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DEVELOPMENT OF MATHEMATICS LEARNING TOOLS BASED ON A SCIENTIFIC APPROACH USING THE PROBLEM-BASED LEARNING (PBL) MODEL TO IMPROVE STUDENTS' MOTIVATION AND LEARNING ACHIEVEMENT

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Abstrak - Penelitian ini bertujuan untuk mengembangkan perangkat pembelajaran matematika berbasis pendekatan saintifik dengan model Problem Based Learning (PBL) serta mengetahui efektivitasnya dalam meningkatkan motivasi dan prestasi belajar siswa. Jenis penelitian ini adalah penelitian pengembangan (Research and Development) yang dilengkapi dengan uji kepraktisan, validitas, dan uji efektivitas. Subjek penelitian adalah siswa kelas VIIA dan VIIB SMP Negeri 29 Palembang, dengan jumlah total 54 siswa, di mana kelas VIIA dijadikan kelompok eksperimen dan kelas VIIB sebagai kelompok kontrol. Data dikumpulkan melalui angket motivasi belajar dan tes prestasi belajar, kemudian dianalisis menggunakan perhitungan deskriptif, uji t, dan N-Gain. Hasil penelitian menunjukkan bahwa perangkat pembelajaran yang dikembangkan valid dan praktis dengan skor rata-rata validitas > 4,2. Penerapan perangkat ini meningkatkan motivasi belajar siswa kelas eksperimen dari skor rata-rata 58,7 menjadi 82,4, sedangkan kelas kontrol hanya meningkat dari 59,2 menjadi 63,5. Prestasi belajar siswa kelas eksperimen meningkat dari skor rata-rata 62,5 menjadi 84,3 dengan N-Gain 0,58 (sedang-tinggi), sementara kelas kontrol hanya mengalami peningkatan 61,7 menjadi 68,2 dengan N-Gain 0,16 (rendah).

Kata kunci: perangkat pembelajaran, pendekatan saintifik, Problem Based Learning, motivasi belajar, prestasi belajar

Abstract *- This study aimed to develop mathematics learning devices based on the scientific approach with a Problem Based Learning (PBL) model and to examine their effectiveness in enhancing students' motivation and learning achievement. This research employed a Research and Development (R&D) design, complemented by tests of practicality, validity, and effectiveness. The research subjects were students of classes VIIA and VIIB at SMP Negeri 29 Palembang, totaling 54 students, with class VIIA as the experimental group and class VIIB as the control group. Data were collected using learning motivation questionnaires and achievement tests, and were analyzed through descriptive statistics, paired-sample t-tests, and N-Gain calculations. The results indicate that the developed learning devices were valid and practical, with an average validity score greater than 4.2. Implementation of these devices increased students' learning motivation in the experimental class from a mean score of 58.7 to 82.4, whereas the control class increased only from 59.2 to 63.5. Students' learning achievement in the experimental class improved from an average score of 62.5 to 84.3 with an N-Gain of 0.58 (medium-high), while the control class improved from 61.7 to 68.2 with an N-Gain of 0.16 (low).*

Keywords: *learning devices, scientific approach, Problem Based Learning, learning motivation, learning achievement*

1. INTRODUCTION

Mathematics is a fundamental science that plays an essential role in shaping human logical and systematic thinking (Almira, 2016). As a universal discipline, mathematics is taught from elementary to higher education to develop students' critical, analytical, and creative thinking skills (Kolar & Hodnik, 2020). According to Kurniati et al. (2015), mathematics learning has an important function in helping students meet practical needs and solve everyday problems such as calculating, measuring, interpreting data, and using technological tools like calculators or computers (Harahap & Rakhmawati, 2020). Moreover,

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mathematics serves as a foundation for mastering other sciences such as physics, chemistry, economics, and engineering (Grover & Pea, 2013).

In the educational context of SMP Negeri 29 Palembang, mathematics learning is directed to foster students' logical, systematic, critical, and creative thinking abilities while appreciating the usefulness of mathematics in daily life (Rismen et al., 2022). This aligns with the goals of the 2013 Curriculum, which emphasizes a balance among attitude, knowledge, and skill aspects (Hamidah et al., 2020). However, based on observations and interviews with mathematics teachers at SMP Negeri 29 Palembang, several challenges were identified in the learning process.

Some of the problems found include the dominance of high-achieving students in classroom activities, which causes other students to become passive and reluctant to ask questions (Canbazoğlu & Tarim, 2020). The lack of opportunities for students to communicate and share information with peers, resulting in suboptimal implementation of the scientific communication component in the scientific approach (Keeley et al., 2019); and the use of abstract teaching materials that are not sufficiently contextualized with real-life situations (Baleghizadeh & Maryam, 2019). Consequently, many students exhibit low learning motivation and have difficulty understanding mathematical concepts (Nugraha & Suyatmin, 2021).

The issue of low learning motivation affects students' mathematics achievement, which remains below expectations (Nuraini, 2019). This is consistent with studies showing that students' engagement in active learning can enhance their conceptual understanding and academic performance (Bellini et al., 2019). Therefore, it is necessary to develop learning materials that can foster active participation, encourage critical thinking, and connect mathematical concepts with real-life contexts (Samosir & Dasari, 2022).

One promising solution is the implementation of a Problem-Based Learning (PBL) model integrated with a scientific approach. The PBL model emphasizes solving real-world problems as a context for students to learn critical and creative thinking (Osakue et al., 2011). PBL encourages students to identify problems, formulate hypotheses, seek information, and communicate their findings (Miller et al., 2021;Maulana et al., 2019). In this process, the teacher acts as a facilitator who guides students toward independent conceptual understanding (Jaya et al., 2019).

The scientific approach in the 2013 Curriculum—which includes observing, questioning, experimenting, reasoning, and communicating (Mulyasa, 2013). —serves as an integrative foundation for PBL implementation. Combining these two approaches is expected to enable students to construct knowledge independently and enhance their learning motivation (Jonassen, 2011).

Previous studies have shown that the use of the scientific approach through the PBL model effectively improves students' motivation and learning outcomes (Guo et al., 2020). This model helps students see the relevance of mathematics in everyday life, making learning more meaningful (Ahdhianto et al., 2020). In the context of SMP Negeri 29 Palembang, the application of mathematics learning materials based on the scientific approach and PBL is expected to foster curiosity, enhance higher-order thinking skills, and strengthen students' scientific attitudes (Liu et al., 2020).

Furthermore, developing such learning materials is expected to assist teachers in designing interactive and contextual mathematics lessons Suyitno et al. (2021), well-designed

learning materials not only serve as instructional aids but also as systematic guides for developing students' competencies. Therefore, this research is essential to produce valid, practical, and effective learning materials that can improve students' motivation and academic achievement in mathematics at SMP Negeri 29 Palembang (Sugiyono, 2021;Tarigan et al., 2021).

2. METHOD

2.1 Research and Type Design

This study is a Research and Development (R&D) aimed at producing a mathematics learning device based on the scientific approach integrated with a Problem-Based Learning (PBL) model that is valid, practical, and effective in improving students' motivation and learning achievement at SMP Negeri 29 Palembang.

The development model adopted in this study is the 4D Model (Four-D Model) developed by Thiagarajan, Wismath & Orr (2015), which consists of four main stages:

1. **Define** – defining needs and objectives,
2. **Design** – designing the learning device,
3. **Develop** – developing and testing the device, and
4. **Disseminate** – disseminating the final product.

In this study, the **disseminate stage** was limited because the focus was on the development and effectiveness testing of the learning device within a controlled environment.

2.2 Development Procedure

The development of the learning device followed the 4D model, described as follows:

Table 1. 4D Model

Stage	Main Activities	Output
Define	Needs analysis, student analysis, curriculum analysis, and content concept analysis	Identification of problems, student characteristics, and learning needs
Design	Designing learning devices including lesson plans (RPP), student worksheets (LKPD), assessment instruments, and teaching materials based on PBL and the scientific approach	Draft of learning device (Prototype I)
Develop	Expert validation, revisions, and limited trials in Classes VIIA and VIIB	Valid, practical, and effective learning device
Disseminate	Limited dissemination to mathematics teachers at SMP Negeri 29 Palembang	Implementation report and final product

2.3 Research Instrument

The instruments used in this study included:

1. **Validation Sheets**
   Used by three experts (content, media, and learning experts) to assess the validity of

the learning device. The assessment employed a Likert scale (1–5), covering content relevance, clarity of learning steps, and alignment with the scientific approach and PBL model.

2. **Teacher and Student Response Questionnaires**
   Used to measure the practicality of the learning device after implementation.
3. **Learning Achievement Tests (Pretest and Posttest)**
   Used to measure the improvement in students' learning outcomes. The tests were in essay format and based on basic competency indicators.
4. **Student Learning Motivation Questionnaire**
   Adapted from Keller's ARCS model (Attention, Relevance, Confidence, Satisfaction) (2010) to measure students' motivation before and after the treatment.

2.4 Data Collection Techniques

Data were analyzed in three categories: validity, practicality, and effectiveness.

a. Validity Analysis

Table 2. Validity Categories

Score Range	Category
4.21–5.00	Very Valid
3.41–4.20	Valid
2.61–3.40	Quite Valid
1.81–2.60	Less Valid
1.00–1.80	Not Valid

b. Practicality Analysis

Practicality was assessed from teacher and student responses. A mean score ≥ 3.4 (practical) indicated that the device was feasible for use.

c. Effectiveness Analysis

Effectiveness was evaluated through two aspects:

1. **Student Learning Motivation** – measured using the ARCS questionnaire before and after treatment.
2. **Student Learning Achievement** – assessed by comparing pretest and posttest scores using a paired sample t-test**.**

Table 3. N-Gain Categories

N-Gain Value	Category
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

2.5 Data Validity

Data validity was ensured through triangulation and expert validation involving:

- Mathematics content experts
- Educational media experts
- Mathematics teachers at SMP Negeri 29 Palembang

Additionally, instrument reliability was tested using Cronbach's Alpha (α) to ensure internal consistency of the motivation questionnaire and learning test.

3. RESULT AND DISCUSSION

3.1 Result

a. Validation Results of the Learning Device

The developed learning device includes lesson plans (RPP), Student Worksheets (LKPD), and learning achievement assessment instruments. Validation was conducted by three experts: content expert, media expert, and learning expert. The validation results are presented in Table 4.1.

Table 4. Validation Results of the Learning Device

Assessment Aspect	Validator 1	Validator 2	Validator 3	Average	Category
Content Relevance	4.5	4.3	4.4	4.4	Very Valid
Clarity of Steps	4.2	4.3	4.1	4.2	Valid
PBL & Scientific Approach Relevance	4.4	4.5	4.3	4.4	Very Valid

As shown in Table 4., all aspects scored above 4.2, indicating that the learning device is very valid for use.

b. Practicality Test Results

The practicality of the devices was assessed based on teacher and student feedback. Teachers reported ease in applying lesson plans, managing worksheets, and guiding students

during learning. Students reported that the learning devices were easy to understand and enjoyable, particularly through PBL-based discussion activities.

Table 5. Results of Learning Device Practicality Questionnaire

Assessment Aspect	Average Score	Category
Ease of Use	4.3	Very Practical
Student Engagement	4.2	Very Practical
Teacher & Student Satisfaction	4.4	Very Practical

c. Student Learning Motivation

Student motivation was measured using the ARCS questionnaire before and after the implementation of the learning devices. The results are shown in Table 4.3 and Figure 4.1.

Table 6. Comparison of Student Motivation in Classes VIIA and VIIB

Class	Motivation Before (Mean Score)	Motivation After (Mean Score)	Increase
VIIA (Experimental)	58.7	82.4	+23.7
VIIB (Control)	59.2	63.5	+4.3

The data show a significant increase in motivation for the experimental class compared to the control class, indicating that PBL-based learning devices encourage active participation and interest in learning.

d. Student Learning Achievement

A simple linear regression analysis was conducted to determine the effect of teacher-Student learning achievement was measured using pretest and posttest scores in mathematics. The results are presented in Table 7.

Table 7. Comparison of Student Learning Achievement in Classes VIIA and VIIB

Class	Pretest (Mean Score)	Posttest (Mean Score)	N-Gain	Improvement Category
VIIA (Experimental)	62.5	84.3	0.58	Medium-High
VIIB (Control)	61.7	68.2	0.16	Low

The experimental class demonstrated a **greater improvement in learning achievement** compared to the control class, confirming the **effectiveness of scientific approach-based PBL learning devices**.

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3.2 Discussion

The results indicate that scientific approach-based PBL mathematics learning devices are valid, practical, and effective in enhancing students' motivation and learning achievement at SMP Negeri 29 Palembang.

- **Device Validity:** Average validation scores > 4.2 indicate that the devices are ready for use. This aligns with previous research emphasizing that well-structured learning devices can improve learning effectiveness.
- **Device Practicality:** Teachers and students rated the devices as very practical, consistent with learner-centered principles where students actively engage in problem-solving through PBL.
- **Motivation Improvement:** Student motivation increased significantly in the experimental class. PBL encourages students to ask questions, discuss, and solve real-life problems, thereby enhancing engagement.
- **Learning Achievement Improvement:** The experimental class achieved an N-Gain of 0.58 (medium-high), while the control class achieved only 0.16 (low). These results show that the PBL model develops students' **critical, creative, and analytical thinking skills** in problem-solving
- **Teacher Role as Facilitator:** Teachers guide students **in discovering and solving problems,** rather than serving as the primary source of information. This aligns with the scientific approach, which emphasizes observation, problem identification, hypothesis formulation, experimentation, and result communication

In conclusion, scientific approach-based PBL learning devices not only enhance students' motivation and achievement but also promote independence, critical thinking, and collaborative skills.

4. CONCLUSION

Based on the research results and discussion, the following conclusions can be drawn:

1. **Validity and Practicality of the Learning Devices**
   The mathematics learning devices based on the scientific approach with the Problem Based Learning (PBL) model are proven to be valid and practical. The average validity score is > 4.2, categorized as very valid, and both teachers and students assessed the devices as easy to use, clear, and appropriate for learning needs.
2. **Increase in Students' Learning Motivation**
   The implementation of these learning devices significantly increased the learning motivation of the experimental class students. Students became more active in discussions, asking and answering questions, and identifying mathematical problems in real-life contexts compared to the control class using conventional methods.
3. **Improvement in Students' Learning Achievement**
   The mathematics learning achievement of students in the experimental class improved more than that of the control class. The N-Gain of the experimental class reached 0.58 (medium-high), while the control class only reached 0.16 (low), indicating the effectiveness of the scientific approach combined with the PBL model in developing students' critical, creative, and analytical thinking skills.

4. **Teacher's Role and Implementation of the PBL Model**
   Teachers acted as facilitators guiding students to discover and solve problems independently. The PBL model emphasizes observation, problem identification, hypothesis formulation, experimentation, and communication of results, allowing students to learn actively and collaboratively.
5. **Implications for Learning**
   The use of learning devices based on the scientific approach with PBL not only improves motivation and learning achievement but also fosters independent learning, collaborative skills, and students' critical thinking abilities.

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