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Development of PBL-Based Student Worksheets to Improve Problem-Solving Skills and Collaborative Skills of 11th Grade Students in Reaction Rate Material

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ABSTRACT

Problem-solving and collaboration are essential 21st-century skills, particularly in chemistry education where students must grasp abstract and complex topics like reaction rates. This study aims to develop Problem-Based Learning (PBL)-based *Lembar Kerja Peserta Didik* (LKPD, student worksheets) to enhance these skills among Grade XI students. The research employed a Research and Development (R&D) approach using the ADDIE model. Data were collected through interviews, questionnaires, validation sheets, and user response surveys. Three subject matter experts conducted the validation. Small-scale trials were performed with three students of varying abilities. Large-scale testing used a quasi-experimental pretest-posttest control group design involving 36 Grade XI science students from SMAN 5 Pinggir, selected purposively. User feedback was obtained from three teachers and 30 students across three schools. The developed LKPD achieved a high validity score of 89% from expert validators. Teacher and student responses were also highly positive, scoring 88% and 91% respectively. The large-scale trial revealed statistically significant improvements (t-test, $p < 0.05$) in both collaborative and problem-solving skills. N-Gain analysis showed a moderate increase in problem-solving ability in the experimental group (0.56), compared to a low increase in the control group (0.30). The findings indicate that PBL-based LKPD effectively enhances collaborative and problem-solving skills. This instructional approach supports deeper understanding and engagement in complex chemistry topics, offering a scalable model for science education.

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1. INTRODUCTION

Teaching materials are fundamental to the learning process, serving not only as tools for knowledge transmission but also as frameworks for guiding students toward achieving learning objectives. High-quality materials support educators in promoting conceptual understanding, stimulating critical thinking, and facilitating meaningful student engagement. However, in Indonesia, the scarcity of instructional resources that encourage active learning and critical engagement has hindered learning outcomes, particularly in science subjects such as chemistry.

Ardianto and Rubini (2016) attribute the low problem-solving proficiency among Indonesian students to a predominant reliance on rote memorization rather than instructional strategies that develop analytical and problem-solving competencies. This issue is reflected in international benchmarks such as the Programme for International Student Assessment (PISA). In 2018, Indonesia's science literacy score declined to 396 points from 403 in 2015, placing the country 71st out of 79 participants (Hewi & Shaleh, 2020). This downward trend highlights a deeper systemic concern: the insufficient emphasis on cultivating scientific literacy and higher-order thinking skills in classrooms. In subjects like chemistry—where comprehension relies heavily on reasoning and abstract thinking—such deficiencies impede students' mastery of core concepts.

Beyond scientific literacy, the challenges in Indonesia's education system also extend to collaborative skills. The Indonesia Skills Report (2010) identifies collaboration as a key competency for the modern workforce. Yet, evidence indicates that it remains underdeveloped among Indonesian students. Effective collaboration—central to 21st-century learning—requires active participation, clear communication, and shared problem-solving. However, studies such as Ulhusna, Putri, and Zakirman (2020) reveal that many students remain passive in group settings, struggling to interact productively or contribute meaningfully to collective learning processes.

Preliminary research involving interviews with chemistry teachers and student questionnaires from SMAN 8 Mandau, SMAN 1 Pinggir, and SMAN 5 Pinggir identified several challenges in the learning process. Teachers reported that students exhibited low problem-solving skills, with many passively awaiting guidance rather than actively engaging in problem resolution. This passive learning culture is primarily attributed to traditional, teacher-centred pedagogical approaches that prioritize memorization over active participation. Although the instructional materials used—such as textbooks, PowerPoint presentations, and scientific-based worksheets (LKPD) aligned with the revised 2013 curriculum—are intended to support student learning, the overall teaching methods remain largely lecture-based. As a result, students have limited opportunities to develop essential skills such as problem-solving and collaboration, particularly in complex topics like reaction rates and reaction orders.

The student survey further revealed that 43.3% preferred group learning, indicating potential benefits from incorporating more interactive and collaborative learning strategies. Teachers have attempted to improve the learning process through peer tutoring and encouraging the use of supplemental resources; however, these efforts have had limited impact. A recurring issue is the lack of contextually rich and engaging teaching materials. Nurhasnah and Sari (2020) emphasized that many existing resources are monotonous and fail to incorporate problem-solving or real-world applications. Similarly, Fuadi, Robbia, Jamaluddin, and Jufri (2020) highlighted the need for instructional materials that stimulate critical and contextual thinking.

One effective method to increase student engagement is through group learning, which promotes collaboration and involvement in the learning process (Sanjaya, 2016). This aligns with the preferences of students, as reflected in the 43.3% who favored collaborative settings. Group learning is a key feature of context-based instruction, fostering communication, cooperation, and the exchange of ideas. Collaboration is one of the core competencies emphasized in 21st-century education, essential for both academic success and real-world problem-solving. As noted by Hapsari et al. (2014), students who collaborate effectively can engage in meaningful discussions, share knowledge, and develop creative solutions. Success in completing group tasks is strongly influenced by the level of interaction and cooperation among peers. According to Sanjaya (2016), students who are capable of working and communicating well in teams possess valuable collaboration skills that will benefit their future social and professional lives.

Nurhasnah and Sari (2020) assert that commonly used teaching materials tend to focus solely on content delivery, often lacking contextual relevance, variety, and integration of scientific knowledge into problem-solving scenarios. These materials, though aligned with curricular standards, are limited in quality and fail to adequately support the development of students' problem-solving abilities. This shortfall contributes significantly to the persistently low problem-solving skills observed among Indonesian students, as the materials do not offer an in-depth or practical approach to cultivating this essential competency.

In today's educational landscape, teachers are expected to design interactive and innovative learning experiences (Mairisiska & Sutrisno, 2014). When instructional strategies align effectively with teaching content, students' motivation to learn can increase (Ahmad & Tambak, 2018). However, in practice, many students still face substantial learning barriers (Ismail, 2016). One major issue is the continued use of monotonous teaching models, which often result in boredom and disengagement. This lack of engagement not only hinders the achievement of learning objectives but also poses challenges across various educational settings, both public and private.

To address these issues, implementing an appropriate learning model is essential. The Problem-Based Learning (PBL) model is particularly suitable within the context of the *Merdeka* curriculum (Lestari, Yudhanegara, & Surya, 2023). PBL emphasizes student-centered learning, where learners are encouraged to collaborate and propose innovative solutions to real-world problems (Ariani, 2020; Latifah, Suparmi, & Riyadi, 2020; Yuniarti & Radia, 2021). By giving students the autonomy to explore, discuss, and express their ideas, PBL fosters deeper understanding and critical thinking. However, Abidin (2014) notes that PBL is not without challenges. Students who lack confidence or a firm grasp of the material may struggle to engage with complex problems, and the model often requires significant time for preparation and facilitation.

Despite these limitations, PBL offers valuable opportunities for students to engage in realistic problem-solving while enhancing communication, cooperation, and reasoning abilities (Perusso & Baaken, 2020; Yazar Soyadı, 2015). Garnjost and Brown (2018) further argue that collaborative learning within the PBL framework improves students' teamwork skills and collective problem-solving capabilities. Supporting this, Ma'wa, Hapipi, Turmuzi, and Azmi (2021) demonstrated that PBL-based student worksheets (*LKPD*) significantly enhanced the problem-solving abilities of Grade VIII students on linear equation systems.

Preliminary data collected through teacher interviews and student questionnaires indicate that current teaching materials and strategies are insufficient for developing problem-solving and collaboration skills. Traditional lecture-based instruction remains the dominant method, offering limited student engagement. However, student survey responses show a clear preference for group-based learning, revealing strong potential for the integration of more collaborative teaching approaches.

In response to these challenges and opportunities, this study aims to develop PBL-based LKPD to improve problem-solving and collaboration skills among Grade XI students in the context of reaction rate material. The objective is to design engaging, contextually relevant teaching resources that align with 21st-century learning goals and foster active student participation. By bridging the gaps in current instructional practices, this research aspires to contribute meaningfully to the enhancement of scientific literacy and skill development in Indonesian secondary education.

2. METHODS

2.1 Research Design

This study employs a Research and Development (R&D) approach, utilizing the ADDIE development model as its framework. The ADDIE model comprises five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. Each phase is conducted sequentially to ensure the teaching materials developed—specifically the PBL-based student worksheets (*LKPD*)—are pedagogically sound, contextually relevant, and effectively support the intended learning outcomes.

2.2 Sampling and Participants

In the development stage, the population used is all students in class XII IPA SMAN 8 Mandau, SMAN 1 Pinggir and SMAN 5 Pinggir who have studied the reaction rate . For the purpose of product testing, namely individual trials involving 3 students of class XII IPA SMAN 5 Pinggir who have high, medium and low academic levels. The response of small-scale trials involved 3 teachers and 30 students of class XII from SMAN 8 Mandau, SMAN 1 Pinggir and SMAN 5 Pinggir.

The population in the field trial consisted of all Grade XI students at SMAN 5 Pinggir. The study sample included 36 students from class XI.1 and 32 students from class XI.2, totaling 68 participants. The sampling method used in this research was **purposive sampling**. According to Sugiyono (2017), purposive sampling is a technique used to select data sources based on specific criteria or considerations. Suharsimi Arikunto (2010) explains that this method involves selecting subjects intentionally, based on particular objectives and practical constraints such as limited time, energy, or budget, rather than relying on stratified, random, or area-based sampling techniques.

2.3 Instruments

Instruments are measuring tools used in every research. According to Sugiyono (2015), instruments are research tools used to measure the phenomena to be observed. The questionnaire instrument in this development research was used to obtain data from material experts, teachers, and students as a measure of the practicality of the developed LKPD, and also to measure the level of students' problem-solving abilities after learning to use this problem-based LKPD.

2.4 Data Collection

To ensure comprehensive and reliable coverage of the research objectives, this study employed a multi-method data collection approach. The techniques utilized included interviews, questionnaires, validation sheets, teacher and student response forms, subject-specific test items on reaction rates, and a review of relevant documentation. Interviews were conducted to gather in-depth qualitative insights from key participants, while questionnaires offered quantitative data reflecting the perceptions and responses of both teachers and students.

Validation sheets were used to evaluate the quality, relevance, and alignment of the developed learning materials with established educational standards. Teacher and student response forms provided feedback on the practicality, clarity, and overall effectiveness of the instructional materials. A series of structured test items was administered to assess students' understanding of the topic of reaction rates. Furthermore, supporting documents—such as lesson plans and institutional records—were reviewed to contextualize and corroborate findings obtained from other sources.

By integrating both qualitative and quantitative data collection methods, the study ensured methodological rigour and enhanced the validity and reliability of its findings.

2.5 Data Analysis

A validation assessment was conducted by 3 material experts. Data obtained from the validation sheet assessment is in the form of a scale. The type of scale used is a *Likert scale* with a score of 1-4. This scale provides flexibility to the validator in assessing the validity of the PBL-based LKPD teaching materials developed. Giving meaning and making decisions about product quality PBL-based LKPD on the reaction rate material will use the achievement level conversion in Table 1.

Table 1. Validity Criteria for Material Validator Assessment Questionnaire Data

Percentage (%)	Criteria
81-100	Very worthy / very valid / no need to revise
61-80	Eligible/valid / no revision required
41-60	Inadequate/invalid / needs revision
21-40	Not suitable/invalid / needs revision
< 20	Totally inappropriate / totally invalid / needs revision

(Suharsimi Arikunto, 2010)

The average score results from the teacher response questionnaire that had been obtained were then changed into qualitative data to determine the criteria for using PBL-based LKPD, which can be seen in Table 2.

Table 2. Questionnaire Response Criteria Intervals

Percentage (%)	Criteria
81-100	Very good
61-80	Good
41-60	Pretty good
21-40	Not good
< 20	Very Bad

(Suharsimi Arikunto, 2010)

Based on the analysis of Table 2, the teacher's response to the developed product can be evaluated. A product is considered effective for teachers if it achieves a minimum score of 61%, categorized under "good" criteria.

This study utilized an experimental research design, specifically the Pretest-Posttest Control Group Design (Sugiyono, 2019). This design involved two groups: an experimental class and a control class. Both groups were administered a pretest prior to the intervention and a posttest following the intervention.

To determine the suitability of further statistical analysis, a normality test was conducted to assess whether the data were normally distributed. This test served as a prerequisite for conducting hypothesis testing. The normality test was applied to the pretest and posttest data on students' problem-solving abilities, using the Kolmogorov-Smirnov test.

Following confirmation of normal data distribution, hypothesis testing was conducted using a t-test. Specifically, an independent sample t-test was used to compare the problem-solving ability between the experimental and control groups. Statistical analysis was carried out using SPSS Version 23. The criteria for hypothesis testing are described as follows.

1) If the significance value > 0.05 , then Ho is accepted, so Ha is rejected.
2) If the significance value < 0.05 , then Ho is rejected, so Ha is accepted.

3. FINDINGS AND DISCUSSION

The data obtained in this study align with the research methodology used for the development of the LKPD based on the Problem-Based Learning (PBL) approach. The research followed a Research and Development (R&D) framework, adapted from the ADDIE model, which includes five systematic phases: Analysis, Design, Development, Implementation, and Evaluation. The findings and discussions are presented in accordance with each phase of the ADDIE model to provide a structured and comprehensive overview of the product development process. Each stage contributes to the validation and refinement of the LKPD to ensure its effectiveness in enhancing students' problem-solving and collaboration skills.

3.1. Analysis

Preliminary research for this study was conducted through three key analyses: initial analysis, student analysis, and curriculum analysis. Each phase was guided by established educational theories and supported by relevant empirical studies to ensure that the development of the Problem-Based Learning (PBL)-based *Lembar Kerja Peserta Didik* (LKPD) was both theoretically grounded and pedagogically sound.

The initial analysis involved interviews with three chemistry teachers from different schools implementing the *Merdeka* Curriculum. The findings revealed that chemistry is widely perceived as a difficult and abstract subject, largely due to the lack of relevance students perceive between the content and their daily lives. This aligns with constructivist learning theory, which emphasizes the importance of connecting new knowledge to students' prior experiences (Piaget, 1970). Bruner (1960) also argued that learning becomes more meaningful when linked to real-world contexts, which increases student engagement and understanding—particularly crucial in subjects like chemistry. While the interviewed teachers reported using inquiry-based, scientific, and cooperative learning models, none had previously implemented the PBL approach. As defined by Barrows (1986), PBL is an instructional method in which students learn by actively solving complex, real-world problems. Studies by Fitriyah (2018) and Rahmadani and Anugraheni (2017) have shown that PBL effectively enhances students' problem-solving and collaboration skills, reinforcing its potential as a powerful pedagogical tool in chemistry education.

The student analysis, conducted through questionnaires, revealed that 56.6% of students felt the current teaching materials did not help them understand chemistry, and 55% found the learning process unengaging. These results point to a lack of stimulation and relevance in the materials used, supporting the notion that traditional instruction may not adequately meet students' learning needs. Dawati (2019) emphasized that students often disengage from content that fails to connect with their personal experiences or interests. This highlights the necessity for developing more engaging, context-rich materials that align with students' real-life experiences. According to Social Cognitive Theory, students are more likely to internalize and apply knowledge when they find the material personally meaningful and relevant (Bandura, 1986).

The curriculum analysis was carried out to ensure that the development of the PBL-based LKPD aligns with the learning objectives outlined in the *Merdeka* Curriculum, particularly within the topic of reaction rates. Key concepts such as collision theory and factors affecting reaction rates were identified as core content areas. Drawing on Vygotsky's constructivist perspective (1978), effective learning occurs when it builds upon students' prior knowledge and is situated in meaningful, real-world contexts. By integrating PBL into the curriculum, students can explore scientific concepts through active problem-solving that mirrors real-life situations. This approach aligns with the principles of the *Merdeka* Curriculum, which prioritizes student-centered, experiential learning designed to equip learners with critical thinking and collaboration skills for real-world challenges.

3.2. Design

The design of Student Worksheets (LKPD) based on the Problem-Based Learning (PBL) model was implemented to address issues identified during the initial analysis phase of the research, particularly regarding students' lack of engagement and the need for more meaningful and practical learning materials. PBL, as outlined by Barrows (1986), is a learner-centered instructional strategy that encourages students to work through real-world problems, fostering critical thinking and problem-solving skills. The use of a PBL-based LKPD aims to create more dynamic, interactive learning experiences that link classroom content to everyday life, enhancing student engagement.

The quality of this teaching material was assessed using a comprehensive questionnaire instrument that collected feedback from material experts, media experts, chemistry teachers, and students. This instrument was validated by a chemistry education lecturer at the University of Riau, ensuring the content's relevance and accuracy. Validation results from three material experts confirmed that the LKPD was "Suitable for Use Without Revision," reflecting its alignment with educational standards and its potential effectiveness in improving student learning outcomes. The validation process, which is a common practice in instructional material development (Thiagarajan, Semmel, & Semmel, 1974), is critical for ensuring that the LKPD meets both academic and pedagogical standards before being used in the classroom.

In the product design phase, a storyboard was created as a visual representation of how the PBL-based LKPD would be structured and presented to students. Storyboarding, as suggested by Arifin (2011), helps to clarify the organization of content and activities, providing a roadmap for the material's development. The design process involved using tools like Canva to create an aesthetically appealing and user-friendly layout for the LKPD. Elements such as titles, logos, and relevant images were carefully selected to make the material engaging and accessible. The introduction section was structured to include a foreword, table of contents, and clear instructions on how to use the LKPD, ensuring that students could easily navigate the material.

The core section of the LKPD was developed around four learning activities, each incorporating competency indicators, learning objectives, materials, summaries, independent assignments, practice questions, and feedback. This structure aligns with the PBL approach by guiding students through problem-solving tasks, promoting independent learning, and allowing for continuous assessment. According to Savery and Duffy (2001), these features of PBL support deep learning and the development of higher-order thinking skills. The closing section of the LKPD includes a bibliography of the references used in compiling the teaching materials, ensuring academic integrity and providing students with resources for further study. This structured, PBL-based approach is designed to enhance the learning experience by making chemistry content more relevant, engaging, and effective.

3.3. Development

The prototype development phase involved transforming the previously designed storyboard into a functional prototype of the PBL-based LKPD. This stage focused on realizing the initial design into a visually engaging and pedagogically sound learning tool. To enhance visual appeal and clarity in presenting the learning materials, the prototype was developed using Canva, a digital design platform that supports the creation of interactive and aesthetically attractive educational resources.

To evaluate the quality of the developed prototype, an expert validation was conducted by three subject matter experts using a structured validation sheet based on a 4-point Likert scale. The validation assessed four key aspects: content feasibility, pedagogical quality, language use, and graphic presentation. The purpose of this validation was to determine the alignment of the PBL-based LKPD with educational standards and its effectiveness as a teaching resource. Each expert conducted the validation twice, allowing for iterative feedback and refinement of the material. The average percentage scores for each aspect of the material validation are presented in Table 3, and further details regarding the validation outcomes are discussed in the subsequent sections.

Table 3. Percentage of Expert Validation Results

No.	Rated aspect	Percentage (%)	
		Validation I	Validation II
1	Content Eligibility	83	94
2.	Characteristics of PBL	85	93
3.	Pedagogy	81	89
4.	Language Assessment	67	90
5.	Graphics	62	90
Average		78	91

The first validation results indicated that the developed LKPD was considered *valid* but required revision, with an average score of 78%. While the overall assessment was positive, two aspects—Graphics (62%) and Language (67%)—received lower ratings, highlighting the need for improvement in visual presentation and linguistic clarity. Based on expert feedback, specific suggestions were provided to enhance the readability, clarity, and visual appeal of the materials to better engage students.

After revisions were made in accordance with this feedback, the second validation demonstrated a significant improvement. The average score increased to 91%, categorizing the LKPD as *very valid*. This improvement reflects the effectiveness of the revisions, particularly in the areas of graphics and language, which had previously been identified as weaknesses. In addition, components such as Content Feasibility and PBL Characteristics, which initially received strong ratings of 83% and 85%, respectively, saw further increases to 94% and 93%. These results confirm that the modifications were well-received and successfully enhanced the overall quality of the LKPD.

This iterative validation process aligns with best practices in instructional design, where repeated expert review and revision cycles are essential to ensure the effectiveness and usability of learning materials (Boulmetis & Dutwin, 2011). By incorporating expert input across multiple validation stages, the LKPD was refined to meet pedagogical standards and improve its practical application in the classroom. Such a process is especially critical in the development of PBL-based instructional materials, which must be engaging, clear, and aligned with specific learning objectives to effectively facilitate student-centered learning—particularly in complex subjects like chemistry.

3.4 Implementation

This step involves the implementation of the learning media within the classroom setting. The process includes one-on-one trials, small-scale trials, and large-scale trials, all of which engage students to assess their responses to the PBL-based LKPD learning materials. These implementation stages are designed to gather feedback on the usability, effectiveness, and student engagement with the developed materials, providing critical insights for further refinement and validation.

One-on-One Test

During the one-on-one trial, students were provided with the PBL-based LKPD and guided directly by the researcher in its use. Participants engaged in the learning activities outlined in the LKPD and completed the embedded exercises. Following the session, students were interviewed to gather comments and suggestions regarding the LKPD's content, layout, and usability.

Based on student feedback, the LKPD was generally perceived as interesting, user-friendly, and visually appealing. A student identified as PD1 noted that the color scheme was well-balanced and not monotonous, and the text was clear and easy to read. However, PD1 also recommended including additional sample questions with discussions to aid understanding. Another student, PD2, described the LKPD as unique and efficient in terms of time management but suggested correcting several typographical errors. Similarly, MDA provided positive feedback on the LKPD's design and ease of use, while also recommending improvements in spelling accuracy.

From the collected data, two main suggestions emerged: the inclusion of sample questions with explanations and the correction of typographical errors. However, based on the expert validator's review, the addition of sample questions was deemed unnecessary, as the current structure was considered sufficient for achieving the intended learning outcomes.

Overall, students expressed that the PBL-based LKPD enhanced their interest and motivation in learning. They found the materials engaging, clear, and not monotonous, which contributed to sustained attention during the learning process. This aligns with findings from Adawiyah (2020), who stated that well-designed and visually appealing teaching materials can significantly increase student motivation and participation in learning activities.

Trials Small Scale

User response data were collected through questionnaires completed by chemistry teachers from three schools: SMAN 8 Mandau, SMAN 5 Pinggir, and SMAN 1 Pinggir. The evaluation process began with the distribution of the PBL-based LKPD to participating teachers. They were given sufficient time to thoroughly review the material before completing a structured response questionnaire designed to assess the LKPD's quality, relevance, and usability. The results of the teacher response questionnaire are summarized in Table 4.

Table 4. Teacher Response Questionnaire Data

Respondents	Percentage (%)	Criteria
Teacher 1	90	Very good
Teacher 2	88	Very good
Teacher 3	87	Very good
Average	89	Very good

The teacher's response to the PBL-based LKPD model was assessed as very good overall, with an achievement percentage of 89 %. This result is in line with with the LKPD development research by Apriani et al . (2021) which obtained the results of teacher response assessments with an average percentage of 90% which is categorized as very good. The results shown in Table 4.13 indicate that the PBL-based LKPD is considered very easy to use, the presentation of materials and learning activities is systematic and in accordance with the indicators and learning objectives. In addition, teachers also provide full support for the development of this LKPD because it is considered an alternative teaching material that can attract more attention from students.

The stages of obtaining user responses from the results of the student response questionnaire involved 30 students of class XI I IPA with 10 students each from 3 different schools, namely SMAN 8 Mandau, SMAN 5 Pinggir and SMAN 1 Pinggir. The collection of response questionnaire data involving students was carried out by providing LKPD to students, and then given time to assess the LKPD using the response questionnaire. The results of the student response questionnaire can be seen in Table 5 .

Table 5. Student Response Questionnaire Data

School	Percentage (%)	Criteria
Senior High School 8 Mandau	92	Very good
SMAN 5 Pinggir	91	Very good
SMAN 1 Pinggir	91	Very good
Average	91	Very good

Based on the data presented in Table 5, the distribution of student response questionnaires across three schools yielded an average score of 91%, indicating that the developed PBL-based LKPD (Student Worksheet) received a very positive response from students. These findings are consistent with the study conducted by Apriani et al. (2021), which reported an average student response rating of 87%, also categorized as very good.

This high level of student approval suggests that the LKPD successfully captures students' interest, largely due to its visually engaging design and its ability to foster enthusiasm and motivation for learning. The integration of multimedia elements and the inclusion of active learning strategies contribute to making the content more accessible and the learning process more interactive.

Based on the results of the small-scale trial, it can be concluded that the PBL-based LKPD received highly favorable feedback from both students and teachers. Following the validation and trial phases, necessary revisions were implemented, resulting in the final version of the developed LKPD.

Test Try Large Scale

The implementation of PBL-based LKPD learning on the reaction rate material in the experimental class was observed by 2 chemistry teachers as observers. PBL learning is carried out based on aspects of student orientation to problems, self-organization skills, guiding investigations, developing work results, and analyzing problem-solving processes. The following is a further review of each aspect to understand the extent of progress that has been achieved by students in PBL aspects.

Table 6. Data from Observation Results of PBL Learning Implementation

Aspect	Percentage
Student orientation to problems	93.1
Organizing students	90.6
Guiding individual and group investigations	88.2
Developing and presenting work results	92.2
Analyze and evaluate the problem-solving process	92.2
Average	91.3

Based on Table 6, the implementation of Problem-Based Learning (PBL) showed a significant improvement. Before the use of LKPD (Student Worksheets) based on the PBL model, students achieved an average performance score of 68%. After the introduction of LKPD, this average increased to 89.3%. These results indicate that the application of PBL, when supported by structured LKPD, positively influenced student engagement and learning outcomes.

The first assessed aspect—students' orientation toward problems—reflects their ability to comprehend and focus on the core issue. Before the intervention, a score of 70.0 suggested a moderately good performance, though not yet optimal. Following the implementation of LKPD, the score rose to 93.1. This improvement indicates that teachers were more successful in contextualizing problems, helping students relate them to real-life situations. Consequently, students became more engaged and motivated to solve the given problems.

This aspect encompasses students' ability to manage tasks, ideas, and information effectively. A pre-intervention score of 70.3 indicated that students demonstrated a basic level of organization but needed improvement. Post-intervention, the score increased to 90.6, highlighting better teacher facilitation in guiding both individual and group work. This led to more effective collaboration and a more structured learning process.

The third aspect evaluated students' ability to engage in and collaborate on inquiry-based projects. Before the intervention, a score of 70.1 reflected that while guidance was present, it lacked consistency. After using the PBL-based LKPD, the score rose to 88.2, indicating enhanced teacher support and a more proactive approach in assisting students. This allowed students to work more independently or collaboratively in conducting research and solving problems.

This component measured students' ability to create and present their projects. The initial score of 74.8 showed that students were relatively capable, though there was room for refinement. After the intervention, the score increased significantly to 92.2, demonstrating improved clarity, organization, and confidence in presenting their work.

This final aspect focused on students' critical thinking and their ability to assess the problem-solving process. A pre-intervention score of 64.7 indicated noticeable difficulties in evaluating their own solutions. After the intervention, the score jumped to 92.2, suggesting a marked increase in students' reflective and evaluative abilities regarding both their methods and outcomes.

These findings suggest that the PBL approach, especially when accompanied by well-designed LKPD, enhances various core competencies among students—namely, their problem orientation, organizational abilities, inquiry collaboration, project presentation, and evaluative thinking. The upward trend across all indicators confirms the positive impact of PBL on student learning outcomes.

To better represent these developments, the measurements of students' abilities can be displayed through descriptive statistics, particularly using mean scores and improvements for both the control and experimental groups. These results are summarized in the following table.

Table 7. Descriptive Statistics of Problem Solving Ability Scores

	Experimental Class		**Control Class**	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Sample	36	36	32	32
Average	13	61	14	46
Max Value	18	97	19	66
Min Value	8	40	10	38

As presented in Table 7, the experimental class comprised 36 students, while the control class consisted of 32 students. In the experimental group, the average pre-test score was 13, which increased substantially to 61 following the learning intervention. Similarly, the control group showed an improvement, with the average pre-test score rising from 14 to 46 post-intervention.

Regarding score distribution, the highest pre-test score in the experimental class was 18, which increased to 97 in the post-test. The lowest score in this group rose from 8 to 40. In the control class, the highest score improved from 19 to 66, while the lowest score increased from 10 to 38.

To determine whether the data met the assumption of normality, a normality test was conducted using the Kolmogorov-Smirnov method via SPSS version 24, with a significance level set at 0.05. The Kolmogorov-Smirnov test is recognized as a suitable method for assessing normality in datasets with more than 50 observations. As noted by Dahlan (2010), the Kolmogorov-Smirnov test is appropriate when the sample size exceeds 50, while the Shapiro-Wilk test is preferable for smaller samples.

The results of the normality test for each variable are detailed in Table 8.

Table 8. Normality test of problem-solving ability

Class		**Kolmogorov-Smirnov**	**Conclusion**
		Sig.	
Pretest	Experiment	0.081	Normal Distribution
	Control	0.121	Normal Distribution
Posttest	Experiment	0.127	Normal Distribution
	Control	0.200 *	Normal Distribution

As shown in Table 8, the results of the normality test for the pretest and posttest scores on problem-solving ability in both the control and experimental groups indicate that the data are normally distributed. This is evidenced by significance values greater than 0.005 ($p > 0.005$). Therefore, it can be concluded that all data meet the assumption of normality.

Given that the normality assumption has been satisfied for both groups, the data are suitable for parametric analysis. Consequently, further analysis was conducted using the Independent Samples T-Test.

Table 9. T-test of problem-solving ability

Class		**t-test for equality of means**				**Conclusion**
		F	**T**	**df**	**Sig. (2-tailed)**	
Pretest	Experiment	0.443	2.696	66	0.089	Ha Accepted (There is a Difference)
	Control					
Posttest	Experiment	25,530	4.266	66	0.000	
	Control					

Based on the results of the Independent Samples T-Test, the Sig. (2-tailed) value for students' problem-solving abilities was 0.000. Since this value is less than the significance level of 0.05, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. Therefore, it can be concluded that there is a statistically significant difference in problem-solving abilities between students in the experimental class and those in the control class.

These findings are supported by several recent studies. Putri (2023) found that implementing problem-based learning (PBL) significantly enhanced students' problem-solving abilities in the experimental group compared to those taught using conventional methods. This improvement is attributed to the PBL model's ability to help students better analyze problems and generate creative solutions.

Similarly, research by Rahardjo (2018) revealed that students engaged in project-based or problem-based learning outperformed their peers taught through traditional lecture-based instruction. These students developed stronger problem-solving skills because they were encouraged to think critically and discover solutions independently.

The enhancement of problem-solving abilities in both the control and experimental classes can be further examined through the calculation of the normalized gain score. The results of this analysis are presented in the following table.

Table 10. Data on the increase in problem solving skills in the experimental and control classes

Class	**Average N-Gain Score**	**Category**	**Frequency**	**Percentage (%)**
Experiment	0.56 (Medium)	High	10	28
		Currently	23	64
		Low	3	8
Amount			36	100
Control	0.30 (Low)	High	0	0
		Currently	26	81
		Low	6	19
Amount			32	100

Based on the results of the analysis above, it can be seen that the average gain score of students' problem-solving abilities in the control class is 0.30 which is included in the low category. While the average *gain score of* problem-solving abilities in the experimental class is 0.56 and is included in the medium category, so it can be concluded that there is a difference in the value of problem-solving abilities between the control class and the experimental class. In the experimental class, there was an increase in learning outcomes with an average N-Gain of 0.5 6. This value is included in the medium category ($0.31 \leq N - Gain \leq 0.70$). This is in line with the results of observations in the experimental class regarding students' problem-solving abilities during the learning process.

According to Savery (2015), Problem-Based Learning (PBL) is effective in enhancing problem-solving skills because it engages students beyond rote memorization. Instead, it actively involves them in cognitive processes that require formulating and testing solutions. Moreover, PBL fosters student independence by encouraging them to identify problems, formulate hypotheses, gather relevant information, and critically evaluate the solutions they develop.

This aligns with findings by Loyens et al. (2017), who demonstrated that PBL enables students to develop deeper problem-solving skills compared to traditional instructional methods, which tend to rely heavily on direct teaching. The observed increase in gain scores within the experimental class further supports the conclusion that the PBL approach positively impacts students' problem-solving abilities, as reflected in their improved learning outcomes relative to the control group.

Collaboration skills data were obtained from the results of a questionnaire given to students to determine the level of collaboration skills before and after using Student Worksheets (LKPD) based on Problem-Based Learning (PBL).

Table 11. Descriptive Statistics of Collaboration Skills Scores

No.	**Collaboration skills indicators**	**Percentage (%)**	
		Experimental Class	**Control Class**
1.	Contribute actively	85	65
2.	Work productively	86	66
3.	Responsible	87	64
4.	Demonstrate flexibility	85	67
5.	Respect others	85	65
Combined Average Percentage (%)		86	65

Table 11 shows that students' collaboration skills obtained a combined average percentage of 62% before using LKPD. based on PBL and increased to 86% after using LKPD. This data shows that students' collaboration skills increased after participating in learning using LKPD. PBL based.
The results of the normality test for each variable are as follows:

Table 12. Normality test of collaboration skills

Class		Kolmogorov-Smirnov	Conclusion
		Sig.	
Pretest	Experiment	0.081	Normal Distribution
	Control	0.121	Normal Distribution
Posttest	Experiment	0.127	Normal Distribution
	Control	0.200 *	Normal Distribution

Based on the level of significance in Table 12, which has been presented for the normality test, it shows that the pretest and posttest questionnaire scores for collaboration skills for the control and experimental classes are normally distributed, it is indicated by a significance level of more than 0.005 or $p>0.005$. So, it can be concluded that all data are normally distributed.

Based on the results of the prerequisite test, parametric testing can be continued so that the data can be analyzed using the Independent Sample T-Test.

Table 1T-test of collaboration skills

	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	0.005	0.945	13.801	66	0.000
Equal variances not assumed			13.735	63.484	0.000

Based on the results of the Independent Sample T-Test statistical test above, the sig value (2-Tailed) of the t-test for students' collaboration skills is 0.000. Because the sig value (2-Tailed) <0.05, H0 is rejected and Ha is accepted. Thus, it can be concluded that there is a significant difference in students' collaboration skills between the experimental class and the control class. This is in line with the results of observations in the experimental class regarding students' collaboration skills during the learning process.

Table 14. Data from observations of collaboration skills

Indicator	After
Contribute actively	92.0
Work productively	93.1
Responsible	93.4
Demonstrate flexibility	90.6
Respect others	92.7
Average	92.4

Overall, the average score for students' collaboration skills increased from 68.8 before the intervention to 92.4 afterwards, indicating a substantial improvement in their ability to work effectively within groups. According to cooperative learning theory, as proposed by Johnson & Johnson (2024), effective group collaboration enhances students' social and communication skills—both of which are critical for successful teamwork.

Supporting this, Gillies (2016) highlighted that social interaction in cooperative learning environments enables students to share knowledge, engage in critical thinking, and collaboratively solve problems. These elements play a vital role in developing strong collaboration skills. Interventions that promote group-based learning, peer discussion, and collaborative projects have consistently been shown to foster these abilities, which helps explain the marked improvement observed in students' collaborative performance following the intervention.

3.5 Implementation

The evaluation phase in this study was integrated throughout each stage of the ADDIE model. The goal of the evaluation was to analyze data collected during the research process. This included initial, student, and curriculum analysis during the analysis stage; the development of assessment instruments and storyboard designs during the design phase; material expert validation in the development phase; and implementation activities such as one-on-one testing, limited trials, and broader field trials. The final outcomes of the evaluation phase revealed that the product—Problem-Based Learning (PBL)-based LKPD—was highly valid, received positive feedback from both teachers and students, and was effective in improving students' problem-solving abilities.

Research findings on students' problem-solving and collaboration skills within the context of using PBL-based LKPD indicate that the implementation of this approach had a substantial positive impact on both skill areas. In terms of problem-solving, students demonstrated improved abilities in identifying problems, formulating potential solutions, selecting and applying strategies, and conducting evaluations. The overall average score for problem-solving skills increased significantly, in line with PBL theory, which emphasizes learning through complex, real-world problems and collaborative engagement.

In relation to collaboration skills, students also showed considerable improvement. The use of PBL-based LKPD fostered active participation, effective teamwork, accountability, adaptability, and mutual respect. These results are consistent with the foundations of collaborative learning, which stress the importance of communication, social interaction, and cooperation within group environments.

Despite these positive outcomes, some challenges were encountered in the field during the implementation of PBL-based LKPD. However, the structured nature of the worksheets helped guide students in organizing their prior knowledge and applying it to real-life scenarios, leading to more meaningful learning experiences. This aligns with the theory of meaningful learning, which underscores the need to connect new information and experiences with existing cognitive structures (Bagiya, 2016).

Student intelligence was also found to play a role in the development of problem-solving skills. According to Ausubel (2000), students with higher levels of intelligence tend to enhance these skills more easily. Additionally, the use of LKPD helps students discover and internalize scientific concepts (Hidayah et al., 2018). Compared to traditional teaching methods, PBL has proven to be more effective in fostering problem-solving abilities (Yustina, 2015).

Furthermore, well-designed LKPDs that are visually engaging and systematically structured have the potential to boost student motivation. This increased engagement can, in turn, lead to improved problem-solving and collaboration outcomes. Research also indicates that using contextual LKPDs significantly impacts pre-test and post-test results in both domains. As such, it can be concluded that PBL-based LKPD not only supports higher-order thinking but also enhances students' abilities to gather information, think critically, and deepen their understanding of subject matter—such as in learning about reaction rates.

4. CONCLUSION

The study demonstrated that the Problem-Based Learning (PBL)-based LKPD developed in this research is both valid and effective in enhancing students' problem-solving abilities and collaborative skills. Material expert validation yielded an average score of 89%, categorized as very valid, while user responses from teachers and students scored 88% and 91%, respectively, indicating high satisfaction with the LKPD's quality. Statistical analysis of pretest-posttest data from large-scale trials confirmed significant improvements in students' problem-solving and collaborative skills, with paired t-test results showing a significance value of 0.000 ($p < 0.05$). The experimental class achieved a moderate improvement in problem-solving skills, as indicated by an N-Gain score of 0.56, compared to the low improvement in the control class, with an N-Gain score of 0.30. These findings highlight the potential of PBL-based LKPD to foster essential 21st-century skills in chemistry education, aligning with the goals of competency-based curricula like the Merdeka curriculum. However, the study acknowledges limitations, such as the scope of participants and specific educational settings, suggesting that future research could explore broader implementation and long-term impacts. This research provides a practical framework for integrating PBL into teaching materials, offering valuable insights for educators and curriculum developers aiming to improve engagement and learning outcomes in STEM subjects.

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