).

This study employed indicators of higher-order thinking skills to evaluate all assessments, encompassing three cognitive domains: analyzing, evaluating, and creating. The three components were aligned with the inquiry phase, encompassing problem formulation, hypothesis generation, experimental design execution, data collection, data analysis, and conclusion drawing. The assessment scores for everyone on the indicators of high-order thinking skills C4-C6, as per Bloom's taxonomy, were used to ascertain the level of pupils' high-level thinking abilities, with their effectiveness presented in Table 4.

Table 4, Analysis of high-order thinking skills with N-Gain

Indicator	Question Number	N-Gain Score	Average	Category
Analysis	1	0.86	0.915	High
	3	0.97		
Evaluation	2	0.71	0.675	Middle
	4	0.64		
Create	5	0.54	0.54	Low

According to Table 4, questions requiring higher-order thinking skills (analysis) showed an increase in the average N-Gain score of 0.915, signifying a high level of proficiency. This suggests that students were able to categorize circle-related problems correctly for tests 1 and 3. The C5 process (evaluation) was demonstrated in questions 2 and 4, signifying higher-order thinking skills (HOTS), with an average N-Gain score of 0.675, which falls into the moderate category. This implies that students are not yet fully optimizing their understanding of situations, evaluating contextual information. It is important to note that questions classified as HOTS are not necessarily more difficult than recall-based questions; rather, they

demand a deeper level of comprehension, specifically in the areas of analysis, evaluation, and creation (Suryani, 2022).

The creativity indicator in Question 5, with an average N-Gain of 0.54 in the moderate category, suggested that while students were able to analyze tables with HOTS-based story problems and draw conclusions adequately, their performance is suboptimal. This outcome may be attributed to students' insufficient practice and experience in forming independent judgments. Additionally, Piaget's cognitive development theory posits that students may not have fully reached the formal operational stage, which is essential for deriving complex and abstract conclusions. Effective analysis and comprehension require the systematic organization of knowledge (Areesophonpichet, 2013).

Evaluated using the N-Gain score, a paired sample t-test was also conducted to examine the effectiveness of the PBL-based learning device by using pretest and posttest scores. Test results are as follows:

Table 5 Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pretest & Posttest	22	0,865	0,000

Based on Table 5, a strong relationship was observed between the pre-test and post-test scores following the implementation of the PBL-based learning device, with a correlation coefficient of 0.865. Therefore, it can be concluded that there is a significant relationship between the two students' pre-test and post-test performance.

Table 6 Paired Samples Test

		Paired Differences		95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)	
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper				
Pair 1	Pretest - Posttest	-33,40909	7,46203	1,59091	-36,71757	30,10061	2,1000	21	0,000

In this Paired Sample T Test, the hypothesis is as follows:  
 $H_0$  (Null Hypothesis): The mean scores before and after the intervention are equal, indicating no significant difference.

$H_1$  (Alternative Hypothesis): There is a significant difference between the mean scores before and after the intervention.

Based on the results of the paired sample t-test in Table 6, there was a significant difference between the pre-test and post-test scores of the PBL learning model, the value of  $t\text{-count} = 2.1000 > t\text{-table} = 2.07961$ , the value of  $\text{sig} = 0.000 < 0.05$ . The average score increased by 33.41 points after the use of the PBL learning model, indicating that the use of the PBL learning model had a positive effect on students' higher-order thinking skills (HOTS). Therefore, it can be concluded that the use of PBL learning model tools is an effective form of learning because students' higher-order thinking skills (HOTS) for significantly improving.

The problem-based learning model's instructional resources (teaching modules, student worksheets, and assessment questions) effectively foster students' higher-order thinking skills, as evidenced by the achievement of moderate HOTS indicators. The guided inquiry learning methodology, when combined with LKPD and assessment instruments using HOTS components, was shown to enhance students' higher-order thinking skills. According to Syafi'ah and Setiani (2024), process skills represent the outcomes achieved by individuals, reflecting their ability to perform logical reasoning, communicate scientific findings, and conduct experimental procedures.

Participation in the problem-based learning (PBL) model enhanced students' higher-order thinking skills, as demonstrated by the pre-test and post-test results. The developed learning tools, which implement the PBL approach, integrate scientific phases with problem-based learning, enabling students to actively seek explore, and solve HOTS-related problems to circular material challenges. The phases of the problem-based learning approach are designed to help students to independently construct mathematical concepts, hence enhancing the depth and relevance (Salsabila & Muqowim, 2024). PBL-based instructional tool incorporates learning stages that foster student engagement. The first phase of the PBL technique was orientation, during which the teacher provided a stimulus and encouraged students to identify and engage with the problem. The orientation phase, as presented in the student worksheets, prompted learners to observe, investigate, analyze, and classify the challenges encountered during the initial stage of learning.

## Discussion

The application of this learning model centered on how effectively the mathematics learning tools intended for Problem-Based Learning (PBL) improved students' HOTS. The core objective of this study was to determine whether the PBL model enhanced HOTS. Prior studies, such as those by Harris and Bacon (2019) and Sukackè et al. (2022), have demonstrated that PBL enhances cognitive abilities through active learning and real-world application. This study hypothesized that by

encouraging deeper engagement and critical thinking, combining PBL with certain mathematical learning tools would further enhance HOTS. Moreover, these findings were consistent with empirical findings that mathematics instructional tools aligned with PBL can enhance student learning outcomes compared to traditional teaching methods (Carter, 2016; Holmes & Hwang, 2016). This theory aligns with educational approaches that support active learning and cognitive engagement in activities involving problem-solving. Through empirical data, this research provides evidence to reinforce those claims.

Notable improvement in students' higher-order thinking skills is evident in this learning device through the integration of every step of both scientific and PBL approaches. For example, the integration of alignment between the understanding indicator is evident in this device, specifically for the understanding indicator in the scientific aspect and Phase 1 on PBL, which involves introducing students to the problem through guiding questions. Both elements operate concurrently in the development of this learning device. This alignment extends beyond Phase 1 through to Phase 5 of the PBL stages. In the N-Gain analysis, the analysis indicator at the HOTS level received a high criterion, the evaluation criterion received a medium criterion, and the creation indicator received a low criterion. On average, this study resulted in a product that is reasonably effective at enhancing students' HOTS. The findings imply that implementing HOTS-based learning requires substantial instructional time and effort, as it involves cultivating new and complex cognitive processes (Tyas et al., 2019; Wijayasari et al., 2020).

The comparison between this research and previous theories reveals new insights into how PBL can be maximized to foster HOTS. Prior research, conducted by Saepuloh et al., (2021), has demonstrated that problem-based learning (PBL) has a strong potential to enhance students' higher-order thinking skills. However, this study distinguishes itself in emphasizing the integration of specialized mathematical learning tools—a topic that has been underexplored in existing literature. The findings indicate that when learning tools complement the PBL approach, they foster HOTS development by offering a dynamic and interactive environment that engages students more deeply than the traditional method. In addition, contextual examples and problem scenarios increase students' motivation and engagement in participating in the learning process.

The results of this study illustrate how students' critical thinking processes are shaped through the use of the mathematics learning device. This finding aligns with Jablonka's (2020) view that critical thinking comprises a set of skills used to develop reasoning and reflective thinking, which can be cultivated through various learning experiences. By providing HOTS-based questions as manageable segments,

this learning device offers a systematic approach to problem-solving and supports the development of higher-order thinking skills. Research by Pepin et al., (2025) has revealed that students who use interactive learning tools demonstrate improved understanding and reflecting on mathematical problems. Consistent with finding by Ghani et al., (2021) demonstrated, this problem-based learning tool also provides instant feedback to students so they can immediately correct their mistakes.

The implementation of the Problem-Based Learning (PBL) Learning approach in mathematics education to enhance higher-order thinking skills (HOTS) has its advantages and challenges. This learning method allows students to be more actively involved in problem-solving and facilitates material comprehension, as they are encouraged to think scientifically at a higher level through Higher Order Thinking Skills (HOTS) questions and the scientific process, which includes observing, questioning, reasoning, experimenting, and presenting. This finding aligns Hursen (2021) research has shown that the use of problem-based learning devices can enhance students' critical thinking skills. Five elements of Problem-Based Learning are integrated into all these learning devices, with increasingly sophisticated contextually designed to support understanding concepts related to circular geometry. The experiments that students must conduct in the LKS (students' worksheets) include detailed instructions and example problems that guide students through each step of the solution process. Students generally appreciate this task because it is practical and clear. Students are directed to collaborate and share knowledge during the learning process. This is evident in collaborative tasks, as proficient students assist peers who face difficulties. During the learning outcome assessment, it indicated that the students achieved satisfactory results in performance level.

## Conclusion

The Problem-Based Learning (PBL) model demonstrates high effectiveness in enhancing students' higher-order thinking skills (HOTS) in mathematics education. This study highlights several key findings: 1) Development of Learning Tools: The creation of PBL-based instructional materials, including teaching modules, student worksheets, and assessment instruments, was validated by subject matter experts and practitioners. These tools were determined to be valid, practical, and effective in supporting students' learning processes, 2) Effectiveness of PBL significantly improves students' HOTS, particularly in analysis, evaluation, and creation, as demonstrated by the increase in N-Gain scores, 3) Identified Research Gaps: The study identifies several research gaps, including the need for longitudinal studies to assess the long-term impact of PBL, exploration of its

effectiveness across diverse educational settings, and examination of the role of teacher training in its successful implementation. Additionally, further exploration of the integration of technological tools, such as *GeoGebra*, could enhance the effectiveness of PBL in fostering HOTS. Future research should aim to address the identified gaps to further refine and optimize the implementation of PBL in mathematics education.

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