

Development of a Problem Based Learning Student Worksheet on the Hydrocarbon Topic for Grade XI Students

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Abstract

This development research aims to produce a Problem-Based Learning (PBL)-based Student Worksheet on Hydrocarbon material that is valid, practical, and effective. The research method used was Research and Development (R&D) with the 4D model (Define, Design, Develop, Disseminate), combined with the Tessmer evaluation model. Data were collected using validation sheets, student response questionnaires, and conceptual understanding tests. Expert validation results indicate that the worksheet meets the very valid criteria with Aiken's V scores of 0.92 (subject expert), 0.96 (design expert), and 0.90 (pedagogical expert). In the practicality test involving 9 grade XI students, the worksheet achieved a practicality percentage of 98.4% (very practical category). Furthermore, the effectiveness test, measured by the N-gain score, resulted in a value of 0.8, which is categorized as high. It is concluded that the developed PBL-based worksheet has been proven to meet the criteria of being valid, practical, and effective for use in learning Hydrocarbon material.

Keywords: Worksheet, Problem Based Learning, Hydrocarbon



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Introduction

Education plays a crucial role in efforts to improve the quality of human resources who are productive and capable of facing the challenges of the 21st century. The paradigm shift in education during this era demands the development of critical thinking, creativity, collaboration, and communication skills (4C). A study by Septiani et al. (2020) emphasizes that these 21st-century skill demands require a transformation of learning models from teacher-centered to student-centered. In response to these demands, the Indonesian government introduced the *Kurikulum Merdeka*, which emphasizes relevant, contextual, and student-centered learning (Kemendikbudristek, 2022). In the context of chemistry education, this curriculum provides teachers with the flexibility to design learning experiences using diverse models, methods, and instructional materials to help students understand abstract concepts through authentic problem-solving.

Previous literature indicates that the Problem-Based Learning (PBL) approach has been widely recognized as an effective model for realizing student-centered learning. PBL employs contextual problems as learning triggers, encouraging students to learn independently and collaboratively in solving real-world issues (Winoto & Prasetyo, 2020). The effectiveness of PBL in enhancing conceptual understanding and critical thinking skills in science has been supported by meta-analyses, such as that conducted by Liu & Pásztor (2022), which found that PBL produces significantly positive effects on student learning outcomes compared to traditional methods. This

model not only helps create a relevant learning environment (Suswati, 2021) but also promotes a shift in the teacher's role toward becoming a facilitator (Masduriah, 2020).

On the other hand, Student Worksheets (LKPD) serve as essential instructional materials supporting the learning process. Their function extends beyond a collection of exercises; they act as guides that assist students in understanding the material more effectively (Afriandi, 2020). Well-designed LKPDs are created to scaffold students in discovering concepts step by step according to the learning model being applied. LKPDs also play a vital role in cultivating students' scientific attitudes. Through structured activities, students are encouraged to think objectively, carefully, and systematically in solving problems. As shown by Okta Vernanda & Zulyusri (2023), inquiry-based LKPDs can significantly build scientific attitudes such as objectivity, curiosity, and accuracy in drawing conclusions. Numerous studies have developed LKPDs integrated with various learning models, including PBL, designed by following its phases—from orienting students to the problem, organizing for learning, conducting individual and group investigations, presenting results, to evaluation (Arends, 2012).

However, preliminary observations at SMA Negeri 12 Palembang, supported by findings in the literature, reveal that Hydrocarbon is a challenging topic. A study by Anwar & Ilyas (2022) confirms that students' primary difficulty lies in visualizing the three-dimensional structure of molecules and connecting it to symbolic representations, which frequently leads to misconceptions. Existing learning resources, such as textbooks, tend to be theoretical and lack contextual problems that can guide students through systematic problem-solving processes to address these specific challenges. In other words, although PBL and LKPD are not new, the development of PBL-based LKPDs specifically designed to address visualization difficulties and conceptual understanding in Hydrocarbon topics (as identified by Anwar & Ilyas, 2022), while explicitly aligning with the principles and flexibility of the *Kurikulum Merdeka*, remains very limited.

Based on these considerations, the present study aims to develop a PBL-based LKPD on Hydrocarbon material for Grade XI students at SMA Negeri 12 Palembang that is valid, practical, and effective.

Methods

This study employed development research using the 4D model. This development model was selected because it effectively guides researchers in producing a product and testing the effectiveness of the learning product (Tegeh & Kirna, 2013). The strength of the 4D model lies in its systematic and easy-to-understand stages, making it widely used for developing books and instructional materials (Rahmadoni & Aini, 2025). In general, the 4D model by Thiagarajan (1974) consists of four stages: Define, Design, Develop, and Disseminate. However, in this study, the Disseminate stage was not conducted. Instead, the final stage of the study involved evaluation using Tessmer's formative evaluation model. This is because the aim of the research was to produce a Student Worksheet (LKPD) that meets the criteria of validity, practicality, and effectiveness.

The first stage is Define. At this stage, a front-end analysis was conducted to identify the main problems in the learning process. These primary problems were obtained through interviews with a Grade XI chemistry teacher at SMA Negeri 12 Palembang. Next, a learner analysis was carried out to identify problems from the students' perspective. Based on a questionnaire, 72.9% of students experienced difficulties in understanding hydrocarbon material using the instructional materials provided by the teacher. The next step involved task, concept, and learning objective analysis. This analysis aimed to identify the concepts to be taught, beginning with the analysis of the Learning Outcomes (Capaian Pembelajaran/CP), followed by breaking down the hydrocarbon content into Learning Objectives (Tujuan Pembelajaran/TP), and finally developing an instructional sequence (Alur Tujuan Pembelajaran/ATP) to ensure that students achieve mastery of the material by the end of the lesson.

The second stage is Design. At this stage, the storyboard for the LKPD was drafted, including the cover page layout, visual design, and preparation of instruments and questionnaires. The third stage is Develop. Here, the LKPD storyboard was completed and turned into an initial prototype before evaluation. The fourth stage involved Tessmer's formative evaluation. At this stage, the LKPD developed from the storyboard was first reviewed by the academic supervisors and subsequently revised. The revised LKPD was then validated by two expert validators who assessed it in terms of content, design, and pedagogy. The next step was the One-to-One evaluation, in which three students with varying levels of understanding were interviewed to provide detailed feedback on the LKPD. This was followed by the Small Group evaluation involving nine students with different levels of competence, who then assessed the LKPD from the user perspective using the questionnaire.

The next step was the Field Test. In this stage, students from one class were first given a 10-item pre-test to measure their initial understanding. They then engaged in the learning activities using the LKPD, and finally completed a post-test to assess improvement in their learning outcomes after using the PBL-based LKPD on Hydrocarbon material.

This research was conducted at SMA Negeri 12 Palembang, located on Lorong Sedulur No. 04, Karang Jaya, Gandus District, Palembang City, South Sumatra. The research subjects included Grade XI students, a Grade XI chemistry teacher, and two expert validators who evaluated three aspects of validity: content, learning design, and pedagogy. The object of the research was a Problem-Based Learning (PBL)-based Student Worksheet (LKPD) on Hydrocarbon material. Data were collected through observation, interviews, questionnaires, and tests.

The analysis of the questionnaire sheets provided by the validators produced validation scores. The data obtained were then calculated using Aiken's V formula as follows :

$$V = \frac{\sum s}{[n(c-1)]} \quad (\text{Aiken, 1985})$$

Description:

- V : Validity
- s : r - lo
- r : Score given by the evaluator
- lo : Minimum validity score
- n : Number of experts evaluating
- c : Highest possible validity score

Table 1 presents the validation criteria based on Aiken's V..

Table 1.
Validation Score Criteria

Score Range	Category
0,68 – 1,00	High
0,34 – 0,67	Medium
0,00 – 0,33	Low

(Aiken, 1985)

To calculate the percentage, the following formula was used :

$$\text{Practicality Percentage} = \frac{\text{Total Score}}{\text{Maximum Score}} \times 100\% \quad (\text{Bintiningyas dan Lutfi, 2016})$$

The criteria for assessing practicality are presented in Table 2.

Table 2.
Practicality Criteria

Score	Category
81%-100%	Very Practical
61%-80%	Practical
41%-60%	Fairly Practical
21%-40%	Less Practical
0%-20%	Not Practical

(Bintiningyas dan Lutfi, 2016)

To calculate the effectiveness of the LKPD, the N-Gain formula (Hake, 1998) was used:

$$g = \frac{\text{Post test Score} - \text{Pre test Score}}{\text{Maximum Ideal Score} - \text{Pre test Score}}$$

The average results obtained after calculation using the gain formula were interpreted according to Table 3.

Table 3.
Gain Level Criteria

Score range	Category
$g \geq 0,7$	High Gain Score
$0,3 \leq g < 0,7$	Medium Gain Score
$G < 0,3$	Low Gain Score

(Hake, 1998)

Results and Discussions

The final product of this development research is a Problem-Based Learning-based Student Worksheet (LKPD) for Hydrocarbon material for Grade XI at SMA Negeri 12 Palembang. The primary objective of this development effort is to produce a Student Worksheet that is valid, practical, and effective.

1. Results

a. Validity

The results of the validity assessment of content, design, and pedagogical aspects of the Problem-Based Learning (PBL)-based Student Worksheet (LKPD) for Hydrocarbon material can be seen in Table 4.

Table 4.
Summary of Validation Results from the Expert Review Stage

No.	Validation	Aiken's Coefficient	V	Category
1	Content	0,92		HIGH
2	Design	0,96		HIGH
3	Pedagogy	0,90		HIGH
-	Average	0,93		HIGH

Based on Table 4, the evaluation by two experts across the three categories yielded an average Aiken's V value of 0.93, which falls into the high category, indicating that the worksheet is valid and suitable for implementation in learning.

b. Practicality

The results of the practicality test conducted by nine Grade XI students on the PBL-based worksheet are presented in Table 5.

Table 5.
Calculation Results of the Small Group Evaluation Questionnaire

No.	Name	Practicality Score	Category
1	SAD	$= \frac{20}{21} \times 100\% = 95,23\%$	Very Practical
2	PM	$= \frac{21}{21} \times 100\% = 100\%$	Very Practical
3	MF	$= \frac{21}{21} \times 100\% = 100\%$	Very Practical
4	VL	$= \frac{21}{21} \times 100\% = 100\%$	Very Practical
5	ZM	$= \frac{20}{21} \times 100\% = 95,23\%$	Very Practical
6	PA	$= \frac{21}{21} \times 100\% = 100\%$	Very Practical
7	J	$= \frac{21}{21} \times 100\% = 100\%$	Very Practical
8	NAP	$= \frac{21}{21} \times 100\% = 100\%$	Very Practical
9	VNR	$= \frac{20}{21} \times 100\% = 95,23\%$	Very Practical
-	Average	$= 98,41\%$	Very Practical

Based on Table 5, the practicality test involving nine Grade XI students, divided into three levels of ability—low, medium, and high—produced an average score of 98.41%, indicating that the worksheet is very practical from the users' perspective and can be implemented effectively in learning.

c. Effectiveness

The results of the field test conducted with 33 Grade XI-2 students on the PBL-based worksheet are presented in Table 6.

Table 6.
Results of the Effectiveness Test

No.	Variable	Average	Category
1	<i>Pre-test</i>	72,85	-
2	<i>Post-test</i>	92,85	-
3	N-Gain	0,8	TINGGI

Based on Table 6, the results of the pre-test and post-test for the 33 students showed improvement after learning using the PBL-based LKPD, with an N-Gain score of 0.8, categorized as high. This indicates that the worksheet is effective when applied in the learning process.

2. Discussions

a. Validity

The validation data for the worksheet were obtained from two chemistry lecturers at the FKIP Chemistry Education program. The components assessed during the validation stage included content, design, and pedagogy. Content validity aimed to measure the alignment of the material with the Learning Outcomes (CP), Learning Objectives (TP), Instructional Sequence

(ATP), material accuracy, support for content presentation, and adherence to the Problem-Based Learning (PBL) syntax. Design validity evaluated the appropriateness of the visual layout, cover page, content pages, and presentation style in accordance with PBL syntax. Pedagogical validity assessed the alignment of competencies with students' abilities, the appropriateness of language usage in Indonesian, and overall effectiveness in supporting learning.

Based on expert validation, the Problem-Based Learning-based worksheet for Hydrocarbon material obtained an average Aiken's V coefficient of 0.93, categorized as very high. This indicates that the developed product meets the criteria for high validity across content, design, and pedagogical aspects. The high validation score demonstrates that the worksheet accurately represents the assessed content and aligns with the intended learning objectives (Aiken, 1985).

Regarding content, the Aiken's V coefficient of 0.92 indicates that the validators considered the worksheet material to be well-aligned with the Learning Outcomes, Learning Objectives, and Instructional Sequence, accurate, and consistent with the PBL syntax. According to Magdalena et al. (2020), it is essential to emphasize both the depth and breadth of content, curriculum alignment, and the characteristics of the learners.

The design aspect received a validation score of 0.96, suggesting that the worksheet's visual elements—including structured layout and harmonious color choices—effectively reduce extraneous cognitive load (Sweller et al., 2019) and meet high-quality standards. As Prastowo (2015) notes, visually appealing instructional materials can enhance student motivation and facilitate better conceptual understanding.

Meanwhile, the pedagogical aspect received a score of 0.90, indicating that the worksheet adheres to sound instructional principles, particularly in implementing PBL syntax. This demonstrates that the learning steps in the LKPD are appropriate for the students' characteristics and promote active engagement in the learning process (Arends, 2012), while the language used is accurate and effective.

b. **Practicality**

Based on the practicality test conducted during the small group evaluation, the worksheet obtained an average score of 98.41%, which falls into the **very practical** category. This high score was consistently reflected across various aspects.

Regarding ease of use, students rated the worksheet as easy to understand, efficient for learning activities, and capable of enhancing their engagement and self-confidence. For the visual appeal aspect, the worksheet achieved a perfect score of 100%. This indicates that the visual presentation—including relevant images and illustrations, color combinations, and typography choices—met students' visual expectations and supported content readability. Similarly, in terms of language, the worksheet received an optimal score of 100%. This success reflects the use of clear, communicative sentence structures and standardized terminology in accordance with the rules of Indonesian, minimizing potential comprehension barriers for students. For the usefulness aspect, the worksheet scored 98.41%, remaining in the very practical category. Although slightly lower than the other aspects, this score confirms that the worksheet is effective as a tool for independent learning and serves as a reference resource that enhances students' knowledge and understanding.

c. **Effectiveness**

The effectiveness test was conducted through a field test involving all 33 students in a Grade XI class at SMA Negeri 12 Palembang. The field test assessed students' performance by

comparing pre-test and post-test scores to calculate the N-Gain. Both the pre-test and post-test consisted of 10 multiple-choice questions.

Based on the field test results, the average pre-test score was 72.85, with the highest score of 90 and the lowest score of 10. The post-test results showed an average score of 92.85%, with the highest score of 100 and the lowest score of 70. This improvement aligns with the fundamental principles of Problem-Based Learning (PBL), where students are actively engaged in authentic problem-solving rather than passively receiving information, encouraging them to construct knowledge through exploration, discussion, and synthesis (Liu & Pásztor, 2022). Activities in the LKPD, such as analyzing the impacts of hydrocarbon combustion or designing solutions for gas leaks, simulate real scientific work, thereby training higher-order thinking skills. These findings support previous research by Mairani et al. (2022) and Rahmadoni & Aini (2025), which also reported the validity and practicality of PBL-based worksheet for Hydrocarbon material.

From the test results, the calculated N-Gain score was 0.8. Since the N-Gain is greater than 0.7, it falls into the high category, indicating that the Problem-Based Learning-based worksheet is effective for supporting student learning.

Conclusion

Based on the results of the development research on the Problem-Based Learning (PBL)-based LKPD for Hydrocarbon material in Grade XI at SMA Negeri 12 Palembang, it can be concluded that the LKPD is valid, practical, and effective. The LKPD was declared valid with an average validation score of 0.93 based on expert evaluations of the material, design, and pedagogical aspects. It was categorized as highly practical with a practicality score of 98.41% obtained from the small group trial. The LKPD was also found to be effective, with an n-gain value of 0.8, which falls into the high category based on the results of the field test.

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Acknowledgment

The author would like to express sincere gratitude to all those who supported this research. Special thanks are extended to the supervisor Dr. Effendi, M.Si., validators Eka Ad'hiya, S.Pd., M.Pd., and Rodi Edi S.Pd., M.Si. also teacher and students of SMA Negeri 12 Palembang for their participation, guidance, and assistance throughout the development and testing of the Problem-Based Learning-based Student Worksheet for Hydrocarbon material.