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PENELITIAN R&D: E-LKPD LINGKARAN BERBASIS PBL-TARL TERHADAP KEMAMPUAN PEMECAHAN MASALAH SISWA SMP

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ABSTRACT

This Research and Development (R&D) study aims to develop and evaluate the feasibility of an interactive e-LKPD based on Problem-Based Learning (PBL) integrated with the Teaching at the Right Level (TaRL) approach. The novelty of this study lies in combining PBL and TaRL to accommodate students' diverse cognitive abilities. The research involved 22 eighth-grade students of SMP Negeri 2 Menes and employed the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Data were collected using expert validation sheets, practicality questionnaires, and mathematical problem-solving tests on circle material. The results showed that the e-LKPD achieved a high level of validity, with an average expert validation score of 85%. The practicality level reached 90% based on teacher responses and 86.96% based on student responses, both categorized as very practical. Effectiveness testing using the N-Gain score showed an increase of 0.4412, which falls into the moderate category. In addition, the paired sample t-test yielded a significance value of 0.000 ($p < 0.05$), indicating a significant improvement in students' mathematical problem-solving skills after using the e-LKPD. In conclusion, the integration of PBL and TaRL in this e-LKPD is proven to be valid, practical, and effective. This study contributes by providing an adaptive learning medium aligned with students' initial ability levels, which can be implemented by educators to enhance problem-solving skills at the junior high school level.
Keywords: *e-lkpd; mathematical problem-solving; problem-based learning; teaching at the right level.*

ABSTRAK
Penelitian Research and Development (R&D) ini bertujuan untuk mengembangkan sekaligus menguji kelayakan e-LKPD interaktif berbasis Problem-Based Learning (PBL) yang diintegrasikan dengan pendekatan Teaching at the Right Level (TaRL). Kebaruan (novelty) penelitian ini terletak pada sinergi model PBL dan pendekatan TaRL yang dirancang secara spesifik guna memfasilitasi heterogenitas pemahaman kognitif siswa secara adaptif. Penelitian ini melibatkan sampel uji coba sebanyak 22 siswa kelas VIII di SMP Negeri 2 Menes. Proses pengembangan produk berlandaskan pada model instruksional ADDIE (Analysis, Design, Development, Implementation, Evaluation). Pengumpulan data dilakukan melalui instrumen lembar validasi ahli, angket kepraktisan, serta tes kemampuan pemecahan masalah matematis pada materi lingkaran. Hasil analisis data mengindikasikan bahwa e-LKPD memenuhi kriteria sangat valid dengan skor rata-rata validasi ahli materi dan media sebesar 85%. Tingkat kepraktisan produk berdasarkan respon guru dan siswa berturut-turut mencapai 90% dan 86,96% (kategori sangat praktis). Pengujian efektivitas melalui analisis N-Gain score menghasilkan peningkatan sebesar 0,4412 (kategori sedang). Lebih lanjut, uji paired sample t-test menunjukkan nilai signifikansi 0,000 ($p < 0,05$), yang mengonfirmasi adanya peningkatan kemampuan pemecahan masalah matematis secara signifikan pasca-penggunaan e-

LKPD. Kesimpulannya, integrasi PBL dan TaRL dalam e-LKPD ini terbukti valid, praktis, dan efektif. Kontribusi utama dari penelitian ini adalah tersedianya alternatif media pembelajaran matematis yang adaptif terhadap tingkat kemampuan awal siswa, yang secara praktis dapat diimplementasikan oleh pendidik untuk mengoptimalkan kemampuan pemecahan masalah di tingkat sekolah menengah pertama.
Kata kunci: *: e-lkpd; pemecahan masalah; problem-based learning; teaching at the right level.*

Introduction

Mathematics is an essential subject that underpins the devel Mathematics is a opment of students' logical, systematic, and critical thinking skills. Mastery of this discipline serves as the primary foundation for fostering the analytical mindset crucial for addressing 21st-century problem-solving challenges. However, students' achievement of mathematical competencies in Indonesia still faces serious structural challenges. This is empirically evidenced by the 2022 Programme for International Student Assessment (PISA) report, which shows that the average mathematics score for Indonesian students dropped to 366 points from 379 points in 2018. The fact that only 18.35% of students achieved the minimum competency level indicates low numeracy literacy and massive difficulties in solving problems that require higher-order reasoning. In response to this numeracy crisis, the government, through Ministry of Education Regulation No. 9 of 2025, established the Academic Ability Test as an innovation in standardized educational assessment (Sukamto & Nurvayanti, 2026) . The TKA is specifically designed to measure Higher Order Thinking Skills through numerical, logical, and spatial reasoning, which demands deep analytical skills rather than mere memorization.

In line with the HOTS orientation of the TKA policy, mathematical problem-solving ability is an absolute key indicator of learning achievement (Husna, 2025). This ability represents students' comprehensive competence in understanding problems, In abstract subjects such as circle geometry, this competency becomes particularly crucial. Students are required to translate contextual information from a problem into precise mathematical representations and independently select solution steps (Tanudjaya & Doorman, 2020) . Mathematics learning should not only be oriented toward improving student learning outcomes, but also toward improving problem-solving skills (Komariya, et al., 2018).

To facilitate this cognitive complexity, innovative instructional designs that are interactive and adaptive are required. The Problem-Based Learning (PBL) approach has proven essential for stimulating conceptual understanding and problem-solving through investigation of real-world cases (Husniah & Azka, 2022). However, in heterogeneous classroom settings, the implementation of PBL requires structured guidance to ensure that the entire spectrum of students is supported. Therefore, PBL is conceptually integrated with the Teaching at the Right Level (TaRL) approach. The synergy between these two approaches operates complementarily: PBL acts as a stimulus guiding the flow of analytical thinking in mapping mathematical representations, while TaRL functions as a scaffolding for differentiation that aligns the complexity of problems with students' actual cognitive capacities (Putri et al., 2024). There are four steps in problem solving: understanding the problem, planning the problem, solving the problem, and rechecking the steps (Vahlia et al., 2022).

Various previous studies have examined the effectiveness of these two approaches. The development of PBL-based Student Worksheets (LKPD) on abstract geometry topics has previously been validated and deemed practical for implementation at the junior high school level (Abdillah & Astuti, 2021). The transition to digital platforms also confirms that the integration of PBL and differentiation strategies can significantly boost motivation and mathematical learning outcomes (Januari et al., 2025). Furthermore, the validity and feasibility of PBL-TaRL-based learning instruments have been successfully tested in other disciplines such as chemistry (Parhusip & Iryani, 2024). Nevertheless, the existing literature still has substantial limitations. Most studies tend to focus on measuring the affective domain or evaluating learning outcomes in general without specializing in the development of responsive electronic-based instruments to train higher-order cognition.

These limitations leave a fundamental research gap. Specifically, the conceptual integration of how TaRL differentiation scaffolding is embedded into PBL stages through interactive electronic media (e-LKPD) formats, particularly for dissecting circle-related material, remains very under-explored empirically (Putri et al., 2024). difficult for educators to guide logical thinking processes for students with diverse ability profiles. Exploring the development of media capable of mapping abstract problems into mathematical representations in an adaptive manner is crucial for positioning this research to enrich the literature on digital mathematics education.

To address this gap, this study aims to develop and test the validity, practicality, and effectiveness of a PBL-model e-LKPD using the TaRL approach in improving junior high school students' mathematical problem-solving skills regarding circle-related topics (Silvi & Fathurrohman, 2024). The novelty of this research clearly lies in the construction of a digital e-LKPD instrument that synergizes problem exploration stimulation (PBL) with precise task difficulty calibration (TaRL). This output was implemented using the Liveworksheets platform to provide an interactive, accessible learning experience with real-time assessment capabilities. This innovation is expected to offer practical benefits as an adaptive learning tool for educators, while also contributing theoretically to the development of inclusive and equitable formative assessment strategies.

Results and Discussion

Research Design

This study is a development research project that adapts the ADDIE instructional model framework, which systematically consists of five integrated stages. The details of the activities in each phase are as follows (Sugiyono, 2013):

Analyze: Includes identifying problems with conventional mathematics learning in the field, analyzing curriculum needs, and determining the specifications of circle-related material for students identified as having low mathematical problem-solving skills.

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Design: This involves creating a storyboard to visualize the page structure, instructions, content, and interactive features of the e-LKPD, which integrates Problem-Based Learning (PBL) syntax and the Teaching at the Right Level (TaRL) approach.

Development: This involves the implementation of the e-LKPD design using the Canva platform, which is then digitally integrated into Liveworksheets. This phase is followed by a product feasibility validation process conducted by subject matter and media experts, along with revisions to ensure the instrument is suitable for pilot testing.

Implementation: This involves the direct application of the validated e-LKPD product into actual classroom learning processes.

Evaluation: This entails measuring the product's practicality through the distribution of response questionnaires to students and teachers, as well as testing the effectiveness of the e-LKPD in improving mathematical problem-solving skills via assessment instruments.

Research Subjects

The e-LKPD implementation pilot was conducted during the second semester of the 2024/2025 academic year. The subjects in this study consisted of 22 eighth-grade students at SMP Negeri 2 Menes. The selection of subjects was not random but utilized purposive sampling based on the results of preliminary observations and interviews with the mathematics teacher. Methodologically, this class was selected because it was empirically identified as having a track record of problem-solving skills that were still relatively low, while also exhibiting a highly varied level of cognitive understanding among its students. The heterogeneity and low level of numeracy literacy in this class provided an ideal and relevant justification for directly testing the effectiveness of the adaptive scaffolding offered by the TaRL approach.

Although a sample size of 22 students is practically considered sufficient and representative for a limited-scale pilot test in evaluating the initial feasibility of an R&D product (Sugiyono, 2007), the researcher acknowledges limitations regarding generalizability. The use of a relatively small sample means that conclusions regarding the effectiveness of the e-LKPD in this study are contextual and can only be strongly represented in populations with similar characteristics. Therefore, to draw more comprehensive conclusions and strengthen the external validity of the instrument, it is recommended that the product be tested on a broader population in follow-up studies or implementations.

Research Instruments

The data collection instruments used in this study consisted of validation sheets completed by subject matter experts and media experts to assess the validity of the e-LKPD, teacher and student response questionnaires to assess practicality, and a mathematical problem-solving ability test to measure the product's effectiveness in enhancing mathematical problem-solving skills. Test data collection was conducted twice, namely through pretest and posttest phases (Sugiyono, 2007).

The mathematical problem-solving test was specifically designed based on Polya's four-step problem-solving process (Risma & Isnarto, 2019) : (1) understanding the problem, (2) planning the solution, (3) implementing the

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solution plan, and (4) checking the answer. Although this test instrument consists of only three items, each item is constructed as a complex and contextual Higher Order Thinking Skills (HOTS) instrument. These three open-ended items were comprehensively designed so that each item could explore Polya's four indicators in a layered manner. Therefore, the number of three questions is considered highly representative, proportional to the allotted time for completion, and sufficiently in-depth to map students' cognitive processes comprehensively. Each indicator at the Polya stages is measured using an analytical scoring rubric with a scale ranging from 0 to 3 (Risma & Isnarto, 2019).

To ensure the validity and reliability of the test instrument before its use in the research class, the questions were first empirically pilot-tested on a non-sample class with equivalent characteristics that had studied circle-related material. The instrument's quality was quantitatively analyzed, covering validity, reliability, difficulty level, and discriminative power (Arikunto, 2021).

Based on the analysis results, the validity test of the test items using the Pearson Product Moment correlation formula showed that all three items had a calculated $r_{value} > r_{table}$, meeting the validity criteria. Furthermore, the reliability test of the instrument using Cronbach's Alpha yielded a reliability coefficient of 0.967, indicating that the test has a high level of reliability. The results of this empirical pilot study methodologically confirm that the test instrument used is valid, reliable, and academically appropriate for measuring improvements in students' problem-solving abilities.

Data Analysis Techniques for E-LKPD

In this development study, data analysis was conducted using descriptive and inferential quantitative methods based on the scores obtained from the research instruments. The data details include the processing of scores from the expert validation sheets, student and teacher response questionnaires, and the mathematical problem-solving ability test. The data was systematically analyzed to evaluate three main aspects of the e-LKPD product: validity, practicality, and effectiveness.

Validity Analysis of the e-LKPD

Before being pilot-tested with students, the e-LKPD was theoretically validated by subject matter experts and media experts. The content validity scores from the experts were calculated using Aiken's V validity index (Suhardi, 2022). The formula used is as follows:

$$V = \frac{r - l_0}{n(c-1)}$$

Keterangan:
V= Alken validity index
r = Score assigned by the validator
l_0 = Lowest score in the scoring category
n = Number of validators
c = Number of scoring categories

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Analysis of the Practicality of E-LKPD

The practicality analysis utilized response sheets; in this study, two types of response sheets were used: one for students and one for teachers. Each statement in the response sheet was scored according to the answers obtained. The scoring scale was adapted from Arikuto (Ali dkk., 2022) with some modifications. The criteria used to assess the practicality of the product are presented in detail in Table 1 below:

Table 1. Practicality Scoring Criteria

Skor	Description
5	Excellent
4	Good
3	Fair
2	Poor
1	Very Poor

Based on Table 1, the scoring criteria are divided into five levels, ranging from a score of 1 for the "Poor" category to a score of 5 for the "Excellent" category. These criteria serve as the primary reference for quantifying each statement on the response sheet. The practicality score in this study is calculated using the following formula:

$$p = \frac{Total\ Score\ Obtained}{\text{Maximum Score}} \times 100\%$$

The practicality calculation method was adapted from (Sugiyono, 2013) and subsequently modified. The results of the practicality calculations were then interpreted using the five test criteria shown in Table 2:

Table 2. Criteria for the practicality test results of the e-LKPD Response Sheet

No	Interval	Category
1	$81\% < p \leq 100\%$	Very Practical
2	$61\% < p \leq 80\%$	Practical
3	$41\% < p \leq 60\%$	Fairly Practical
4	$21\% < p \leq 40\%$	Less Practical
5	$0\% < p \leq 20\%$	Not Practical

Table 2 shows the percentage range intervals for the practicality of the e-LKPD, where the instrument is categorized as 'Very Practical' if its score falls between 81% and 100%, and categorized as 'Not Practical' if its score falls within the range of 0% to 20%.

Analysis of E-LKPD Effectiveness

Descriptive Analysis of Score Improvement (N-Gain Test)

The level of e-LKPD effectiveness is descriptively measured by calculating the increase in student scores before and after learning using the Normalized Gain formula. This test is used to normalize the difference between posttest and pretest scores to avoid bias from students' initial abilities. The N-Gain formula used is:

$$g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}}$$

Keterangan:
G = N-Gain score
S_{post} = Posttest score

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S_{pre} = Pretest score
S_{max} = Ideal maximum score

The interpretation rules for N-Gain score categories refer to the following standard criteria:

$g \geq 0.7$ is categorized as High
$0.3 \leq g < 0.7$ is categorized as Moderate
$g < 0.3$ is categorized as Low

Inferential Analysis of Hypothesis Testing (Paired Sample t-Test)

To test the statistical significance of this increase in scores, a parametric Paired Sample t-Test was conducted using SPSS software. The use of this test was based on a research design involving a single sample group (Sugiyono, 2007). A prerequisite for this test is that the data must be normally distributed (as determined by the Shapiro-Wilk test).

The statistical hypotheses formulated in this study are:

H_0: There is no significant increase in the average mathematical problem-solving ability of students following the use of the e-LKPD based on the Problem-Based Learning (PBL) model using the Teaching at the Right Level (TaRL) approach.

H_1: There is a significant increase in the average mathematical problem-solving ability of students following the use of the e-LKPD based on the Problem-Based Learning (PBL) model with the Teaching at the Right Level (TaRL) approach.

Decision Criteria:

Conclusions are not drawn based on calculated results but rather guided by probability values (Significance). If the Sig. (2-tailed) value is < 0.05, then H_0 is rejected and H_1 is accepted. This serves as the methodological basis for interpreting that the e-LKPD intervention has a significant effect.

Results and Discussion

The researchers conducted this development to produce an Electronic Student Worksheet (e-LKPD) based on the Problem-Based Learning (PBL) model with a Teaching at the Right Level (TaRL) approach to improve junior high school students' mathematical problem-solving skills regarding the topic of circles. The resulting e-LKPD product is deemed suitable for use if it meets the criteria of validity, practicality, and effectiveness based on media development standards.

Analyze

During the analysis phase, based on observations, the researchers identified that the mathematics learning process, particularly regarding the topic of circles, is still dominated by conventional approaches. Instructional activities generally rely on the use of textbooks and lecture methods as the primary learning resources. Educators were found to rarely utilize interactive learning media or technology-based innovations that adapt to the diversity of students' cognitive levels. This situation directly results in low levels of active student engagement during the learning process, which in turn leads to suboptimal development of their mathematical problem-solving skills.

To address these issues, the researchers concluded that there is a need to develop an interactive e-LKPD based on PBL with a TaRL approach. This medium

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is expected to adapt learning to students' ability levels, increase active engagement in the learning process, and support the improvement of mathematical problem-solving skills (Zuhri et al., 2024). As a reference for developing e-LKPDs to align with curriculum needs, the results of the curriculum analysis are presented in Table 3.

Table 3. Curriculum Analysis Table

Core Competencies	Competency Achievement Indicators (IPK)
3.7 Explain central angles, inscribed angles, arc lengths, and sector areas of a circle, as well as their relationships	• Identify the elements of a circle (center, radius, diameter, arc, chord, sector, and apothem) • Explain the relationship between central angles, arc lengths, and sector areas
4.7 Solve problems related to central angles, circumferential angles, arc lengths, and the area of a circular sector, as well as their relationships.	• Calculate the circumference and area of a circle using the appropriate formulas • Solve contextual problems related to arc lengths and the area of a circular sector

Table 3 outlines the results of the curriculum analysis covering Basic Competencies 3.7 and 4.7 along with the elaboration of their Competency Achievement Indicators. The researcher focused the development process by referring to this table to ensure alignment with the minimum competency standards for circle-related learning.

Design

After completing the analysis phase, the development process proceeds to the design phase. This phase aims to design an initial prototype of the learning product to be developed: an e-LKPD based on Problem-Based Learning (PBL) with a Teaching at the Right Level approach, to be applied to circle-related material in 8th-grade junior high school. This design is based on the findings from the needs and curriculum analysis stages, ensuring that the resulting media is targeted, contextual, and aligned with students' needs. In this context, the design phase for creating the e-LKPD involves the development of a storyboard.

A storyboard is a visual design containing sketches of the content display for each section of the e-LKPD (Sugiyono, 2013). The storyboard was created so that the researcher, teachers, and validators could visualize the page structure, instructions, text content, image elements, and interactive features to be included in the e-LKPD.

Development

In this development phase, the researcher implemented the design previously formulated in the planning phase. The product developed was an e-LKPD based on the Problem-Based Learning (PBL) model with a Teaching at the Right Level (TaRL) approach, created using the Canva platform and subsequently implemented on the Liveworksheet platform. The initial development phase resulted in an e-LKPD that had not yet been reviewed by subject matter experts or media experts. The results of the initial development stage in this study are listed in the links in Table 4:

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Table 4. e-LKPD Links

Session	**Level**	**e-LKPD Link**
	Easy	pertemuan 1 mudah
1	Medium	pertemuan 1 sedang
	High	pertemuan 1 tinggi
	Easy	Pertemuan 2 Mudah
2	Medium	Pertemuan 2 Sedang
	High	Pertemuan 2 Tinggi
	Easy	Pertemuan 3 Mudah
3	Medium	Pertemuan 3 Sedang
	High	Pertemuan 3 tinggi
	Easy	Pertemuan 4 mudah
4	Medium	Pertemuan 3 sedang
	High	Pertemuan 3 TInggi

Table 4 summarizes all access links to the e-LKPDs developed for the four sessions, each of which was specifically designed to accommodate three levels of student ability: easy, moderate, and advanced.

Subsequently, the e-LKPD was submitted to subject matter experts and media experts for validation. Validation by subject matter experts was conducted by two individuals: Mr. Ihsanudi, M.Si., a mathematics education lecturer at Sultan Ageng Tirtayasa University, and Ms. Umul Himah, S.Pd., a mathematics teacher at SMP Negeri 2 Menes. Meanwhile, media validation was conducted by Prof. Maman Fathurrohman, Ph.D., a mathematics education lecturer at Sultan Ageng Tirtayasa University, and Ms. Tati Mulyati, S.Pd., a mathematics teacher at SMP Negeri 2 Menes. This validation process aimed to assess the suitability of the e-LKPD before its implementation in the field, while also gathering feedback and suggestions for improvement from the experts. The results of the validation by the content experts and media experts are as follows in Table 5:

Table 5. Results of the Subject Matter Expert Validity Test

Validasi Ahli Materi				
No	**Aspek Penlialaian**	**Validator**		**Skor Max**
		1	2	
1	Didaktik	27	27	30
2	Model PBL	22	22	25
3	Model TaRL	18	17	20
4	Konstruksi	18	18	20
	TOTAL	85	84	95

Based on the results from the validators in Table 5, the first validator assigned a score of 85 (89%), while the second validator assigned a score of 84 (88%). Thus, both validators provided evaluations within a nearly identical score range, and the average score obtained was 89%. Consequently, this e-LKPD falls into the “highly valid” category. The highest score was given for the didactic aspect, reflecting that the content aligns with the learning objectives. Meanwhile, for the Teaching at the Right Level (TaRL) approach, the score was slightly lower for one of the validators; however, it remained within a range indicating the applicability of this approach in the e-LKPD. Thus, the validation results indicate that the Problem-Based Learning (PBL) model e-LKPD with the Teaching at the Right Level (TaRL) approach on circle-related content has been deemed content-appropriate and is ready to proceed to the pilot testing phase.

Media expert validation was conducted to comprehensively assess the suitability of the e-LKPD, particularly regarding the user interface, presentation design, and the reliability of technical operational functions. This evaluation process involved two media expert validators who assessed the instrument with a maximum overall score of 75 points shows in Table 6.

Table 6. Results of Media Expert Validity Testing

Media Expert Validation				
No	**Aspek Penilaian**	**Validator**		**Skor Max**
		1	2	
1	E-LKPD Desaign	27	32	35
2	Technical	30	36	40
	Summary	**57**	**68**	**75**

Based on the results of the quantitative assessment shown in Table 6, the first validator assigned a total score of 57 (78%), which falls within the “Valid” category. Meanwhile, the second validator assigned a higher score, with a total of 68 (90%), which corresponds to the “Highly Valid” category.

This level of validity is supported by a qualitative analysis explaining why this e-LKPD was deemed suitable. According to the second validator’s notes, the e-LKPD received the “Highly Valid” category because its visual design was deemed highly proportional; the color combinations and layout do not distract students’ focus on learning. From a technical completeness perspective, the interactive features functioned very responsively and stably. The e-LKPD’s structure also successfully presented geometric visual elements with clear resolution, thereby supporting students’ exploration optimally.

On the other hand, the score of 78% (“Valid”) from the first validator was based on several minor improvement notes that needed to be addressed before the field trial. The first validator suggested that some typography sizes (fonts) needed to be enlarged and their color contrast adjusted to make them easier to read when the e-LKPD is accessed via students’ mobile devices (smartphones). Additionally, minor adjustments are needed to the layout of the Problem-Based Learning (PBL) instructions to make the flow more intuitive. All these improvement notes have been accommodated and thoroughly revised to refine the product.

Thus, based on the integration of quantitative assessment and qualitative improvements from media experts, it can be concluded that the Problem-Based Learning (PBL) model e-LKPD with the Teaching at the Right Level (TaRL) approach for this circle-related material has firmly met the media feasibility criteria and is deemed valid to proceed to the pilot implementation phase in schools.

Implementation

After completing the development and revision phases based on the validation results from experts, the next step is the implementation phase. This phase is conducted to test the practicality and effectiveness of the Problem-Based Learning (PBL) model e-LKPD with the Teaching at the Right Level (TaRL) approach in real-world learning situations. This field trial was conducted in the 8th-grade class at SMP Negeri 2 Menes, involving 22 students as research subjects.

The implementation of this intervention is grounded in various empirical findings from prior research confirming the success of integrating the PBL and TaRL models in practice. Operationally, the combination of these two approaches has been proven to create a measurable positive leap in student engagement and interest in learning (Putri et al., 2024) . Furthermore, the implementation of PBL combined with TaRL at the junior high school level consistently reports a significant increase in the percentage of mastery of mathematics learning outcomes (Fitria et al., 2024). This success is also supported by previous research and development (R&D) studies that prove that PBL-TaRL-based mathematics teaching materials are academically valid and effective in a junior high school setting (Hidayatni & Fathani, 2023).

Although these empirical studies provide a strong foundation for implementation, the pilot study in this research focuses on specific objectives and outcomes that contribute to its novelty. While most previous studies tested implementations aimed at general learning outcomes, interests, or social-emotional competencies, the implementation phase of this study focused on the use of digital tools (e-LKPD supported by Liveworksheets). The primary objective is specifically designed to boost higher-order thinking skills, namely students' mathematical problem-solving abilities through adaptive and interactive learning experiences.

Evaluation

The final step in this study is the evaluation phase, which aims to assess the practicality and effectiveness of the e-LKPD that has been developed. The evaluation was conducted through an analysis of student and teacher feedback, as well as through tests of students' mathematical problem-solving skills. This evaluation also serves as a basis for identifying areas that need improvement so that the e-LKPD can be used to its full potential in classroom instruction.

a) Teacher Response Sheets and Student Response Sheets

Data collection for this study was conducted after the e-LKPD was implemented in classroom activities. A practicality questionnaire consisting of 23 statements was completed by all students, covering aspects such as the e-LKPD's attachments, ease of use, clarity of instructions, and support in understanding the material. The summary results showed an average practicality score of 82% from the students. This indicates that the e-LKPD was considered easily accessible, visually appealing, and capable of facilitating students in solving problems. Additionally, an evaluation was provided by the mathematics teacher, Mrs. Tati Astuty, S.Pd., through a response sheet. The teacher's feedback indicated that the e-LKPD met the criteria for effective instructional materials in terms of content alignment with learning objectives, visual structure, and ease of implementation in the classroom. Based on the survey results, the teacher assigned a practicality score of 94%, which also falls into the "very practical" category.

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Overall, the evaluation results indicate that the e-LKPD possesses a high level of practicality from both the students' and educators' perspectives. This suggests that the product is suitable for use in mathematics instruction and has the potential to support a more meaningful and self-directed learning process for students.

b) Effectiveness of the e-LKPD

A mathematical problem-solving ability test was administered during the fourth session, after students completed their learning using the developed e-LKPD. This test consisted of three questions designed based on Polya's stages of problem-solving: understanding the problem, planning the solution, implementing the strategy, and checking or concluding.

1) Normality Test

To measure students' mathematical problem-solving abilities before and after using the e-LKPD, the researcher administered a pretest and a posttest. Data from both tests were then analyzed using the Shapiro-Wilk normality test via SPSS software, as the sample size was less than 50. This test is crucial for determining the data distribution and subsequently selecting the appropriate statistical test. The results of the normality test are presented in Table 7

Table 7: Results of the normality test:

Normaly Test Results			
	Shapiro-Wilk		
	Statistic	df	Sig.
Data *Pretest*	0.973	22	0.787
Data *Posttest*	0.945	22	0.250

Table 7 presents the results of the normality test using the Shapiro-Wilk method. Based on the analysis results, it is found that the significance value for the pretest data is 0.787 and for the posttest data is 0.250. Since both significance values are greater than 0.05, the data is proven to be normally distributed. Therefore, the data meets the prerequisite for direct analysis in the subsequent statistical process, namely hypothesis testing using the Paired Sample t-Test.

2) N-Gain Test

To determine the extent to which the Problem-Based Learning (PBL) model of e-LKPD, using the Teaching at the Right Level (TaRL) approach, is effective in improving students' mathematical problem-solving skills, an N-Gain analysis was conducted on the pretest and posttest results. The results of the calculation are presented in Table 8:

Table 8. N-Gain Test Results

N-Gain Test results				
	N	**Minimum**	**Maximum**	**Mean**
N-Gain Score	22	0.13	0.54	0.4412
N-Gain Persen	22	13%	54%	44%

Based on the results of the analysis in Table 8, it was found that the average improvement in students' mathematical problem-solving skills reached 0.4412 (44%), which falls within the moderate category (fairly effective). The distribution of individual improvements indicates that out of a total of 22 research subjects, the majority (20 students) experienced an improvement in the moderate category, 1 student in the high category, and 1 student in the low category, with the range of improvement percentages varying between 13% and 54%. Cumulatively, these findings demonstrate that the use of the Problem-Based Learning (PBL) model e-LKPD with the Teaching at the Right Level (TaRL) approach has a positive impact on students' cognitive abilities.

Critically, the average N-Gain score in the "moderate" category is not a weakness but rather a very reasonable and successful achievement for an interactive learning innovation. Based on a comprehensive review, classes implementing the Interactive Engagement method generally yielded an average N-Gain of 0.48 ± 0.14. The score of 0.4412 obtained in this study is highly consistent with this standard of achievement and is significantly superior compared to the average N-Gain in traditional learning methods, which is only in the range of 0.23 ± 0.04.

Although this e-LKPD has proven to be far more effective than conventional methods, there are several limiting factors and operational constraints preventing the class average score from reaching the "high" category. Analysis of these constraints includes:

The Influence of "Hidden Variables": Improvements in individual scores are heavily influenced by various latent variables that students bring with them prior to the intervention, such as their level of basic mathematical proficiency and spatial visualization skills. Given the high heterogeneity of the study subjects, these disparities in basic mathematical proficiency prevent all students from simultaneously and instantly mastering the Polya problem-solving steps (Delima et al., 2021).

Limitations of the Intervention Duration: The PBL-TaRL e-LKPD was designed to provide scaffolding. However, due to the short duration of the field trial, the group of students at the lower cognitive level did not have sufficient time to adapt and shift from conventional learning habits toward higher-order thinking, thereby holding back the overall average progress of the class (Sukmadinata, 2021) . Based on this analysis, the e-LKPD system, as a whole, is considered effective in changing students' learning patterns. Moving forward, this product has the potential to be further optimized by extending the implementation period and adjusting scaffolding strategies to account for the influence of students' baseline abilities, thereby maximizing improvements in learning outcomes.

3) Paired T-Test

After the normality test indicated that the data were normally distributed, a hypothesis test was conducted using a paired-sample t-test. This test was chosen because the data came from the same group of subjects, with two different conditions: before and after the use of e-LKPD. The purpose of this test was to determine whether there was a significant difference in the mean pretest and posttest scores following the implementation of e-LKPD show in Table 9.

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Table 9. Results of the Paired t-Test Hypothesis Test

Statistik Uji Paired T-Test	Value
Mean Pretest	22
Mean Posttest	27.73
Mean Difference	35.73
Standard Deviation Difference	-8
t-Score	3.309
df (degrees of freedom)	-11.34
Sig. (2-tailed)	21
Pretest–Posttest Correlation	0,000
Mean Pretest	0.965

Based on the results presented in Table 9, it was found that since the significance value of 0,000 < 0,05, H_0 is rejected and H_1 is accepted. Thus, it can be concluded that there is a significant difference between students' pretest and posttest scores, indicating that the use of the Problem-Based Learning (PBL) model e-LKPD with the Teaching at the Right Level (TaRL) approach significantly influences the improvement of students' mathematical problem-solving skills.

Discussion

This study aims to develop an e-LKPD based on the Problem-Based Learning (PBL) model with the Teaching at the Right Level (TaRL) approach on circle-related material to improve students' mathematical problem-solving skills. Philosophically, the development of this instrument is grounded in constructivist theory. This theory views learning as an active process in which students gradually construct their own meaning and knowledge through interaction with contextual problems (Wahab & Rosnawati, 2021). The synergy between PBL and TaRL in this e-LKPD constructs a learning ecosystem that is personalized, participatory, and reflective (yuberti, 2014) , where students are no longer passive recipients but problem-solvers facilitated according to their actual cognitive level.

Based on expert evaluation, the e-LKPD was deemed "Highly Valid," with an average score of 89% for the content aspect and 84% for the media aspect. The PBL syntax (from problem orientation to reflection) and TaRL scaffolding were assessed as being well-integrated into the structure of the electronic activities. These findings align with (Vonna et al., 2022) who state that the validity of technology-based learning media is measured by the alignment between content and ease of interaction. Critically, the similarity between this study and previous research lies in the successful digitization of worksheets. However, the fundamental difference lies in the e-LKPD architectural design, which specifically organizes the TaRL difficulty level hierarchy within a single integrated platform, aligning with the principles of effective differentiated learning (Rahmadani et al., 2025).

The practicality of the product is evidenced by highly positive response scores, with 82% of students and 94% of teachers rating it as "Very Practical." Teachers confirmed that this e-LKPD facilitates the management of heterogeneous classes by providing systematic and in-depth activities. This high level of operational practicality aligns with the perspective (Firtsanianta & Khofifah, 2022) regarding the accessibility of e-LKPDs, and supports the findings (Fitri et al., 2024) that the combination of PBL-TaRL effectively ensures the engagement of the entire spectrum of students. The novelty in this aspect of practicality lies in the availability of adaptive digital tools that allow educators to facilitate three levels of student ability synchronously without disrupting the systematic flow of problem-solving.

The effectiveness of e-LKPD was inferentially demonstrated through a Paired Sample t-Test, yielding a significance value of 0.000 ($p < 0.05$). This result statistically confirms the rejection of H_0, indicating a significant improvement in students' mathematical problem-solving abilities between pretest and posttest intervention. This finding aligns with the postulate (Febriyanti et al., 2024) asserting that optimal improvements in cognitive abilities can be achieved through structured and contextualized learning.

Complementing this inferential evidence, the descriptive analysis of N-Gain indicates an average class improvement of 0.4412 (moderate category). Critically, this "moderate" N-Gain score is a highly positive achievement. Referring to foundational research (Hake, 2001) , classes using the Interactive Engagement method typically yield an average N-Gain of 0.48 ± 0.14 , far exceeding conventional learning. Therefore, the score of 0.4412 in this study meets the standard for intervention success. The factors preventing the class's average score from reaching the high category are closely related to hidden variables, such as gaps in basic math proficiency and students' initial spatial abilities (Hake, 2001).

Despite these latent variables, TaRL differentiation in the e-LKPD proved capable of facilitating improvement at every cognitive level: the Low group still showed significant improvement due to gradual scaffolding support (Dewanda et al., 2025) , the Intermediate group became more confident and independent in identifying and formulating problem-solving strategies (Istiqomah dkk., 2024), and the High group achieved the most optimal improvement because the principle of PBL's freedom of exploration was maximally fulfilled (Fitria et al., 2024).

Although these results philosophically support previous studies (Febriyanti et al., 2024) , the main contribution (novelty) of this study lies in the precision of its measurement focus. While previous studies were predominantly oriented toward general learning outcomes or the affective domain, this study specifically demonstrates that the e-LKPD digital instrument has a direct impact on the development of higher-order thinking skills (HOTS), particularly in mathematical problem-solving. This success demonstrates that adaptive formative assessment tools tailored to students' needs are a crucial key to creating an inclusive and high-quality educational ecosystem (Rahmatunnisa et al., 2025)

Conclusion and Suggestion

Conclusion

Based on the results of the research and development conducted, it can be concluded that the Problem-Based Learning (PBL)-based e-LKPD on circles, integrated with the Teaching at the Right Level (TaRL) approach, has been successfully developed and proven to be suitable for use. Specifically, the summary of the research findings is as follows: Validity: The e-LKPD product was deemed highly valid theoretically based on the assessment results from content experts (average 89%) and media experts (average 84%). Practicality: The e-LKPD product was proven to be highly practical in operation, as indicated by the high percentage of positive responses from educators (94%) and students (82%). Effectiveness: The e-LKPD product is effective in improving students' mathematical problem-solving skills. This is evidenced by an average N-Gain score of 0.4412 (moderate category), as well as the results of the Paired Sample t-Test, which showed a significance value of 0.000 ($p < 0.05$).

This study has demonstrated the feasibility of the product; however, it still leaves several unresolved limitations. Therefore, recommendations for future research are: Extend the Duration of the Intervention: Future researchers are advised to implement this e-LKPD with a longer trial period. This is necessary to provide a more optimal adaptation period for students at lower cognitive levels so they can become accustomed to higher-order reasoning methods. Analyzing Hidden Variables: Further studies are needed to specifically control for or analyze the influence of students' inherent variables, such as basic mathematical ability and visual-spatial intelligence, on the optimization of N-Gain gains in the implementation of the PBL-TaRL e-LKPD. Large-Scale Dissemination Testing: It is recommended to test the product on a broader and more diverse sample population across various schools to strengthen the generalizability of the findings

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