International Journal of Multicultural and Multireligious Understanding

http://ijmmu.com
editor@ijmmu.com
ISSN 2364-5369
Volume 12, Issue 10
October, 2025
Pages: 377-393

Development of Approach-Based Learning Tools Problem-Based Learning Assisted Desmos Classroom Activities Oriented to the Critical Thinking Skills of High School Students

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http://dx.doi.org/10.18415/ijmmu.v12i10.7158

Abstract

This study aims to develop a problem-based learning (PBL) learning tool with the help of Desmos Classroom Activities that is oriented towards the critical thinking skills of high school students. The development model involves validation stages, limited trials, and field trials. The research subjects consisted of expert lecturers as validators, a mathematics teacher, and 34 grade X high school students. The validation results show that the tool meets the criteria of "valid" to "very valid." In terms of practicality, the tool received an assessment of "very practical" from teachers and "practical" from students, and the implementation of learning is in the high category. The effectiveness of the tool is reflected in the results of the field test, where more than 70% of students exceeded the Learning Objective Completion Criteria (KKTP) with an average critical thinking ability score of 81.33. Thus, the developed tool is proven to be valid, practical, and effective, so that it is suitable for use in mathematics learning to improve students' critical thinking skills.

Keywords: *Learning Tools; Critical Thinking Skills; Problem-Based Learning Approach; Desmos Classroom Activities*

Introduction

Mathematics education plays a strategic role in developing students' potential to think logically, analytically, and systematically. This aligns with Law Number 20 of 2003 concerning the National Education System, which emphasizes that education aims to shape knowledgeable, capable, creative, independent, and responsible citizens. Mathematics, as a basic science, not only provides conceptual understanding but also trains relevant skills to face the dynamics of modern life. Therefore, mathematics education contributes significantly to realizing national education goals as mandated by law. Within this context, mathematics learning needs to be directed toward strengthening critical thinking skills as one of the core competencies of the 21st century.

National Council of Teachers of Mathematics (NCTM, 2000) emphasizes that critical thinking is a fundamental element in the five standards of mathematics learning: problem solving, reasoning and proof, communication, connections, and representation. This ability requires students to analyze information, evaluate arguments, and connect various concepts logically. Dwyer et al. (2014) explains that critical thinking involves cognitive activities such as reasoning, analysis, evaluation, and synthesis of information to produce appropriate decisions and effective solutions. In line with this, Ennis (1996) defines critical thinking as a process aimed at making reasoned decisions about what to believe and what actions to take. Thus, critical thinking not only supports mathematical understanding but also equips students with the ability to make rational decisions when facing real-world problems.

Although critical thinking is recognized as a key skill of the 21st century, the fact is that many educational curricula have not yet placed it as a core part of learning (ten Dam & Volman, 2004). This situation prevents students from gaining sufficient learning experiences to develop critical thinking skills in a structured and sustainable manner. This situation is further exacerbated by the dominance of traditional teaching approaches that emphasize memorization over the development of analytical and evaluative skills (Hitchcock, 2017; Huber & Kuncel, 2016). As a result, students' space to explore ideas reflectively and critically is limited. Furthermore, many learning strategies still lack student engagement in contextual and active activities, even though methods such as problem-based learning have been proven effective in fostering the development of critical thinking skills (Niu et al., 2013; ten Dam & Volman, 2004).

To address these challenges, learning innovations are needed that foster active student engagement in the learning process. One approach considered effective is problem-based learning (PBL), a learning approach that places students at the center of learning activities. Through PBL, students are invited to confront real-world, open-ended problems, encouraging them to engage in collaborative investigation, discussion, and reflection. This process not only helps students build knowledge based on experience but also strengthens critical thinking skills, independence, and motivation to learn (Torp & Sage, 2002).

Problem-based learning (PBL) is seen as a learning approach that emphasizes active student involvement through real-world problem-based learning experiences. In its application, students are encouraged to explore and analyze complex problems designed to fit the context of everyday life (Arends & Kilcher, 2010). Through this approach, learning not only connects theory with practice, but also provides space for students to develop knowledge, skills, and attitudes through independent and collaborative problem solving (Alavi, 1995). Thus, PBL serves as an effective means to equip students to face real-world challenges in a more reflective and meaningful way.

Research result Weng et al. (2022) revealed that the application of problem-based learning (PBL) can encourage mastery of 21st-century skills. Specifically, PBL has been shown to strengthen critical thinking skills through reflective data analysis and in-depth modeling, foster creativity through the search for original ideas and solutions, and enhance communication and collaboration skills through guided group interactions. Similar findings were also demonstrated by Luvia Ranggi et al. (2021) which confirms that the use of PBL has a significant impact on improving students' critical thinking skills. Thus, the application of PBL can be a relevant alternative to facilitate more meaningful and contextual mathematics learning.

Exponential material is also seen as an important foundation in learning mathematics because it is the basis for mastering more complex concepts. (Pitta-Pantazi et al., 2007) emphasizes that a good understanding of exponents is necessary to support the learning of advanced topics, such as exponential functions, logarithms, calculus, and various growth and decay models. In other words, mastering the concept of exponents is not only relevant in the theoretical realm but also crucial for practical applications related to everyday life phenomena. Therefore, exponents need to be taught contextually so that students can relate abstract concepts to real-life situations.

The findings from various studies emphasize the importance of paying attention to students' conceptual difficulties in learning exponents. Ulusoy (2019) highlighted that common misconceptions occur when students are asked to understand zero and negative exponents. Matlala & Kakoma (2018) shows that errors often arise in the application of basic exponentiation rules such as $a^m \times a^n = a^{m+n}$. Meanwhile, Şenay (2024) emphasized that the high level of abstraction makes it difficult for students to bridge the concept of exponents with real contexts, and Ramazan (2010) added that variations in the ability to compare exponents are influenced by the base and the exponent used. This series of research results shows that obstacles to learning exponents encompass both procedural aspects and deeper conceptual understanding.

In line with these findings, research by Hakiki et al. (2022) demonstrates that integrating digital technology into mathematics learning tools not only improves conceptual understanding but also contributes to the development of critical thinking, creativity, and problem-solving skills. The designed tools are proven valid and practical, making them suitable for use in classroom learning. Furthermore, the implementation of the contextual project-based STEM-PjBL model encourages active student engagement and enables them to construct knowledge more meaningfully. The use of visualization media such as Desmos also enriches the learning experience by facilitating the exploration of abstract concepts, particularly quadratic functions. Although technical challenges were initially encountered due to students' lack of experience in using the software, with teacher guidance and systematic guidance, the technology can be optimally utilized to improve learning effectiveness.

Although some studies on the development of learning tools have been conducted, there is still a gap in studies that specifically combine problem-based learning tools with the support of interactive technology, such as desmos classroom activities. Most existing devices have not been explicitly designed to integrate the PBL approach with digital media that can strengthen student engagement in the learning process. Observational findings at a high school in Banguntapan, Yogyakarta, also indicate that the learning devices used do not utilize the desmos classroom activities as a supporting tool. This condition emphasizes the need for learning tools that not only meet valid criteria but are also practical and effective in their classroom application. Validity is necessary to ensure the suitability of materials and methods to students' needs and pedagogical principles, while the practical aspect refers to the ease with which teachers can implement the tools. Effectiveness relates to the tool's contribution to improving learning outcomes, particularly critical thinking skills. Therefore, this research aims to fill this gap by developing learning tools based on problem-based learning integrated with desmos classroom activities, so that it can address the challenges of learning in exponential material while providing innovation in the development of mathematics learning tools.

The products to be developed are teaching modules and assisted LKPD desmos classroom activities, with the characteristics of teaching modules and LKPD following the steps of the learning approach, problem-based learning. One of the main advantages of assisted LKPD desmos classroom activities is that they present content in various formats, such as text, images, and sliders, making it easier for students to visualize abstract concepts and increasing their active engagement in the learning process.

This study aims to describe the development stages and results of learning tools designed using a problem-based learning approach and oriented towards strengthening students' critical thinking skills. Furthermore, this study also focuses on assessing the quality of the resulting learning tools through aspects of validity, practicality, and effectiveness. Therefore, the developed learning tools are expected to be a viable and relevant alternative for implementation in the learning process.

Method

This research is included in the type of development research or Research and Development (R&D). The focus of the research is to develop learning tools with a collaborative approach, problem-based learning supported by desmos classroom activities, to facilitate critical thinking skills. The development model used is ADDIE, which includes five systematic stages, namely Analysis, Design, Development, Implementation, and Evaluation. The application of the ADDIE model emphasizes the process of designing and developing learning products through these stages, so that the resulting products are more focused, effective, and in accordance with learning objectives (Tegeh et al., 2014). The selection of the ADDIE model in this study is based on its systematic and flexible characteristics, thus enabling the development of products that are relevant to needs in the field (Branch, 2010).

The initial testing phase involved expert validation to assess the validity of the learning tools. Expert lecturers were involved to review the feasibility of the design, content, and the device's alignment with the learning objectives. The validation results were used as a reference to determine whether the tool was ready for use or required revisions based on the validators' suggestions. This step ensured the tool met quality standards before further testing.

After going through the validation stage, the learning device was trialed with teachers and students to assess its level of practicality. During the implementation, teachers and students used the device in the learning process, then provided an assessment through an evaluation sheet that covered aspects of ease of use and design appeal. The results of the assessment were analyzed to determine the extent to which the device met the practicality criteria. The trial was conducted on grade X students of SMA Negeri 1 Banguntapan, Yogyakarta, in the 2025/2026 academic year, with the research implementation taking place from February to August 2025.

The data collection technique in this study was conducted through a critical thinking skills test. The instrument, in the form of test questions, was used to measure students' critical thinking skills after using the student worksheet (LKPD) with the assistance of the teacher desmos classroom activities. The test results serve as the basis for assessing the effectiveness of the learning tools. In addition, non-test instruments were used to obtain data related to the product's validity and practicality, including validation sheets, teacher assessment sheets, student assessment sheets, and learning implementation observation sheets.

The data analysis techniques in this study included qualitative and quantitative analysis. Qualitative data were obtained from validator suggestions and comments on the validation sheet and observation notes during the implementation process, which were then analyzed to refine and improve the learning tools. Meanwhile, quantitative data came from the results of the device validation sheet, the practicality sheet, and the critical thinking skills test scores. Next, the quantitative data were converted into qualitative data by referring to the guidelines Widoyoko (2025) as presented in Table 1.

Table 1. Validity Criteria for Teaching Modules

Interval Shoes	Category
$84 < X \leq 100$	Very Valid
$68 < X \leq 84$	Valid
$52 < X \leq 68$	Less Valid
$36 < X \leq 52$	Invalid
$20 < X \leq 36$	Totally Invalid

In this study, the teaching module is declared "valid" if the validation score from the validator is within the minimum score interval $68 < X \leq 84$.

Next, the validity criteria for the assisted LKPD are presented desmos classroom activities in terms of material and media are shown in Table 2.

Table 2. Validity Criteria for Assisted LKPD Desmos Classroom Activities

Interval Shoes (in terms of material)	Interval Shoes (from a media perspective)	Category
$46{,}2 < X \leq 55$	$42 < X \leq 50$	Very Valid
$37{,}4 < X \leq 46{,}2$	$34 < X \leq 42$	Valid
$28{,}6 < X \leq 37{,}4$	$26 < X \leq 34$	Less Valid
$19{,}8 < X \leq 28{,}6$	$18 < X \leq 26$	Invalid
$11 < X \leq 19{,}8$	$10 < X \leq 18$	Totally Invalid

In this study, LKPD was assisted by desmos classroom activities in terms of material and media. It is declared "valid" if the validation score from the validator is within the minimum score interval $37{,}4 < X \leq 46{,}2$, and $34 < X \leq 42$ consecutively.

Next, the criteria for teacher practicality regarding the teaching modules that have been developed are presented in Table 3.

Table 3. Criteria for Teacher Practicality of Teaching Modules

Interval Shoes	Category
$63 < X \leq 75$	Very Practical
$51 < X \leq 63$	Practical
$39 < X \leq 51$	Less practical
$27 < X \leq 39$	Impractical
$15 < X \leq 27$	Very Impractical

In this study, the teaching module is declared "practical" if the validation score from the validator is within the minimum score interval $51 < X \leq 63$.

Furthermore, the practicality criteria for teachers towards LKPD and students towards LKPD that have been developed are presented in Table 4.

Table 4. Practicality Criteria for Assisted LKPD Desmos Classroom Activities

Interval Shoes (by teacher)	Interval Shoes (by students)	Category
$67{,}2 < X \leq 80$	$67{,}2 < X \leq 80$	Very Practical
$54{,}4 < X \leq 67{,}2$	$54{,}4 < X \leq 67{,}2$	Practical
$41{,}6 < X \leq 54{,}4$	$41{,}6 < X \leq 54{,}4$	Less practical
$28{,}8 < X \leq 41{,}6$	$28{,}8 < X \leq 41{,}6$	Impractical
$16 < X \leq 28{,}8$	$16 < X \leq 28{,}8$	Very Impractical

In this study, LKPD was assisted by desmos classroom activities terms of material and media. It is stated as "practical" if the validation score from the validator is within the minimum score interval $54{,}4 < X \leq 67{,}2$.

The assessment criteria for analyzing product practicality are based on the results of implementation observations. The assessment criteria for learning implementation can be seen in Table 5, referring to (Sudjana, 2017).

Table 5. Assessment Criteria for Learning Implementation

Interval Shoes	Category
$p \geq 90\%$	Very good
$80\% \leq p < 90\%$	Good
$70\% \leq p < 80$	Pretty good
$60\% \leq p < 70\%$	Not Good Enough
$p < 60\%$	Very Bad

The practicality of learning devices based on the results of observations of learning implementation is declared practical if the percentage of learning implementation achieved is at least in the "Good" category at a minimum interval $80\% \leq p < 90\%$.

The effectiveness analysis of learning tools was conducted to determine whether the developed product met the effectiveness criteria. Effectiveness was measured based on the results of students' critical thinking ability tests. The analysis process was carried out by examining students' test and questionnaire answers according to the established scoring guidelines. The effectiveness criteria in the critical thinking ability aspect were: (1) average critical thinking ability test score > KKTP (75); and (2) percentage of students who obtained a score of ≥ 75 on critical thinking ability ≥ 70%. The classification of critical thinking ability criteria is shown in Table 6.

Table 6. Criteria for the Effectiveness of Critical Thinking

Interval Shoes	Category
$80 < X \leq 100$	Very Effective
$60 < X \leq 80$	Effective
$40 < X \leq 60$	Less Effective
$20 < X \leq 40$	Ineffective
$0 < X \leq 20$	Very Ineffective

Data analysis to assess product effectiveness based on test results was carried out using a one-sample t-test. This test is used to evaluate the extent to which the developed product is oriented towards students' critical thinking skills. Through this test, the one-sample t-test, it can be seen whether the product is effective in facilitating the targeted variables.

Result and Discussion

Result

The products produced in this research are in the form of learning devices consisting of Teaching Modules and Student Worksheets (LKPD) with assistance desmos classroom activities with the approach of problem-based learning on the exponent material for grade X SMA. The device development was carried out by adapting the ADDIE model. The Teaching Module serves as a teacher guide, while the LKPD is assisted by desmos classroom activities used directly by students through a smartphone or a laptop connected to the internet. This device is designed to facilitate more interactive exponent learning, equipped with images, example questions, exercises, and problem-solving steps arranged according to the syntax of problem-based learning. In addition to enriching the learning experience, LKPD also supports students in practicing critical thinking skills through various problem-solving activities.

The device development process follows the ADDIE stages, namely: Analyze, Design, Development, Implementation, and Evaluation. At the level Analyze, researchers analyzed needs, student characteristics, and the curriculum as the basis for product design. Design-focused on the design of the device and the components that must be in it. Next, at the stage of development, the product is developed based on the design results, equipped with research instruments, and validated by experts and tested on a limited basis.

The products that have been developed are then presented in the form of teaching modules and LKPD, with the initial and final covers of the teaching modules shown in Figure 1.

Picture 1. Initial Cover and Final Cover of Teaching Module

This teaching module also contains general information that includes module identity, initial competencies, Pancasila Student profiles, as well as facilities and infrastructure that support the learning process in Figure 2.

Figure 2. General Information in the Teaching Module

Furthermore, the teaching module contains core components consisting of learning outcomes, learning objectives, and starting questions as shown in Figure 3.

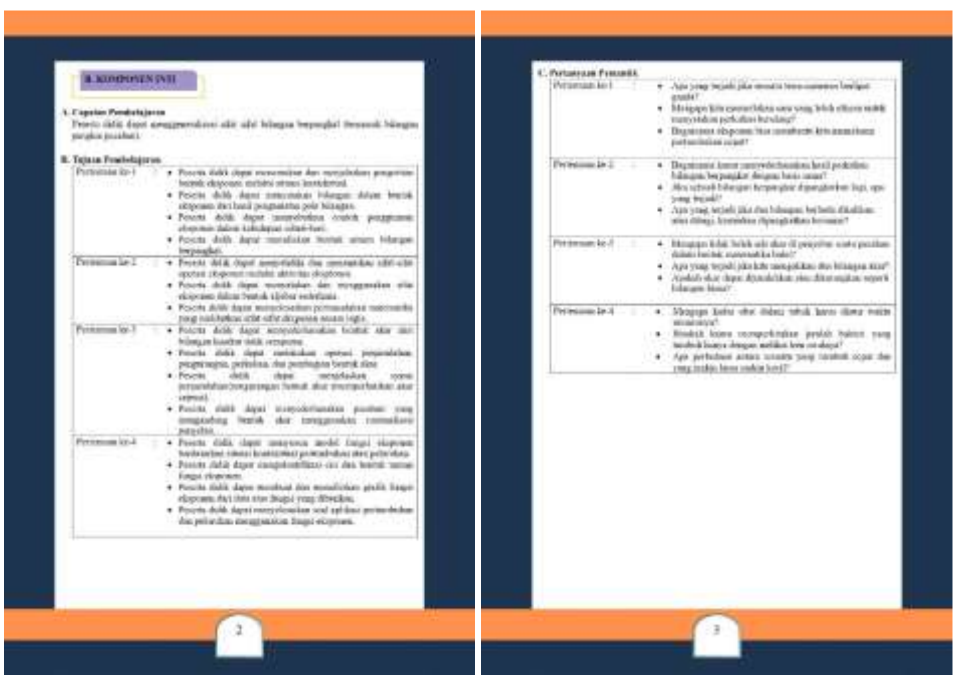

Figure 3. Core Components of the Teaching Module

Learning activities in the teaching module contain teacher activities and student activities, which systematically describe the learning activities shown in Figure 4.

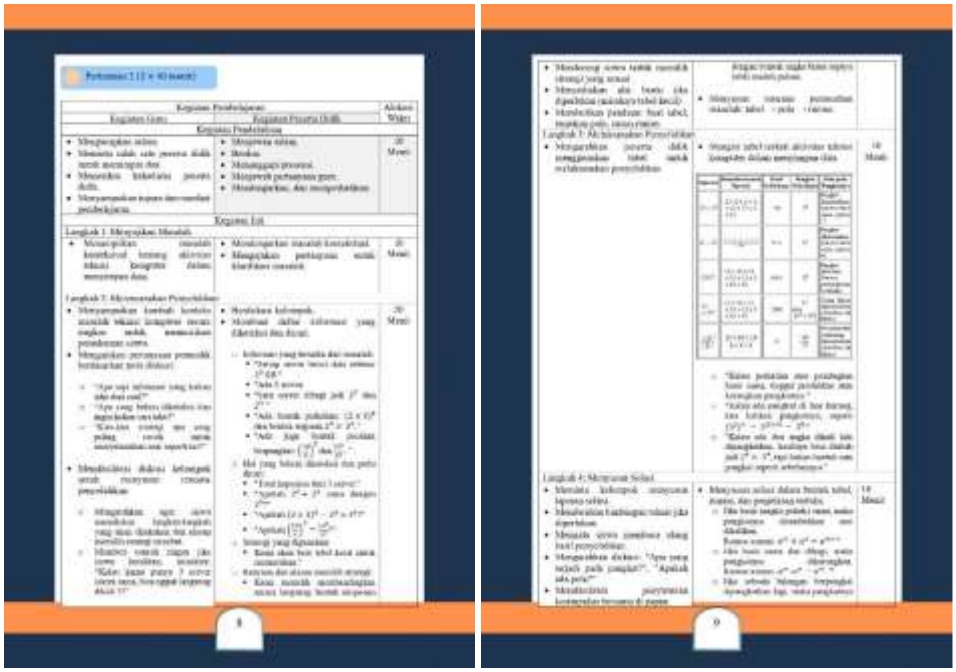

Figure 4. Learning Activities in the Teaching Module

The teaching module contains an attachment of assisted LKPD desmos classroom activities, which have been developed based on a problem-based learning approach, and are oriented towards critical thinking skills in Figure 5.

Figure 5. Attachment to Assisted LKPD Desmos Classroom Activities

The teaching module includes a critical thinking skills test to evaluate student learning achievement. This component includes assessment instruments, criteria, and indicators that align with the learning objectives formulated in Figure 6.

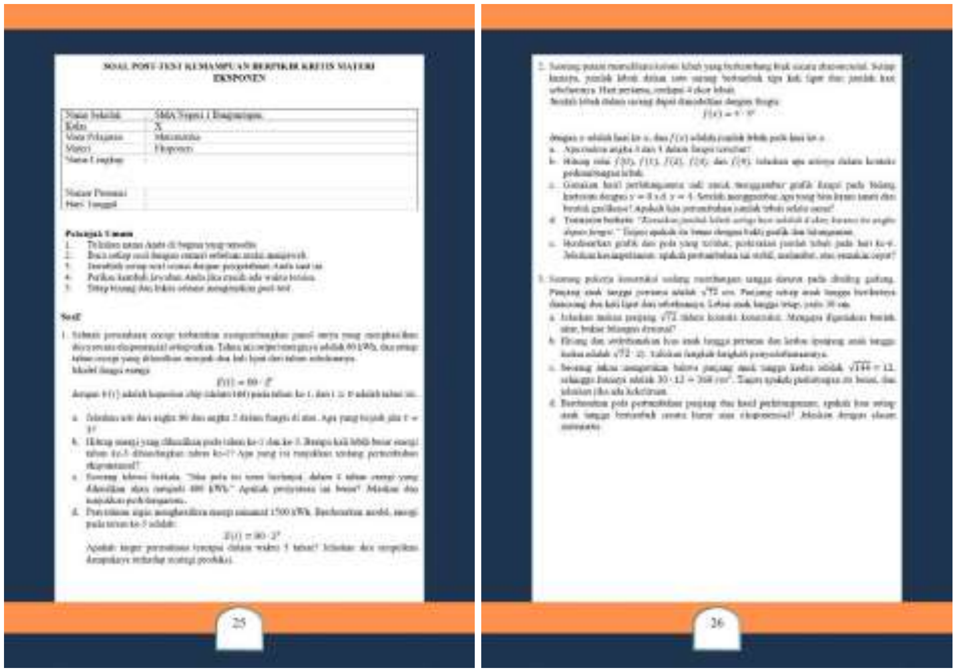

Figure 6. Critical Thinking Ability Test in the Teaching Module

Finally, in the teaching module, there is a summary of the teaching materials used as reference materials for developing the teaching module and LKPD in Figure 7.

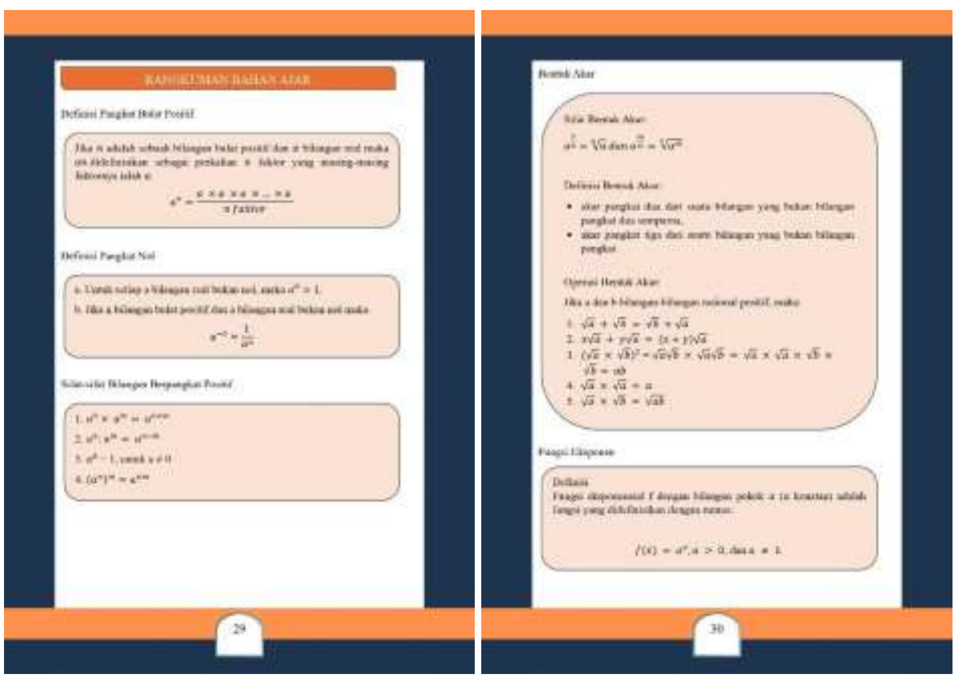

Figure 7. Summary of Teaching Materials in the Teaching Module

Furthermore, the LKPD was developed with assistance from desmos classroom activities. Each meeting contains four learning activities, which are arranged systematically according to the learning objectives set out in Figure 8.

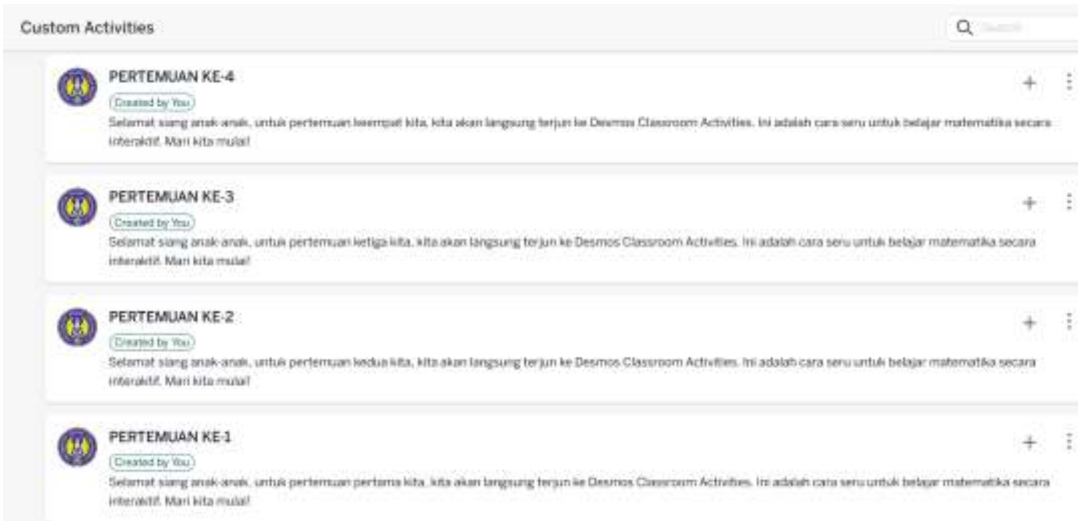

Figure 8. Assisted LKPD Desmos Classroom Activities at Every Meeting

The number of screens at each meeting varies. In the assisted LKPD Desmos Classroom Activities, the first meeting, many screens were developed, as many as fifteen slides. The results of the development of the first meeting are shown in Figure 9.

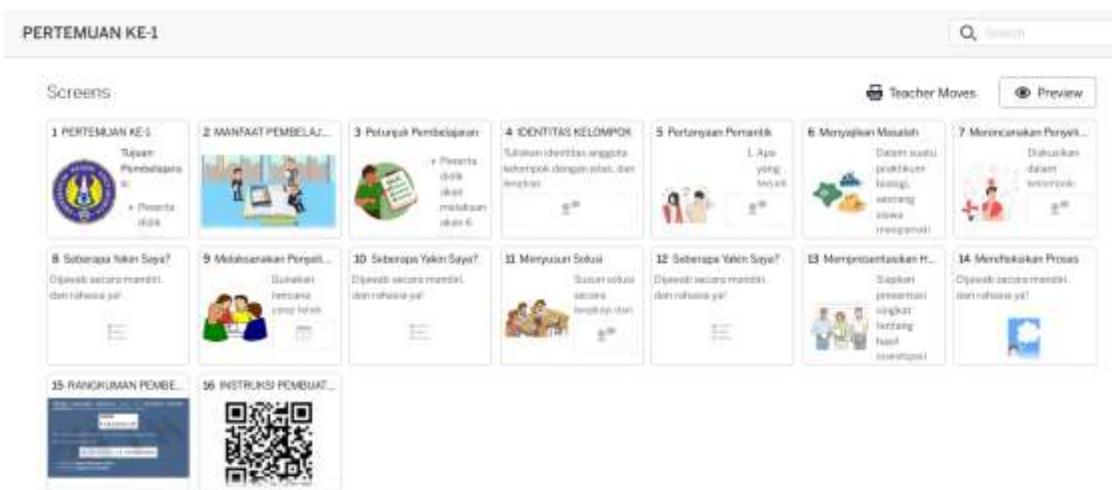

Figure 9. Assisted LKPD Desmos Classroom Activities: The first meeting

At the second meeting, fifteen slides were developed. The results of the second meeting's development are shown in Figure 10.

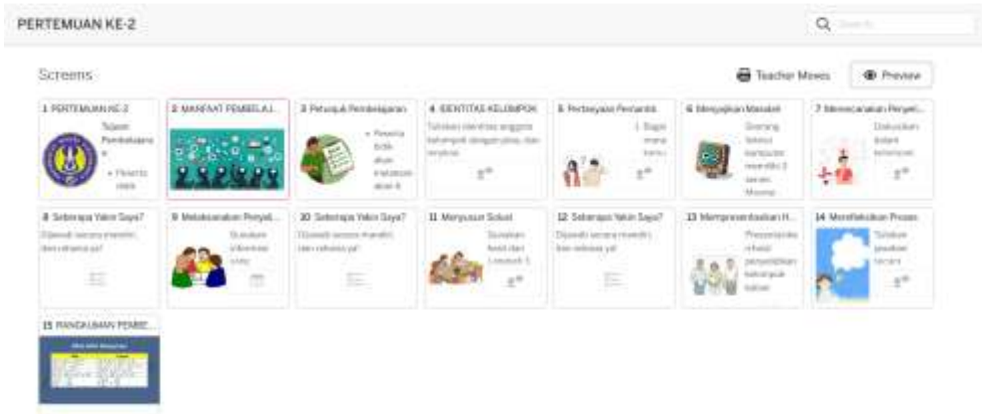

Figure 10. Assisted LKPD Desmos Classroom Activities, Second Meeting

At the third meeting, fifteen slides were developed. The results of the third meeting's development are shown in Figure 11.

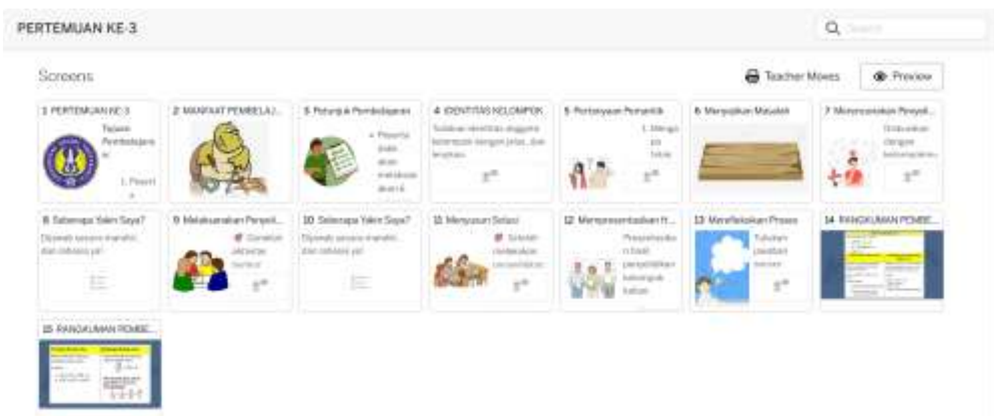

Figure 11. Assisted LKPD Desmos Classroom Activities, Third Meeting

At the fourth meeting, a total of twenty-four slides were developed. The results of the fourth meeting's development are shown in Figure 12.

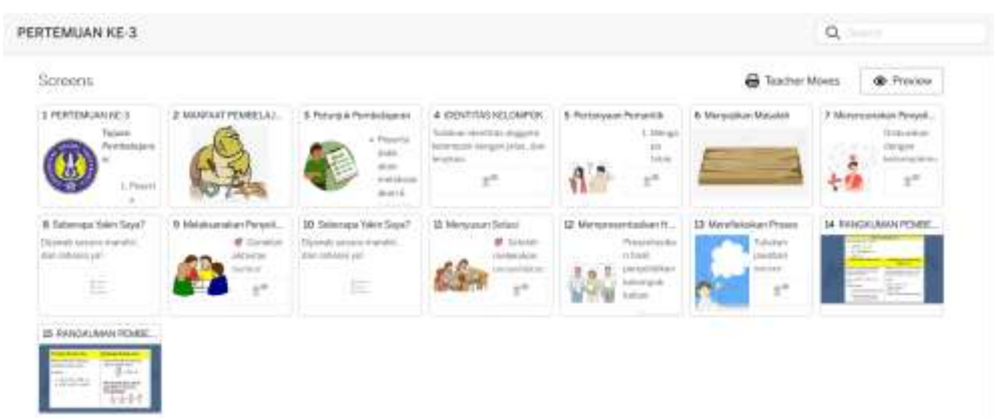

Figure 12. Assisted LKPD Desmos Classroom Activities, Fourth Meeting

A small-scale trial (limited trial) in this study was conducted to assess the practicality of the learning device before it was implemented on a wider scale. The limited trial was conducted involving 8 grade 10 students. The learning device was based on problem-based learning, assisted desmos classroom activities. The critical thinking-oriented learning tool has previously been declared valid, so it was tested on a limited basis and then applied to research subjects in grade X of high school. This trial aims to evaluate the effectiveness and practicality of the learning tool.

The evaluation stage is the final part of the ADDIE development model, which includes an assessment of the practicality and effectiveness of the product. The products developed are teaching modules and student worksheets (LKPD), assisted by the ADDIE model. The practicality of the teaching module is assessed through the practicality assessment sheet completed by the teacher, while the practicality of the Student Worksheet (LKPD) is assessed through teacher and student input, and is supported by the results of observations of the learning implementation. The effectiveness of the learning tools is focused on the tools' ability to facilitate students' critical thinking skills.

Product validity was obtained through expert validation results from Mathematics Education lecturers at Yogyakarta State University and Sanata Dharma University. The validation results showed that: (1) the critical thinking ability test instrument was in the very valid category; (2) the teaching module was declared very valid; (3) the LKPD assisted desmos classroom activities very valid from the material and media aspects; (4) the observation sheet for the implementation of learning is very valid; and (5) the validation sheet for the practicality of the teaching module and LKPD by teachers and students is also included in the very valid category. This confirms that the learning tools developed have met the validity criteria.

During the validation process, the validator also provided input and suggestions, which were then revised until the product was suitable for use. The learning tools were deemed valid because they were based on relevant theories. This aligns with the opinion of Nieveen (1999) states that a product can be declared valid if it has the appropriate framework and components.

The learning tools developed consist of teaching modules and student worksheets based on problem-based learning, assisted by desmos classroom activities oriented toward critical thinking skills, which were declared to meet the practicality criteria. This result was obtained through teacher assessments of the teaching module, which were categorized as "very practical." Furthermore, teacher assessments of the student worksheets were also categorized as "very practical," while student assessments of the student worksheets were categorized as "practical." The practicality component assessed encompasses several relevant aspects of learning.

In addition, the results of observations of the implementation of learning show that at each meeting, the percentage of implementation always reaches $\geq 80\%$This proves that the learning tools, in the form of teaching modules and student worksheets (LKPD), have met practicality criteria, making them easy to use by both teachers and students. This finding aligns with the opinion of Nieveen (1999) which states that a product is considered practical if it is deemed easy to use by both teachers and experts. Thus, the assessment results from teachers and students confirm that this product is practical for use in achieving learning objectives.

Furthermore, learning devices are based on problem-based learning, assisted desmos classroom activities, which have also proven to meet the effectiveness criteria. Based on the results of the critical thinking ability test, the value obtained $p - \text{value} = 0{,}0004797 < 0{,}05$, so that according to the criteria, it can be concludedH_0 rejected. Thus, the average critical thinking ability of students after using learning devices ($81{,}33$) is higher than the KKTP (75) and the average before learning ($36{,}07$).

The results of the proportion test also strengthen this finding. At a significance level of 0.05, $Z_{count} = 1{,}946 > Z_a = 1{,}645$, so that H_0 rejected. This means that the proportion of students who achieved a score $\geq$ KKTP (75) on the critical thinking ability test more than 70%. Based on these results, it can be concluded that learning devices based on problem-based learning, assisted by desmos classroom activities, which are oriented towards critical thinking skills, are declared effective.

Discussion

This research into the development of learning tools resulted in a product that is valid, practical, and effective. This learning tool can be recommended for use as a learning tool based on the learning approach, problem-based learning, which is oriented towards students' critical thinking skills. The results of this study are in line with previous research conducted by Hakiki et al. (2022) showed that integrating technology into learning devices also obtained valid, practical, and effective categories.

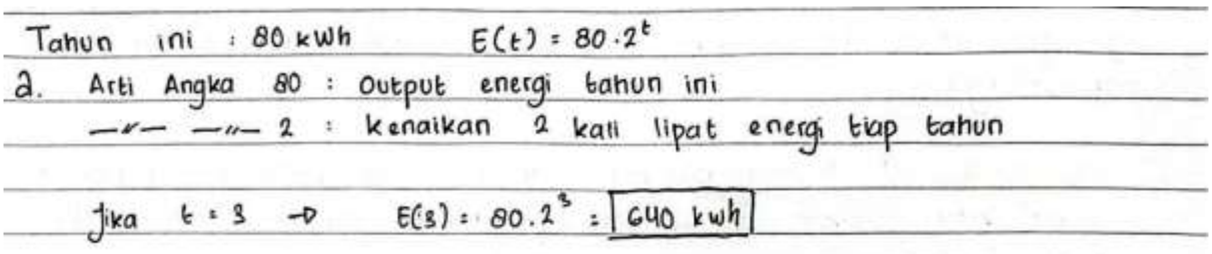

Figure 13. Student Answers for Indicator 1

Based on the results of one of the students' answers in Figure 13, it can be seen that he was able to solve critical thinking problems correctly. The first indicator, namely interpretation, shows that students can understand and interpret information from data, facts, or situations, as well as identify the core of the problem or main idea, as reflected in the results of their answers.

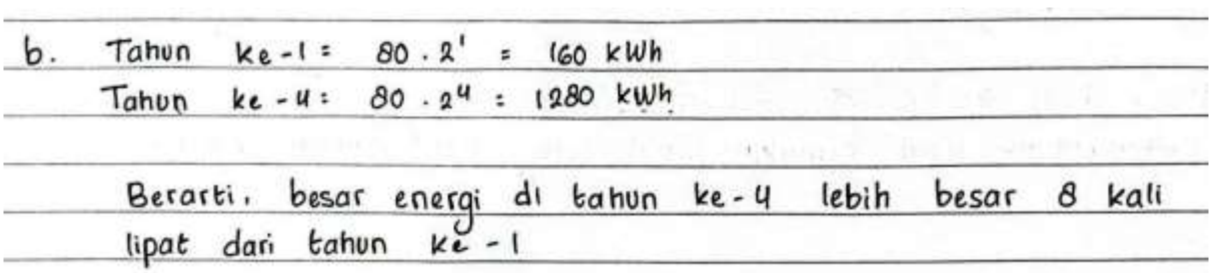

Figure 14. Student Answers for Indicator 2

Based on the results of one of the students' answers in Figure 14, it can be seen that he was able to solve critical thinking problems correctly. The second indicator, namely analysis, shows that students can identify relationships between statements, evidence, or arguments, as reflected in the results of the answers.

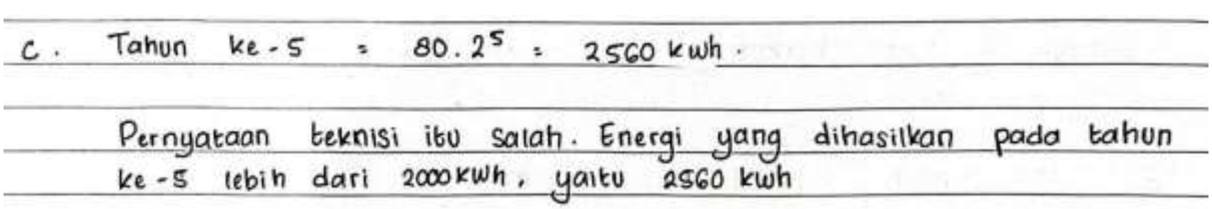

Figure 15. Student Answers for Indicator 3

Based on the results of one of the students' answers in Figure 15, it can be seen that he was able to solve critical thinking problems correctly. The third indicator, namely analysis, shows that students can assess the quality of arguments, the credibility of sources or evidence, and evaluate the logical strength of an argument, as reflected in the results of their answers.

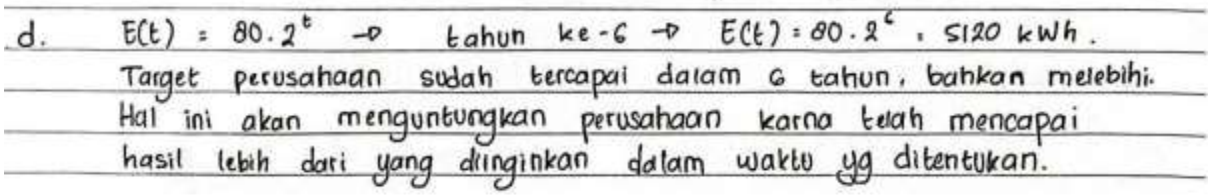
d. $E(t) = 80.2^t$ -> tahun ke-6 -> $E(t) = 80.2^6$. 5120 kWh.
Target perusahaan sudah tercapai dalam 6 tahun, bahkan melebihi.
Hal ini akan menguntungkan perusahaan karna telah mencapai
hasil lebih dari yang diinginkan dalam waktu yg ditentukan.

Figure 16. Student Answers for Indicator 4

Based on the results of one of the students' answers in Figure 16, it can be seen that he was able to solve critical thinking problems correctly. The fourth indicator, namely inference, shows that students can draw logical conclusions from data or information, as reflected in the results of their answers.

Overall, most students achieved all four indicators of critical thinking skills, as demonstrated by their written answers. However, implementation still faced several challenges, such as time constraints and technical issues, which meant that certain aspects still needed improvement.

Conclusion

The conclusion of this study is that the results of the development of learning devices consisting of teaching modules and LKPD assisted by desmos classroom activities oriented towards critical thinking skills has met the criteria of being valid, practical, and effective. The results of the validation of the teaching module by experts showed the criteria of being "very valid," while the validation of the LKPD assisted by desmos classroom activities in terms of materials and media, the learning tools also achieved the "very valid" criteria. The practicality of the learning tools was demonstrated through the results of teachers completing the practicality sheets for the teaching modules and student worksheets (LKPD) with a "very practical" category, as well as students completing the practicality sheets for the LKPD, which received the "practical" category. Furthermore, the results of observations on the implementation of learning showed the achievement of $\geq 80\%$. The effectiveness aspect is achieved through the results of critical thinking ability tests, where field trials show that $\geq 70\%$students have achieved the Learning Completion Criteria (KKTP) with an average critical thinking ability of $81{,}33$.

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