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Development of PBL-Based LKPD to Enhance Students' Mathematical Literacy Skills

Ismayawati[1], Sri Yuliyanti[2], Eliska Juliangkary*[3]

[1,2,3]Department of Mathematics Education, Faculty of Science, Technology, and Teaching, Mandalika University of Education
*Corresponding author: *eliskajuliangkary@undikma.ac.id*

Abstract: *This study aims to develop and evaluate a Problem Based Learning (PBL)-based Student Worksheet (LKPD) on polynomial material for 11th-grade students at SMAN 1 Lingsar. The development of the LKPD follows the modified 4-D model, which includes the Define, Design, and Develop stages, due to time and budget constraints. This research employs a one group pre-test and posttest experimental design, involving 30 11th grade students as subjects. The LKPD was validated by two experts: a content expert (80%) and a media expert (90%), who assessed aspects of content accuracy, instructional relevance, clarity, language, simplicity, visual design, and the integration of PBL components. The practicality of the LKPD was measured through questionnaires given to both teachers and students, with results showing a practicality level of 97% in terms of usability and instructional value. The effectiveness of the LKPD was tested through a mathematical literacy assessment given before and after the learning intervention. Data analysis was performed using a paired sample t-test, which showed a statistically significant improvement ($p < 0.05$) in students' mathematical literacy scores, particularly in problem formulation and solving indicators. These findings empirically support the use of the PBL model as a framework for designing instructional materials that can enhance mathematical literacy. The use of Canva as a design tool also increased student engagement through appealing and functional visual displays. The results of this study demonstrate that contextual and visually designed instructional materials can be effective pedagogical instruments, especially for abstract mathematics topics like polynomials. This research contributes to mathematics education by presenting a validated PBL based LKPD design model that can be adapted for various subjects and educational levels.*

Keywords: *Problem Based Learning, Student Worksheet, polynomials, mathematical literacy, mathematics education.*

Abstract: Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi Lembar Kerja Peserta Didik (LKPD) berbasis Problem Based Learning (PBL) pada materi polinomial untuk siswa kelas XI di SMAN 1 Lingsar. Pengembangan LKPD mengikuti model 4-D yang telah dimodifikasi meliputi tahap Define, Design, dan Develop karena keterbatasan waktu dan anggaran. Penelitian ini menggunakan desain eksperimen one group pretest and posttest dengan melibatkan 30 siswa kelas XI sebagai subjek. LKPD divalidasi oleh dua ahli, yaitu ahli materi (80%) dan ahli media (90%), yang menilai aspek ketepatan konten, relevansi instruksional, kejelasan, bahasa, kesederhanaan, desain visual, serta integrasi komponen PBL. Kepraktisan LKPD diukur melalui angket yang diberikan kepada guru dan siswa, dengan hasil menunjukkan tingkat kepraktisan sebesar 97% dalam aspek kegunaan dan nilai instruksional. Efektivitas LKPD diuji melalui asesmen literasi matematis yang diberikan sebelum dan sesudah intervensi pembelajaran. Analisis data dilakukan menggunakan uji paired sample t-test, yang menunjukkan peningkatan signifikan secara statistik ($p < 0,05$) pada skor literasi matematis siswa, khususnya pada indikator perumusan dan penyelesaian masalah. Temuan ini secara empiris mendukung penggunaan model PBL sebagai kerangka dalam merancang bahan ajar yang dapat meningkatkan literasi matematis. Penggunaan Canva sebagai alat desain turut meningkatkan keterlibatan siswa melalui tampilan visual yang menarik dan fungsional. Hasil penelitian ini menunjukkan bahwa bahan ajar yang kontekstual dan dirancang secara visual dapat menjadi instrumen pedagogis yang efektif, terutama untuk topik matematika yang bersifat abstrak seperti polinomial. Penelitian ini memberikan kontribusi pada pendidikan matematika dengan menyajikan model perancangan LKPD berbasis PBL yang tervalidasi dan dapat diadaptasi pada berbagai mata pelajaran dan jenjang pendidikan.

Kata Kunci: Problem-Based Learning (PBL), Lembar Kerja Peserta Didik (LKPD), polinomial, literasi matematis, pendidikan matematika.

INTRODUCTION

Mathematics plays a critical role in shaping students' abilities to think critically, logically, systematically, and creatively. As a core subject mandated at all levels of education in Indonesia, mathematics is not only a means for computational proficiency but a medium through which students develop essential life skills. The Indonesian National Education Ministry Regulation (Permendiknas, 2006) highlights the importance of mathematics in fostering problem-solving, reasoning, communication, and collaboration abilities. These skills collectively form the foundation of what is referred to as mathematical literacy.

Mathematical literacy, as defined by the OECD, is the capacity to formulate, apply, and interpret mathematics in a variety of contexts, including real-world situations (Rawani et al., 2019). It involves reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. International assessments such as PISA are designed to evaluate these competencies in diverse and complex problem-solving contexts (Son et al., 2020). In Indonesia, enhancing mathematical literacy has become a pressing issue, especially considering the country's consistently low rankings in global assessments. In PISA 2018, for example, Indonesia ranked 72nd out of 78 participating countries (Son et al., 2020).

Despite its central role in education, both international and national assessments consistently report low mathematical literacy levels among Indonesian students. The OECD's PISA results in 2015 and 2018 show that Indonesian students scored 387 and 379, respectively far below the OECD average of 490 (Ate & Lede, 2022). Multiple studies indicate that the contributing factors include insufficient teacher training, a lack of contextually relevant learning materials (Kismiantini et al., 2021), and socioeconomic disparities that limit students' access to quality educational resources (Chang et al., 2024).

At the local level, observations conducted at SMAN 1 Lingsar revealed that many eleventh-grade students struggle with contextual mathematical problem-solving. A preliminary test involving 30 students showed that only 26% of them could successfully solve mathematical literacy tasks related to polynomial material. These findings suggest that students experience difficulties in interpreting problems, applying mathematical concepts accurately, and justifying their solutions hallmarks of low mathematical literacy. Contributing factors include a reliance on rote memorization, lack of conceptual understanding, and limited exposure to learning tools that encourage exploration and reasoning.

To address these challenges, there is a need for innovative instructional strategies that go beyond conventional methods and actively cultivate mathematical literacy. One such approach is Problem-Based Learning (PBL), a student-centered pedagogical model that engages learners in solving authentic, real-world problems. PBL emphasizes critical thinking, inquiry, collaboration, and application competencies that directly align with mathematical literacy indicators (Rohaeti et al., 2023); (Wati et al., 2022). Empirical studies have shown that compared to other models like RME and POE, PBL is particularly effective in promoting students' engagement and their problem-solving abilities in realistic contexts (Edwar et al., 2023); (Trinanda et al., 2024).

While PBL has been widely recognized for its effectiveness, most existing worksheet (LKPD) developments in Indonesia still rely on alternative models such as Realistic Mathematics Education (RME) (Erita et al., 2022); (Marpaung et al., 2024) or Predict-Observe-Explain (POE) (Setiyani et al., 2023). These approaches have demonstrated success in improving reasoning and representation skills but rarely focus on leveraging PBL specifically to enhance mathematical literacy in abstract topics such as polynomials.

PBL-based LKPDs offer distinct advantages, including the use of real-life problems and collaborative learning settings, which are particularly suitable for complex topics like polynomials (Permatasari et al., 2018); (André et al., 2020). The structured exploration process inherent in PBL helps students not only understand mathematical concepts but also apply them in diverse and unpredictable contextsan essential component of mathematical literacy.

Therefore, this study aims to develop and evaluate a PBL-based student worksheet (LKPD) specifically designed to improve the mathematical literacy skills of Grade XI students at SMAN 1 Lingsar. The design of the worksheet integrates PBL principles and OECD-defined literacy indicators, ensuring that each learning activity is both contextually meaningful and pedagogically sound.

By responding to local classroom needs and grounding the design in theoretical and empirical research, this study contributes to mathematics education by offering a validated instructional model that bridges the gap between abstract mathematics and real-world application. Moreover, it addresses the need for contextually relevant materials that can foster deeper student engagement and understanding in line with national and international educational goals.

METHOD

Research Design

One type of research that can be conducted to produce new products, such as learning innovations, and to test product effectiveness, is Research and Development (R&D) (Nusantara et al., 2023). The development model used for the Problem-Based Learning (PBL) student worksheets (LKPD) is the 4-D model proposed by (Santi et al., 2022), which consists of four stages: Define, Design, Develop, and Disseminate. However, in this study, the 4-D model is modified to a 3-D model (Define, Design, and Develop) due to time and budget constraints.

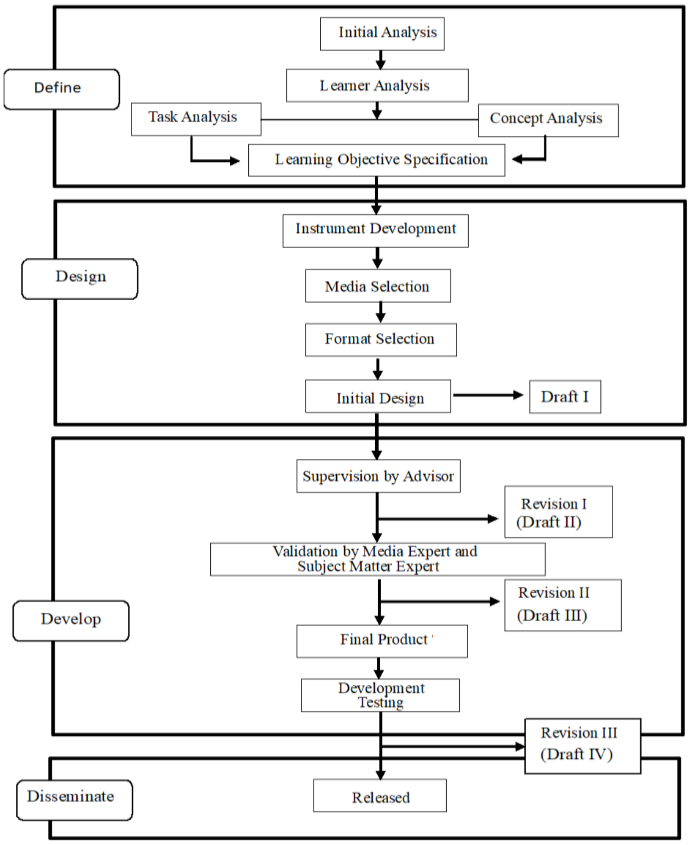


Figure 1. Diagram of the Steps in the Development Research of LKPD

Materials

The primary material used in this research is the Problem-Based Learning (PBL) Student Worksheets (LKPD). Additional materials include validation sheets for validators, questionnaires to measure the practicality and validity of the LKPD, and test questions designed to assess students' mathematical literacy skills. These materials are crucial for the development and evaluation of the LKPD, ensuring that the worksheets are both effective and practical for use in educational settings (Sugiyono, 2011).

Sample Preparation

The study was conducted at SMAN 1 Lingsar with students from Grade XI. Sampling was purposive, selecting students who had not previously used PBL-based learning tools. The preparation process involved:

- Preliminary analysis to identify key issues in mathematics instruction.
- Student analysis to determine the learners’ mathematical literacy baseline.
- Task analysis based on Core and Basic Competencies from the 2013 Curriculum.
- Concept analysis to outline relevant concepts supporting learning objectives.
- Learning objectives analysis to ensure alignment between content and assessment criteria.

Experimental Procedure

The experimental phase consisted of three key activities:

1. Validation: The LKPD draft was submitted to two experts (content and media) who completed structured validation sheets. Revisions were made based on their feedback and repeated until both validators deemed the material appropriate.
2. Implementation: The revised LKPD was implemented through a one-group pre-test–post-test design. Students first completed a pre-test on mathematical literacy. Then, they participated in a series of lessons using the developed LKPD over three sessions. After completing the instructional intervention, students took a post-test to measure improvements.
3. Data Collection: Practicality questionnaires were administered to both students and teachers at the end of the learning sessions.

Parameters

The study evaluated three main aspects:

1. LKPD Validity**:** Measured using a Likert-scale validation sheet that assessed content, language, presentation, and PBL integration. Results from two validators were averaged to determine category:
   $0 < \bar{X} \leq 1$→ Strongly Disagree
   $1 < \bar{X} \leq 2$→ Disagree
   $2 < \bar{X} \leq 3$→ Agree
   $3 < \bar{X} \leq 4$→ Strongly Agree
2. LKPD Practicality: Measured via teacher and student questionnaires using a 4-point scale. Percentage scores were interpreted using the following classification:
   0%–40%: Very Impractical
   41%–60%: Impractical
   61%–80%: Practical
   81%–100%: Very Practical
3. Mathematical Literacy Skills: Assessed through pre- and post-tests, covering problem-solving, interpretation, and reasoning components in polynomial contexts.

Statistical Analysis

The analysis consisted of two parts:

- Descriptive Analysis was used to calculate average scores for validity and practicality ratings.
- Inferential Analysis: A paired sample t-test was conducted to compare students' pre-test and post-test scores, determining whether the observed improvement in mathematical literacy was statistically significant. This test was conducted using SPSS software, with a significance level of $\alpha = 0.05$. Normality of the score distribution was first assessed using the Shapiro–Wilk test.

These analyses ensured that claims of effectiveness were supported by statistical evidence, beyond descriptive measures alone.

RESULT AND DISCUSSION

Development Results of Problem-Based Learning (PBL) Student Worksheets (LKPD)

The development of Problem-Based Learning (PBL) Student Worksheets (LKPD) for polynomial material followed the 4-D model by (Santi et al., 2022), modified to 3-D (Define, Design, Develop) due to resource constraints. In the Define stage, learning issues at SMAN 1 Lingsar were analyzed alongside the 2013 curriculum's core and basic competencies. In the Design stage, the LKPD was developed using Canva, structured according to PBL syntax. It includes:

- Cover Page (Figure 2)
- Learning Instructions Page (Figure 3)
- Competencies to be Achieved (Figure 4)
- Material Presentation (Figure 5)
- Learning Activities (Figure 6)

Figure 2 displays a motivational and visually engaging cover designed to trigger curiosity and introduce context.

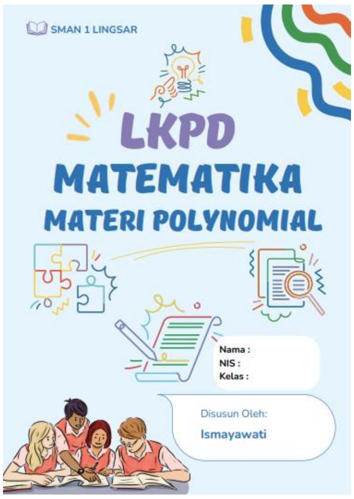
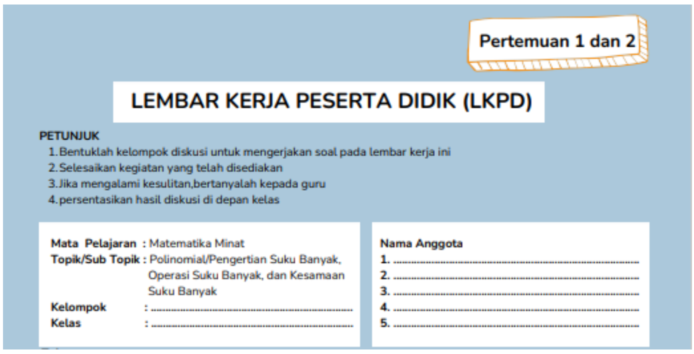


Figure 2. Cover Page

Figure 3. illustrates the learning instructions, which guide students through PBL stages such as problem identification, exploration, group discussion, and reflection.



Pertemuan 1 dan 2

LEMBAR KERJA PESERTA DIDIK (LKPD)

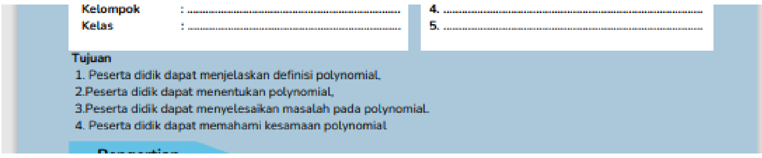
PETUNJUK
1. Bentuklah kelompok diskusi untuk mengerjakan soal pada lembar kerja ini
2. Selesaikan kegiatan yang telah disediakan
3. Jika mengalami kesulitan,bertanyalah kepada guru
4. persentasikan hasil diskusi di depan kelas

Mata Pelajaran : Matematika Minat
Topik/Sub Topik : Polinomial/Pengertian Suku Banyak, Operasi Suku Banyak, dan Kesamaan Suku Banyak
Kelompok : ....
Kelas : ....

Nama Anggota
1. ....
2. ....
3. ....
4. ....
5. ....

Figure 3. Learning Instructions Page

Figure 4 shows a breakdown of competencies and literacy indicators targeted by the worksheet. This connects directly with curriculum outcomes.

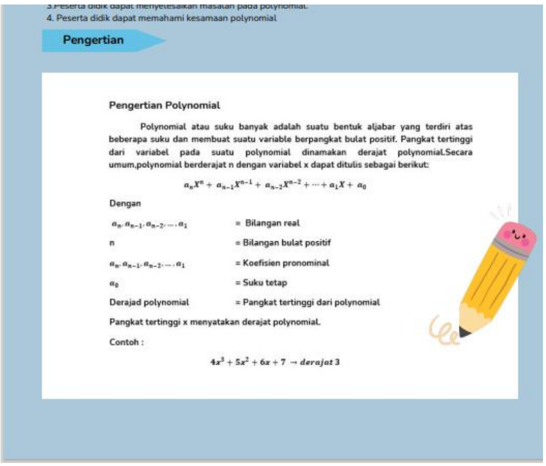


Kelompok : ....
Kelas : ....
4. ....
5. ....

Tujuan
1. Peserta didik dapat menjelaskan definisi polynomial.
2. Peserta didik dapat menentukan polynomial,
3. Peserta didik dapat menyelesaikan masalah pada polynomial.
4. Peserta didik dapat memahami kesamaan polynomial

Figure 4. Competencies to be Achieved Page

The material page (Figure 5) contextualizes polynomial content using real-life examples to support conceptual understanding.



3. Peserta didik dapat menyelesaikan masalah pada polynomial.
4. Peserta didik dapat memahami kesamaan polynomial

Pengertian

Pengertian Polynomial

Polynomial atau suku banyak adalah suatu bentuk aljabar yang terdiri atas beberapa suku dan membuat suatu variable berpangkat bulat positif. Pangkat tertinggi dari variabel pada suatu polynomial dinamakan derajat polynomial.Secara umum,polynomial berderajat n dengan variabel x dapat ditulis sebagai berikut:

$$a_n X^n + a_{n-1} X^{n-1} + a_{n-2} X^{n-2} + \cdots + a_1 X + a_0$$

Dengan

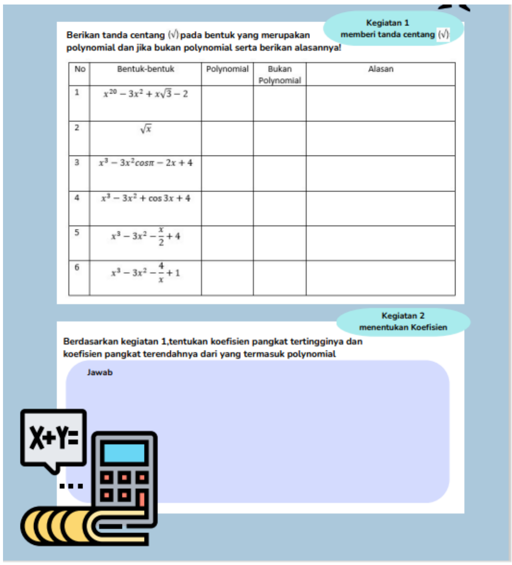
$a_n, a_{n-1}, a_{n-2}, \cdots, a_1$ = Bilangan real
n = Bilangan bulat positif
$a_n, a_{n-1}, a_{n-2}, \cdots, a_1$ = Koefisien pronominal
a_0 = Suku tetap
Derajad polynomial = Pangkat tertinggi dari polynomial
Pangkat tertinggi x menyatakan derajat polynomial.

Contoh :

$$4x^3 + 5x^2 + 6x + 7 \rightarrow derajat\ 3$$

Figure 5. Material Page

Figure 6 presents the learning activities that stimulate mathematical literacy through tasks requiring formulation, reasoning, and reflection.



Kegiatan 1
memberi tanda centang (√)

Berikan tanda centang (√) pada bentuk yang merupakan polynomial dan jika bukan polynomial serta berikan alasannya!

No	Bentuk-bentuk	Polynomial	Bukan Polynomial	Alasan
1	$x^{20} - 3x^2 + x\sqrt{3} - 2$			
2	$\sqrt{x}$			
3	$x^3 - 3x^2 cos\pi - 2x + 4$			
4	$x^3 - 3x^2 + \cos 3x + 4$			
5	$x^3 - 3x^2 - \frac{x}{2} + 4$			
6	$x^3 - 3x^2 - \frac{4}{x} + 1$			

Kegiatan 2
menentukan Koefisien

Berdasarkan kegiatan 1,tentukan koefisien pangkat tertingginya dan koefisien pangkat terendahnya dari yang termasuk polynomial

Jawab

X+Y=

Figure 6. Learning Activities Page

Findings Description

The developed LKPD achieved strong validation results, scoring 80% from content experts and 90% from media experts. The validators highlighted its strengths in terms of content clarity, contextual alignment, visual design, and structural coherence with the PBL framework.

The practicality test also showed high levels of user satisfaction, with an average score of 97% from both teachers and students. These results reflect the LKPD's clarity of instructions, ease of use, and its capacity to foster motivation and learning engagement. However, several teachers recommended the addition of more scaffolding prompts for lower-ability students.

Effectiveness Analysis

A pre-test and post-test were conducted using a one-group experimental design to assess the impact of the PBL-based LKPD on mathematical literacy. A paired sample t-test showed a statistically significant improvement in students' scores ($p < 0.05$), particularly in the "formulate" and "solve" components.

These findings are consistent with previous research indicating that PBL significantly enhances students' ability to construct and solve mathematical problems in real-world contexts (Hendriana et al., 2018); (Michalsky & Cohen, 2021). The structured problem-analysis and solution process in PBL activates students' higher-order thinking and supports better learning retention compared to traditional approaches.

Critical Discussion: Strengths, Limitations, and Comparison to Literature

This study demonstrates that integrating PBL into worksheet design can substantially improve mathematical literacy. Compared to RME-based worksheets (Erita et al., 2022; Marpaung et al., 2024), the PBL-based approach emphasizes student autonomy, critical engagement, and real-world problem contexts.

One of the key strengths of this LKPD lies in its open-ended task design, which promotes student creativity and multiple problem-solving pathways. This aligns with findings that open-ended mathematical tasks foster learner autonomy and deeper conceptual engagement (Weinhandl et al., 2020); (Papasarantou et al., 2023). Furthermore, students who engage with such tasks tend to show greater initiative and sustained interest in learning (Lindenbauer et al., 2023).

Nevertheless, one notable limitation is the absence of structured group reflection sessions within the LKPD. Although the design encourages individual problem-solving, it lacks a formal mechanism for collaborative reflection, which is essential in the PBL process. Group reflection enhances students' metacognitive skills and conceptual understanding by allowing them to share insights and strategies (Demo et al., 2021); (Fernandes et al., 2021); (Cervantes-Barraza & Araújo, 2023). Addressing this component in future iterations could further enrich the learning experience.

Compared to prior research (Setiyani et al., 2023; Trinanda et al., 2024), this study extends the application of PBL not merely as an instructional approach but as a design principle for learning materials targeting complex and abstract content like polynomials. The ability of the PBL-based LKPD to contextualize polynomials makes it a promising model for other challenging mathematical topics.

Scientific and Practical Implications

Scientifically, this study supports the adaptability of the 4-D development model (even in its 3-D form) and affirms that embedding PBL principles into instructional materials directly impacts key aspects of mathematical literacy, especially in problem formulation and resolution.

Practically, the integration of visually engaging digital platforms like Canva contributes to higher student interest and motivation. This is aligned with evidence showing that digital learning tools enhance learner interaction and information processing, especially when supported by relevant and valid visual content (Meletiou-Mavrotheris et al., 2023); (Lindenbauer et al., 2023). Such media are well-suited for Kurikulum Merdeka, which encourages the adoption of technology to support flexible and meaningful learning experiences.

Conclusion of the Discussion

The results of this study indicate that PBL-based LKPD is a valid, practical, and effective tool for developing students’ mathematical literacy. Its integration of open-ended tasks, real-world contexts, and interactive design contributes to students’ deeper engagement with mathematical concepts. Statistically, the LKPD demonstrates measurable improvement in learning outcomes, particularly in core competencies of literacy.

Future improvements may include integrating group reflection elements and digital interactivity to further support diverse learning environments. The framework presented in this study can be adapted across different mathematical topics and educational levels, offering a replicable and empirically grounded model for instructional design in mathematics education.

CONCLUSION AND SUGGESTIONS

This study aimed to develop and evaluate Problem-Based Learning (PBL)-based Student Worksheets (LKPD) on polynomial material for Grade XI high school students. The development process adopted a modified 4-D model, excluding the dissemination stage due to practical constraints.

The findings indicate that the developed LKPD meets the criteria of validity, practicality, and effectiveness. Validation results showed an 80% score from content experts and 90% from media experts, covering aspects such as content accuracy, language clarity, simplicity, integration, and PBL framework components. The practicality test conducted with a small group of students and mathematics educators also yielded a highly positive result, with an average score of 97% from both teachers and students. These indicate that the LKPD is easy to use, informative, and motivating.

Beyond these descriptive outcomes, the findings also carry important scientific implications. The study reinforces the theoretical proposition that learning tools grounded in PBL principles and designed systematically can significantly contribute to enhancing students' mathematical literacy. In particular, this research supports the integration of real-world problems and active inquiry in worksheet-based learning as a way to operationalize literacy indicators such as reasoning, interpreting, and formulating solutions.

In terms of practical implications, the validated LKPD is suitable for broader implementation across other educational institutions, especially in contexts where abstract mathematical concepts like polynomials are challenging for students. Its visually engaging format using Canva not only aids comprehension but also aligns with modern educational design practices that prioritize student engagement.

For future development, it is recommended to integrate digital features and interactive elements into the LKPD to support hybrid and remote learning contexts. Further research could also expand the application of this approach to other mathematical topics or across different grade levels. Additionally, incorporating more structured reflection activities and group feedback sessions within the LKPD could strengthen its alignment with the full PBL cycle.

In conclusion, this study contributes to the growing body of literature on innovative teaching materials by providing empirical evidence that a PBL-based approach can be both pedagogically sound and practically implementable. The developed LKPD not only improves mathematical literacy but also serves as a replicable model for designing instructional tools that are engaging, effective, and aligned with current educational demands.

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