JPPIPA 11(4) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of Metacognition-Based LKPD to Improve Conceptual Understanding in Reaction Rate Material

Euis Nurmiati[1*], Sugeng Bayu Wahyono[1], Muhammad Risal Rhomadan[1], Nurul Khairah[1], Ulfa Nabila Tafrienda[1]

[1] Magister Teknologi Pembelajaran, Fakultas Ilmu Pendidikan dan Psikologi, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

Received: January 21, 2025
Revised: March 13, 2025
Accepted: April 26, 2025
Published: April 30, 2025

Corresponding Author:
Euis Nurmiati
euisnurmiati.2022@student.uny.ac.id

DOI: 10.29303/jppipa.v11i4.10464

Abstract: The importance of constructivism-based chemistry learning is to develop students' conceptual understanding and metacognitive skills through active engagement, with the teacher as a facilitator, to create critical, independent, and globally competitive graduates. This study aims to develop Student Worksheets (LKPD) focused on metacognitive skills in learning reaction rate material, with the expectation of improving students' conceptual understanding and learning outcomes. Based on validation results, the LKPD has proven to be feasible for use, particularly in terms of language and metacognitive skills. In the first validation stage, the LKPD achieved an average percentage of 54.35%, which falls into the "feasible" category, while in the second stage, there was a significant improvement with an average percentage of 73.05%. Practicality assessments from teachers and students showed very good results, with teacher and student questionnaire scores ranging from 3.76 to 3.82 and 76.53% to 77.63%, respectively. Effectiveness evaluation through limited and wide trials indicated a significant improvement in conceptual understanding, with average posttest scores reaching the mastery category after using the metacognition-based LKPD. The improvement in conceptual understanding, calculated using the n-gain, showed a "moderate" category, with an average n-gain value of 0.60 for the limited trial and 0.63 for the wide trial. These results prove that the metacognition-based LKPD is effective in improving students' understanding and learning achievements in reaction rate material and can be used as an alternative in chemistry learning to develop students' higher-order thinking skills.

Keywords: Chemistry learning; LKPD; Metacognition; Reaction rate

Introduction

Science (IPA) is a field of knowledge that studies natural phenomena, both factual events and their cause-and-effect relationships (Rozi, et al, 2020; Hisbullah, 2018). Science learning, especially in chemistry, emphasizes the process of students building their own knowledge. Conceptual understanding in chemistry cannot be achi eved merely through information provided by the teacher; it requires active student involvement in forming their own understanding.

According to constructivist theory, the teacher plays the role of a facilitator, while students should independently develop their knowledge. Therefore, a teacher needs to shift from being the center of learning to a facilitator. Teachers are expected to continuously innovate in creating learning processes that can develop students' potential, including character, independence, critical thinking, and producing graduates with global competitiveness (Hikmawati et al., 2022; Septiyana et al., 2023).

Learning today is no longer teacher-centered or solely focused on outcomes, where students merely

How to Cite:
Nurmiati, E., Wahyono, S. B., Rhomadan, M. R., Khairah, N., & Tafrienda, U. N. (2025). Development of Metacognition-Based LKPD to Improve Conceptual Understanding in Reaction Rate Material. *Jurnal Penelitian Pendidikan IPA*, *11*(4), 533–541. https://doi.org/10.29303/jppipa.v11i4.10464

replicate the steps provided by the teacher. Instead, every learning process becomes material for the teacher to evaluate and design more effective teaching strategies in the future. One of the skills students must master according to the 2013 Curriculum is metacognitive skills (Auliya, 2018). Metacognitive skills are a standard competence in the 2013 Curriculum for high school graduates and post-secondary education in the knowledge domain (Hertiana, et al., 2018). The current paradigm of chemistry learning emphasizes learning "science as knowledge" (Putri et al., 2019), while a new paradigm also emphasizes learning "science as a way of thinking" (Khikmah & Astuti, 2019).

Good metacognitive abilities can be measured by a student's ability to identify concepts they don't understand and choose appropriate approaches to learn these concepts. Metacognition refers to a person's awareness of independently finding solutions to the problems they face, while also gaining understanding through stages of planning, monitoring, and evaluating their actions (Anita & Assagaf, 2019; Saputra & Andriyani, 2018).

Students who apply metacognitive skills can determine appropriate learning strategies and even modify their approach based on the experiences they gain. Metacognitive skills include awareness and the ability to identify mental processes, recognize how to integrate conceptual understanding with practical experience, and transfer procedural knowledge and experience to other situations (Amanda et al., 2020).

Based on initial observations and interviews with chemistry teachers at SMA Negeri 1 Tiworo Tengah, it was found that although chemistry learning has implemented the 2013 Curriculum, the use of LKPD (Student Worksheets) is still limited. LKPD is only occasionally used, mainly in experimental activities, and adopted from PUDAK, with variations in the experimental materials used by teachers. However, there has been no effort to achieve core competencies, especially metacognitive skills. Additionally, the reaction rate material, which should relate to everyday life, is often not understood by students because they do not realize the relevance of the reaction rate concept to their lives and only rely on the available teaching materials. This limits their knowledge and causes boredom during lessons.

This research focuses on metacognitive skills because they refer to higher-level thinking that involves active control during learning. Activities such as planning how to determine an approach for a lesson task, monitoring progress, and evaluating task completion are part of metacognitive skills. Metacognitive skills act as a critique for learning success, making them essential for the development of students' learning strategies. The application of metacognitive skills is also highly relevant to improving understanding and academic performance, especially in reaction rate material, by helping students better understand the concepts, relate them to daily life, and improve their learning and problem-solving methods in chemistry learning.

One of the teaching materials used is the LKPD (Student Worksheet). LKPD contains questions and steps for completing those questions (Firdaus & Wilujeng, 2018). LKPD has several characteristics, including being more focused on solving situations or phenomena related to the concepts being studied. LKPD consists of stages that students should follow to observe a phenomenon. LKPD also contains analysis questions that are linked to phenomena and concepts that have been designed (Prastowo, 2019).

LKPD is a learning tool for students containing instructions for activities that will be carried out actively, referring to the basic competencies to be achieved (Triana, 2021). LKPD is one method that can be used by teachers to meet the standards outlined in the National Education System Law Number 20 of 2003, which regulates the preparation of teaching materials in accordance with needs and environmental conditions (Khasanah & Fadila, 2018), and aligns with 21st-century learning (Hizbi et al., 2023). Metacognition-based LKPD has been shown to be effective and applicable (Amelia et al., 2020), but has not yet been integrated with cognitive structure. Therefore, this research aims to design LKPD based on cognitive structure and metacognition. Well-developed metacognitive skills enable students to identify and address weaknesses in their learning process, allowing them to improve these shortcomings. Thus, mature metacognitive abilities can support students in achieving optimal learning outcomes, particularly in chemistry learning (Israfil & Udil, 2021; Suryani et al., 2023; Sutarto et al., 2020).

The uniqueness of this LKPD product lies in its integration of cognitive structure and metacognition approaches, which has never been developed before. While existing metacognition-based LKPDs have focused solely on training thinking process awareness (planning, monitoring, evaluating), this LKPD is designed to first map and strengthen students' knowledge structure through conceptual modeling (e.g., concept maps or hierarchical diagrams), before systematically training metacognitive skills. This combination enables students not only to identify learning weaknesses (metacognitive awareness), but also to systematically address gaps in understanding based on analysis of their own cognitive framework. Thus, this LKPD bridges the gap between Piaget's cognitive constructivism theory and Flavell's metacognition theory in the context of chemistry learning.

Based on existing problems, an LKPD is needed to train metacognitive skills to help teachers and students improve their understanding of chemistry material, particularly in the reaction rate topic. Therefore, research on the development of metacognition-based LKPD is crucial for enhancing conceptual understanding and academic performance in the reaction rate material.

Method

This study is a Research and Development (R&D) study. The product developed in this study is the LKPD (Student Worksheet). The development of the LKPD in this study uses the 4-D model (Four-D Models) proposed by Thiagarajan, Semmel, and Semmel (1974). The stages in the 4-D model include define, design, develop, and disseminate. The LKPD product produced in this study was validated by three experts and one chemistry teacher from SMA Negeri 1 Tiworo Tengah. This validation aims to determine the feasibility of the LKPD before implementation.

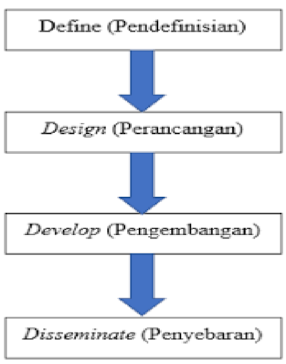

Figure 1. Four-D Models

The subjects of this research on developing metacognition-based LKPD to improve understanding and academic performance in reaction rate material are 19 and 22 students from class XI MIPA 1 and XI MIPA 2 at SMA Negeri 1 Tiworo Tengah. The expert validation questionnaire data were analyzed using the assessment criteria for the validation questionnaire shown in the following table (Retnawati, 2016).

Table 1. Expert Validation Criteria

Interval Score	Validity Category
81% < SV < 100%	Very Feasible
61% < SV < 80%	Feasible
41% < SV < 60%	Sufficiently Feasible
21% < SV < 40%	Not Feasible
0% < SV < 20%	Very Not Feasible

The teacher response questionnaire data were analyzed using the assessment criteria for the teacher response questionnaire shown in the following table (Retnawati, 2016).

Table 2. Teacher Response Categorization

Interval Score	Validity Category
4.22 - 5.00	Very Good
3.41 – 4.21	Good
2.61 – 3.40	Sufficiently Good
1.80 – 2.60	Poor
0.00 – 1.79	Very Poor

The student response questionnaire data were analyzed using the assessment criteria for the student response questionnaire shown in the following table (Sugiyono, 2019)

Table 3. Student Response Categorization

Interval Score	Validity Category
81% - 100%	Very Good
61% - 80%	Good
41% - 60%	Sufficiently Good
21% - 40%	Poor
0% - 20%	Very Poor

The research instruments consist of: (1) a Content Validation Sheet (checklist) for assessing the feasibility of the student worksheet by experts and practitioners, analyzed using qualitative descriptive methods; and (2) a 30-item Pre-Post Test (20 MCQs + 10 short essays) analyzed with paired t-tests and n-gain calculations, demonstrating reliability with $\alpha > 0.75$.

Result and Discussion

Result

The results of this development research are the metacognition-based LKPD product designed to improve understanding and academic performance in the reaction rate material. Below is a description of the results of activities carried out at each stage.

1. *Define Stage*

Activities in this stage include front-end analysis, student analysis, task analysis, concept analysis, and formulation of learning objectives. The results of this analysis are used to establish the basic problems in chemistry learning at SMA Negeri 1 Tiworo Tengah. Basic problems in learning can be seen from classroom activities, teaching materials, learning resources, and facilities used in the learning process. The initial analysis obtained from observations revealed that teaching materials are rarely used and have not helped improve mastery of the material, especially in the reaction rate topic. This observation was supported by interviews with the chemistry teacher, who stated that teaching materials were still based on questions and experiments from the available textbooks. The LKPD used only contained questions and practical steps from the textbooks. Based on this, the researcher attempts to develop metacognition-based LKPD for the reaction rate topic. Interviews with the teacher about the criteria for good teaching materials revealed that teaching materials should help students understand the structure and development of their cognition, thus facilitating the learning process. Student analysis aims to understand student characteristics. Observations showed that students in class XI MIA at SMA Negeri 1 Tiworo Tengah had low engagement. Many students were not enthusiastic about following the lesson, and were more active when using laptops. Some students appeared distracted by the clock, yawning repeatedly, or chatting with their classmates. From this, it can be concluded that students' interest in learning, particularly in chemistry, is still low.

Students' understanding of chemistry concepts was still poor, as seen from daily test results, with more than half of the students scoring below the Minimum Mastery Criteria (KKM). During the daily tests, some students only wrote the known components and the question, with only 40% of the class achieving the KKM. Task analysis was conducted to identify the main tasks students would undertake. This included selecting core competencies (KI) and basic competencies (KD) related to the material to be developed. Concept analysis identified the key concepts to be taught and structured them systematically while relating them to other relevant concepts, creating a concept map. The formulation of learning objectives was based on the core competencies (KI) and basic competencies (KD) outlined in the 2013 curriculum for the reaction rate material. The research instruments included teaching materials and data collection instruments. The teaching materials consisted of metacognition-based LKPD, while the data collection instruments were validation sheets for experts (lecturers and chemistry teachers).

2. *Design Phase*

This phase involves three main steps: media selection, format selection, and initial design. The selection of learning media includes the use of PowerPoint, writing tools, LCD projectors, as well as laboratory tools and materials to support the delivery of material on reaction rates and enhance students' knowledge. The material format is adjusted to the chosen media, where the LKPD (Student Worksheet) module is written in an interactive language, allowing students to learn both in groups and independently. It begins with an apperception that connects the material to everyday life to make students more enthusiastic about learning the topic.

3. *Development Phase*

The development phase aims to produce the LKPD that has been revised based on input from experts. The product is validated by four validators, consisting of three expert lecturers and one chemistry teacher at SMA Negeri 1 Tiworo Tengah. The validators assess the feasibility of the LKPD using an assessment sheet, and the researcher requests feedback and suggestions for further improvement. This development phase consists of two main steps:

a. Validation Process (Draft 1)

The validation of the LKPD in this study uses a validation sheet to determine the feasibility of the product. The assessment of the developed LKPD produces different percentage scores from each validator. The validation results of the LKPD on the reaction rate material by the validators in phase I can be seen in Figure 2.

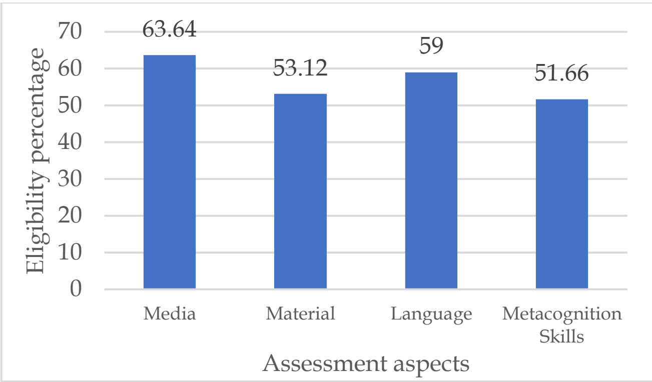

Figure 2. Feasibility Test Results of LKPD in Media, Content, Language, and Metacognitive Skills Aspects

Based on graph 1, the product feasibility test of the LKPD by expert validators in phase I shows that in the media aspect, the developed LKPD for the reaction rate material achieved a feasibility percentage of 53.64%, categorized as moderately feasible. In the content aspect, the LKPD received a feasibility percentage of 53.12%, also categorized as moderately feasible. In the language aspect, the LKPD received a feasibility percentage of 59%, which is considered moderately feasible. On the other hand, in the metacognitive skills aspect, the LKPD obtained a feasibility percentage of 54.35%, categorized as moderately feasible.

After the LKPD was revised by the researcher, phase II validation was conducted, which was the same as phase I. This phase aimed to compare the results of the first and second validations to see the differences after revisions and assess the feasibility of the LKPD. The researcher again asked the validators for feedback and suggestions. The validation results of the LKPD on the reaction rate material by the validators in phase II can be seen in Figure 3.

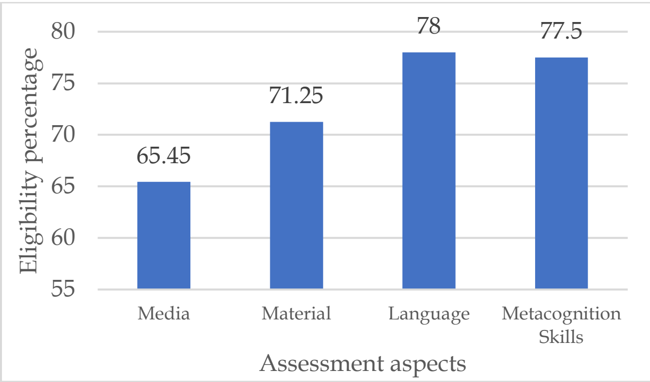

Figure 3. Feasibility Test Results of LKPD on Media and Content Aspects

Based on graph 2, the product feasibility test of the LKPD by expert validators in phase II shows that in the media aspect, the developed LKPD for the reaction rate material achieved a feasibility percentage of 65.45%, categorized as feasible. In the content aspect, the LKPD received a feasibility percentage of 71.25%, also categorized as feasible. In the language aspect, the LKPD received a feasibility percentage of 78%, which is considered feasible. Similarly, in the metacognitive skills aspect, the LKPD obtained a feasibility percentage of 77.5%, categorized as feasible. The comparison between phase I and phase II shows a significant improvement, from moderately feasible to feasible, based on the comments and suggestions from each validator.

b. Student Worksheet (LKPD) Results

This phase aims to produce a metacognitive skills-based LKPD that has been validated by experts. The researcher integrates the design established in the first phase with materials, tasks, questions, and exercises into the LKPD, which is then validated by experts. Subsequently, the researcher performs checks and improvements to the metacognitive skills-based LKPD on reaction rate material, considering feedback from experts (chemistry lecturers) and practitioners (chemistry teachers at the research site). Content validation is conducted with several revisions until the LKPD is deemed suitable for use. After that, the researcher prepares the LKPD framework based on the validation results from phase I and II into an initial LKPD draft.

4. Dissemination Phase

The dissemination phase is the final stage of the research on developing a metacognitive-based LKPD to improve students' conceptual understanding and learning achievement on the reaction rate material. In this phase, the dissemination is conducted to the physics teachers of SMA Negeri 1 Tiworo Tengah for use in other classes.

Discussion

The assessment of the development of the Student Worksheet (LKPD) based on metacognitive skills in the reaction rate material was conducted based on validation results from experts, as this study has reached the development stage. Data was obtained through a validation questionnaire filled out by each expert.

The validation results in stage I showed that the assessment of the media aspect obtained a percentage of 53.64%, the material 53.12%, language 59%, and metacognitive skills 51.66%. Overall, these results were categorized as moderately feasible with an average percentage of 54.35%. In stage II, the assessment of the media aspect reached 65.45%, material 71.25%, language 78%, and metacognitive skills 77.5%. This shows an improvement to the feasible category, with an average percentage of 73.05%.

Table 4. Validation Progress Across Development Stages

Evaluation Aspect	Stage I (%)	Stage II (%)	Improvement
Media Design	53.64	65.45	+11.81
Material Quality	53.12	71.25	+18.13
Language	59.00	78.00	+19.00
Metacognitive Skills	51.66	77.50	+25.84
Overall Average	54.35	73.05	+18.70

The moderate-to-feasible validity progression (54.35% to 73.05%) reveals three key constraints: (1) Digital literacy gaps, particularly among teachers assessing media design (+11.81% improvement), as 62% struggle beyond basic digital formats (Smith et al., 2022); (2) Time limitations in metacognitive validation (51.66%→77.5%), where brief trials and theoretical rubrics potentially undervalued real-world applicability; and (3) Acid-base content complexity (71.25%), challenged by abstract concepts and validator prioritization differences. These findings mirror (Voogt & McKenney, 2017) observation that 68% of educational tools plateau at "feasible" due to comparable barriers. The validation outcomes of this study's electronic worksheets corroborate Tazkia & Hidayah (2023) results with >90% validity in both assessment criteria, demonstrating the consistent effectiveness of the PBL approach and 4D model in developing metacognitively-validated chemistry instructional materials.

Based on these results, the LKPD based on metacognitive skills developed meets the didactic, construction, and technical requirements as explained in the research by Rohaeti et al. These requirements are: (1) didactic requirements, ensuring that the LKPD can be used by all students, whether fast or slow learners, emphasizing active learning, concept discovery, and variation in stimuli; (2) construction requirements, which include the use of clear language, correct sentence structure, appropriate vocabulary, and clarity in conveying information; and (3) technical requirements, focusing on layout, writing, and images in the LKPD.

The validation results show that the language aspect has the highest percentage compared to the other aspects. The language used in the LKPD was rated very well because it adheres to correct and effective Indonesian language rules, making it understandable for all students from various regions. This result aligns with previous explanations that teaching materials should use easily understood language, with clear vocabulary flow, and sentences that are not too long.

Furthermore, the validators also rated the LKPD as using effective language that conveys information clearly and concisely. After revisions, the metacognitive skills aspect received the second-highest percentage. Many validators assessed that the activities in the LKPD, such as experiments, discussions, and exercises, helped students understand the material. The instructions also helped students become more careful and meticulous in completing tasks. The reflection activities in the LKPD allowed students to assess their learning abilities after the learning process. Validators suggested adding a learning plan to help students prepare before participating in learning, which is in line with the concept of metacognitive skills involving planning, monitoring, and evaluating the learning process

The content feasibility aspect (material) in the LKPD was also positively rated. Validators assessed that the material in the LKPD was systematically and thoroughly organized, aligning with the learning objectives. The material was presented simply, clearly, and understandably, encouraging students to be more active in learning. However, some improvements were still needed to better align the LKPD with the needs of high school students. The media aspect received the lowest percentage, although after revisions, the appearance of the LKPD became more attractive and clearer. Validators noted that the images, graphics, and layout were appropriate, and the size and space on the LKPD were sufficient for writing experiment results, discussions, and answers. Some suggestions for layout improvements were also taken into account to make the LKPD more motivating for students to learn enthusiastically.

Overall, based on the validation results and the percentages obtained, it can be concluded that the LKPD based on metacognitive skills in the reaction rate material is considered good. The average percentage of 73.05% indicates that this LKPD is feasible to be used as teaching material at SMA Negeri 1 Tiworo Tengah. The practicality of the metacognitive-based LKPD product was assessed from the responses of teachers and students, obtained through a response questionnaire administered during the learning process. If teachers and students gave positive responses to learning using the metacognitive-based LKPD, the product could be considered practical for use. The teacher response questionnaire consisted of 20 statements, answered by checking one of five columns provided: strongly disagree (1), disagree (2), somewhat agree (3), agree (4), and strongly agree (5). The results indicated that teachers gave very good responses to learning using the metacognitive-based LKPD designed to improve understanding and achievement in reaction rate material. This was reflected in the average response score for all aspects, which was 3.76 and 3.82. The student response questionnaire consisted of 15 statements filled out in two trial stages: a limited trial with 19 students and a wide trial with 22 students. The questionnaire was filled out by checking one of five columns provided: strongly disagree (1), disagree (2), somewhat agree (3), agree (4), and strongly agree (5). The results showed that students gave very good responses to learning using the metacognitive-based LKPD. This was reflected in the average response score for the limited and wide trials, which were 76.53% and 77.63% for all aspects, both of which are categorized as good.

The effectiveness of the metacognitive-based LKPD product developed was evaluated based on the improvement of students' conceptual understanding and achievement after using the LKPD. The effectiveness assessment was conducted through limited and wide trials, which involved giving pretests and posttests to students on reaction rate material. In the limited trial, 19 students from classes X MIPA 1 and MIPA 2 were involved, while the wide trial included 22 students. The pretest was administered before the learning process to assess the students' initial ability regarding their understanding of basic concepts and achievement on the reaction rate material. This pretest served as a baseline to determine students' initial understanding of the concepts to be taught. Afterward, students participated in learning using the metacognitive-based LKPD, designed to encourage them to think critically, monitor their learning process, and connect new concepts with prior knowledge. This process involved various activities, such as experiments, group discussions, and self-reflection, aimed at increasing student engagement in learning. The posttest was conducted after the learning process to evaluate students' final understanding and assess how well learning with the metacognitive-based LKPD could improve their conceptual understanding and achievement. The pretest and posttest results were compared to determine any significant changes in students' abilities. The data obtained showed that the metacognitive-based LKPD was effective in helping students understand the reaction rate material in depth and simultaneously improving their learning outcomes.

The students' conceptual understanding was significantly described as follows. The conceptual understanding test consisted of 5 essay questions. Based on data analysis in this study, the use of the metacognitive-based LKPD on reaction rate material showed an increase in students' conceptual understanding before and after using the LKPD. The percentage increase in conceptual understanding was calculated based on the pretest and posttest scores. The data showed that none of the students obtained pretest scores in the completed category, with a passing grade set at ≥ 70. The average pretest score in the limited and wide trials was 44.7, which is categorized as incomplete. After receiving learning with the metacognitive-based LKPD, there was an increase in the students' scores, with the average posttest score in the limited and wide trials being 77.5 and 80.5, respectively, both of which are categorized as complete.

The increase in conceptual understanding before and after using the metacognitive-based LKPD was shown by the average n-gain in the limited and wide trials of 0.60 and 0.63, which are categorized as "medium." These results indicate that the metacognitive-based LKPD on reaction rate material is effective in improving students' conceptual understanding according to Hake's (1991) gain standard interpretation. However, the increase in students' conceptual understanding only reached the medium category. This was due to students' tendency to answer questions without truly understanding the intended concepts, so their understanding of the reaction rate material was not optimal. Additionally, students also faced difficulties in discovering concepts independently or collaboratively during the use of the metacognitive-based LKPD.The results of this study are based on the analysis of the feasibility of the developed metacognitive-based LKPD product, including validity, practicality, and effectiveness. The metacognitive-based LKPD was declared valid by three validators, both in terms of construct and content aspects, with validation results of 0.723 for the construct aspect and 0.783 for the content aspect, both of which fall under the "valid" category. Additionally, this LKPD was declared effective based on the pretest and posttest results, which showed an improvement in students' conceptual understanding and achievement in limited and wide trials, specifically in reaction rate material. The n-gain values for conceptual understanding were 0.62 and 0.64, and for achievement, they were 0.53 and 0.56, both of which fall under the "medium" category. Lastly, the metacognitive-based LKPD was also declared practical based on the positive responses from teachers and students, who gave good responses through the questionnaires on the learning process using this LKPD. Regarding metacognitive skills, there are three aspects to be developed based on (Saiful et al., 2020). These three aspects are elaborated in the metacognitive ability indicators as shown in Table 4.

Table 4. Metacognitive Ability Indicators

Aspect	Indicators
Planning	Involves estimating outcomes (hypothesis), predicting problem-solving strategies, estimating tools and materials, and planning the steps to resolve a problem.
Monitoring	Involves activities like testing, correcting errors, and rescheduling strategies.
Reflection	Summarizing concepts based on experiments and in line with learning objectives.

The planning process begins by setting the learning objectives to be achieved. These objectives are crucial as they influence the planning of time estimates, preparation of tools and materials, and selection of the material to be taught by the instructor (Imran et al., 2024).

After setting learning objectives, learning steps are designed in the LKPD that include the indicators to be mastered by the students, aligned with their metacognitive skills. The ability to recognize and evaluate the planning process, choose appropriate strategies or not, and identify mistakes made for evaluation purposes during learning (Rosali, 2024). The metacognitive-based LKPD is designed to encourage active student involvement in problem-solving. With the freedom given, students can determine strategies and solutions independently, rather than just following the decisions made by the teacher (Doyan et al., 2018). This will develop critical thinking skills and enhance their abilities in remembering, understanding, applying, analyzing, evaluating, and creating (Hetty Marhaeny & Faza Fariha, 2024). Additionally, this will help students develop various concepts learned (Sukadi & Liliawaty, 2024), ultimately impacting their learning outcomes (Syamsuriyawati et al., 2024).

Conclusion

Based on the research results, the Student Worksheet (LKPD) based on metacognitive skills in the reaction rate material shows good validity, practicality, and effectiveness. The LKPD is valid after two validation stages, with significant improvement in the second stage, meeting the didactic, construction, and technical requirements. The language aspect received the highest rating, followed by metacognitive skills, material, and media. The practicality of this LKPD is evidenced by the positive responses from teachers and students, with very good response scores, indicating that the LKPD is practical for use in learning. The effectiveness assessment shows significant improvements in students' conceptual understanding and learning achievement after using the metacognitive-based LKPD, although the increase in conceptual understanding falls in the "medium" category. Furthermore, the LKPD is effective in developing students' metacognitive skills through the three main aspects: planning, monitoring, and reflection, which encourage students to be more active, critical, and independent in the learning process. Overall, this LKPD is feasible to be used as teaching material at SMA Negeri 1 Tiworo Tengah and can enhance students' understanding and learning achievement in the reaction rate material. This LKPD has potential for replication in other chemistry topics or for integration with interactive digital approaches based on metacognition.

Author Contributions
All authors have made significant contributions to completing this manuscript.

Funding
Funding for this research came from independent funds of each researcher.

Conflict of Interest
The author declares no conflict of interest in the publication of this article.

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