

Enhancing Science Literacy and Active Participation through Guided Inquiry E-Worksheets in Reaction Rate Learning

Herdini¹, Martha Larasaty Hutagalung¹, Sri Haryati^{1*} and Putri Adita Wulandari²

¹*Department of Chemistry Education, Faculty of Teacher Training and Education, Riau University, Pekanbaru, Riau, 28293, Indonesia*

**E-mail: sri.haryati@lecturer.unri.ac.id*

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Abstract

This classroom action research addresses the persistent challenge of low student engagement and limited scientific literacy in learning reaction rate concepts. The study investigates the use of guided inquiry-based electronic worksheets (E-worksheets) as an instructional strategy to promote active learning and support the development of scientific literacy skills. Conducted in two action cycles involving 45 eleventh-grade students at SMAN 12 Pekanbaru during the 2023/2024 academic year, the research employed observation sheets and end-of-cycle assessments to evaluate changes in students' participation and literacy performance. The findings indicate that integrating guided inquiry with digital worksheets fostered more interactive learning experiences and strengthened students' ability to interpret, analyze, and apply scientific concepts in problem-solving contexts. This study contributes theoretically by highlighting the potential of guided inquiry-based digital learning media to support scientific literacy development within constructivist learning environments, particularly in chemistry education.

Keywords: e-worksheet, guided inquiry, learning activity, science literacy skills

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1. Introduction

Meaningful chemistry learning often requires students to have good learning activities and scientific literacy skills. According to Andika & Yudiana (2022) learning activities in the learning process affect scientific literacy skills because active student involvement can train students to construct scientific understanding and solve problems contextually. This view is consistent with global perspectives on science education which emphasize that science learning should actively engage students in inquiry, reasoning, and evidence-based thinking. In addition, the Organisation for Economic Co-operation and Development explains that scientific literacy involves the

ability to explain scientific phenomena, evaluate evidence, and make decisions related to real-world issues.

Inquiry-based learning has been widely recognized as an effective approach for improving conceptual understanding and scientific reasoning in chemistry education. According to Hartono & Sari (2023), inquiry learning encourages students to formulate questions, investigate problems, analyze data, and construct conclusions through systematic inquiry phases. Previous empirical studies also show that inquiry-oriented chemistry learning can improve students' engagement and scientific reasoning skills.

However, learning activities and scientific literacy skills are often still problematic,

including in class XI-4 of SMAN 12 Pekanbaru. Preliminary observations conducted in the even semester of the 2023/2024 academic year showed that students demonstrated limited participation during chemistry learning activities. Only a few students actively asked questions, responded to teacher prompts, participated in discussions, or engaged in problem-solving activities. Most students tended to rely on their peers during group discussions and were less involved in scientific communication processes. In addition, some students appeared distracted during lessons, indicating that classroom learning had not yet fully facilitated active engagement and inquiry-oriented interaction.

According to interviews conducted with chemistry teachers, students' scientific literacy skills were also still relatively low. Students experienced difficulties in formulating scientific questions, proposing hypotheses, solving scientific problems, and drawing evidence-based conclusions. These findings indicate that students still struggle to apply scientific concepts in contextual situations and have not yet developed adequate scientific reasoning skills.

The low learning activities and scientific literacy skills are partly caused by learning practices that still emphasize knowledge transfer rather than inquiry processes. Classroom learning activities were dominated by textbook-oriented exercises and lower-order cognitive questions, while effective scaffolding and collaborative inquiry activities had not been optimally implemented. As a result, students had limited opportunities to actively construct knowledge. This condition contrasts with constructivist learning principles, which emphasize active knowledge construction through interaction and inquiry (Batdi, 2023; Liljestrand, 2024).

Increasing learning activities and scientific literacy skills can be supported through

teaching tools that actively involve students in inquiry activities. Cholifah & Novita (2022) explained that guided inquiry-oriented learning can focus students on finding and solving scientific problems through scientific methods. This is reinforced by Hidayah, et al. (2021) which reveals that guided inquiry-based learning is able to train scientific literacy skills because it can connect learning concepts to real implementation. Putri, et al. (2018) also said that guided inquiry-based teaching tools are able to increase learning activities because they require students to be able to learn by utilizing various learning resources or not only from the teacher. International studies also indicate that inquiry-supported digital learning environments can promote collaboration, engagement, and deeper conceptual understanding in science learning.

One teaching tool that can support inquiry-based learning is the E-worksheet. Guided inquiry-based E-worksheets contain structured inquiry syntax that is aligned with learning activities and scientific literacy development because they engage students in systematic, critical, logical, and analytical investigation processes. From a cognitive perspective, E-worksheets provide scaffolding that helps students organize information, analyze evidence, and construct scientific explanations more independently. Pedagogically, digital worksheets create more interactive and flexible learning environments through multimedia integration, collaborative activities, and guided problem-solving processes (Sari, et al. 2019).

Maullidyawati & Hidayah (2022) also revealed that the guided inquiry model has a linear syntax with scientific literacy indicators. In the problem formulation phase, students are trained to identify and formulate scientific questions. In the hypothesis formulation phase, students are encouraged to propose tentative explanations based on scientific reasoning. During data collection and hypothesis testing, students analyze evidence and solve scientific problems, while in the conclusion phase

students interpret findings and construct evidence-based conclusions. These inquiry stages are consistent with international inquiry frameworks proposed by Pedaste et al. (2015).

Although previous studies have reported the effectiveness of guided inquiry learning, studies specifically investigating guided inquiry-based E-worksheets in improving both learning activities and scientific literacy skills in chemistry classroom action research remain limited. Most previous studies focused primarily on learning outcomes rather than examining how digital inquiry scaffolding facilitates active participation and scientific literacy development during classroom learning.

Therefore, this study investigates the implementation of guided inquiry-based E-worksheets as an effort to improve students' learning activities and scientific literacy skills on reaction rate material. This study contributes to chemistry education research by examining how digitally supported inquiry learning can facilitate active engagement and scientific literacy development within authentic classroom practice.

2. Research Method

This classroom action research was conducted from September 2024 to January 2025. The data collection process took place in two cycles, where cycle 1 was conducted on November 4-5, 2024 and the final test of cycle 1 was conducted on November 6, 2024. Cycle II was conducted on November 11-12, 2024 and the final test of cycle II was conducted on November 13, 2024.

The subjects of this research were 45 students of class XI-4 in the academic year 2024/2025 at SMAN 12 Pekanbaru who showed low learning activities and scientific literacy skills during preliminary observation. The selection of this

class was based on the principles of classroom action research, where participants are selected purposively according to the learning problems identified in the classroom context. The sample size of 45 students is considered adequate in classroom action research because the purpose is to improve authentic classroom practices rather than to generalize findings to a wider population.

This study employed classroom action research because the main objective was to improve teaching practices and student learning outcomes in an authentic classroom setting through iterative reflection and action cycles, rather than to compare treatment effects between groups as in quasi-experimental designs.

The observers in this study consisted of chemistry teacher of class XI-4 and a chemistry education student of Riau University. Observers were tasked with collecting data on learning activities during the learning process through student activity observation sheets and data on scientific literacy skills through end-of-cycle test questions. In addition, at the reflection stage the observer also plays a role in discussing to provide input and explain the learning situation that needs to be improved or maintained to the perpetrator of the action (Suharti, 2021).

To ensure data credibility, several strategies were implemented to minimize validity threats, such as observer bias, teacher expectancy effects, and repeated testing effects. First, two observers independently assessed student learning activities during each meeting. Second, observer scoring results were compared and discussed after each lesson to reach scoring agreement. The inter-rater reliability coefficient between observers was calculated using percentage agreement and reached 0.87, indicating high agreement.

The classroom action research procedure carried out in accordance with the Kurt Lewin model consisting of planning, action implementation, observation, and reflection

stages. In addition, the cyclical improvement process in this study also refers to the reflective action research model of Kemmis et al. (2014), which emphasizes continuous improvement through collaborative reflection. The stages of implementing this research are shown in Figure 1.

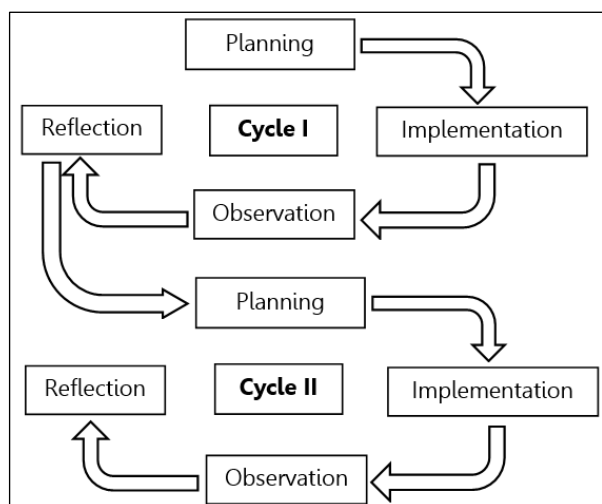


Figure 1. Classroom Action Research Chart

The action implementation and observation stages are carried out simultaneously during the learning process. Meanwhile, revision of the previous cycle implementation and re-planning of the next cycle were carried out during the reflection stage (Pahleviannur et al., 2022).

The data collection instruments included a learner activity observation sheet used for each action and a scientific literacy test question used at the end of the cycle. The observation sheet contains an assessment of each indicator of learning activity at each stage of learning. Learning activity indicators consist of delivering responses or opinions, discussing in study groups, asking questions, watching learning videos, and working on questions on the E-worksheet. The assessment on the observation sheet uses a score scale of 1-4, where a score of 4 indicates learning activities are carried out appropriately and produce excellent answers or results; score 3 indicates activities are carried out quite well but there are still a few shortcomings; score 2 indicates activities are carried out less optimally with many shortcomings; and score 1 indicates

activities are not carried out or carried out but do not produce appropriate answers or results.

Science literacy in this study was operationally defined based on the framework of the Organisation for Economic Co-operation and Development (OECD), which defines scientific literacy as the ability to explain scientific phenomena, evaluate scientific evidence, and interpret data to make decisions in real-world contexts. The scientific literacy instrument consisted of 16 essay questions that were developed based on scientific literacy indicators and reaction rate learning objectives. The instrument was validated through expert judgment involving two experts in chemistry education with doctoral qualifications and more than five years of experience in chemistry curriculum and assessment development. The validation process used a content validation rubric consisting of four aspects: content relevance, conceptual accuracy, language clarity, and alignment with scientific literacy indicators. Each aspect was assessed using a 4-point scale.

The validation results showed that the average content validity score was 3.72 out of 4, categorized as very valid. Based on validator suggestions, several revisions were made before implementation, including simplifying contextual problem statements, improving the clarity of scientific data representations, and revising operational verbs in several questions to better align with inquiry skills. In addition to expert validation, the instrument reliability was tested on students outside the research sample. The reliability analysis showed that the instrument had acceptable consistency for classroom assessment purposes.

Each item was prepared based on the indicators of scientific literacy skills and learning objectives on reaction rate material, including the basic concepts of reaction rates, collision theory, factors affecting reaction rates, and reaction rate law. The indicators and distribution of scientific literacy test questions are shown in Table 1.

Table 1. Indicator and Division of Science Literacy Test Questions

Cycle	Science Literacy Indicator	Question Number	Sub Matter
I	Formulating scientific questions	1, 5	
	Proposing a clear hypothesis	2, 6	- Basic concepts of reaction rate
	Solving scientific problems	3, 7	- Collision theory
	Drawing the right conclusion	4, 8	
II	Formulating scientific questions	1, 5	
	Proposing a clear hypothesis	2, 6	- Factors affecting reaction rate
	Solving scientific problems	3, 7	- Law of reaction rate
	Drawing the right conclusion	4, 8	

Data collection techniques in this study included observation techniques of students' activities and end-of-cycle tests to measure scientific literacy skills. Meanwhile, the data analysis technique for students' learning activities was carried out by calculating the percentage of activity from the total acquisition score divided by the maximum score (Ngalim, 2012).

The results of the scientific literacy test were analyzed by giving a score of 1-4 on each student's answer based on the scoring rubric. The scores were then converted into scientific literacy scores with a scale of 0-100 and analyzed into 3 types of data, including, individual scientific literacy results, classical

scientific literacy results, and classical results for each scientific literacy indicator (Rahmadani et al., 2018).

The implementation of the action was carried out using the methods of discussion, question and answer, lecture, and experimentation combined with the guided inquiry learning model. The teaching media used by students is E-Worksheet which has been adapted to the guided inquiry syntax and accessed through the Liveworksheet platform. This study is considered successful if the learning activities and scientific literacy skills of students have reached the success criteria for the specified action, which is at least 75%. If the action success criteria have not been achieved, the action will continue to the next cycle (Mashuri et al., 2019).

3. Result and Discussion

The implementation of this Classroom Action Research (CAR) took place over two cycles and each cycle was carried out in two meetings. Before the implementation of the action, observations of problems, causes of problems, determination of the class under study, and making research instruments were carried out. This is in accordance with Pahleviannur et al. (2022) which revealed that the planning stage is a stage to identify problems, formulate problems, analyze the causes of problems, and develop interventions (action/solution). This procedure is also consistent with the classroom action research framework developed by Susilowati (2018), which emphasizes iterative cycles of planning, action, observation, and reflection to improve classroom practices.

3.1. Learner's Learning Activity

Students' learning activities were observed during the learning process when implementing actions by applying E-worksheet based on guided inquiry in class XI-4. The data on student learning activities obtained in cycle I shown in Table 2.

Table 2. Data on Students' Learning Activities in Cycle I

Learning Activity (Cycle I)	Average Learning Activity (%)
Delivering responses or opinions	51.10
Discussing in a study group	62.49
Asking questions	55.83
Watching the learning video	75.55
Working on questions in the E-worksheet	56.94
Total	60.38

Based on Table 2, the learning activities of students in Cycle I reached 60.38%, which was included in the fair category but had not yet reached the action success criteria. Reflection results with observers indicated that students were still in the adaptation phase toward inquiry-based learning. Most students were not yet confident in delivering opinions, asking questions, or actively participating in collaborative discussions. Similar findings were reported by Sari et al. (2019), who stated that students in the first cycle of inquiry learning often show hesitation and limited classroom participation.

To minimize observer bias, learning activities were assessed independently by two observers. The inter-rater reliability analysis showed a percentage agreement of 87%, indicating high scoring consistency between observers.

Based on reflection results, several improvements were made in Cycle II, including providing participation points as reinforcement, implementing structured questioning strategies, giving more equitable opportunities for student participation, and increasing teacher scaffolding during group discussions. This is in line with Maesaroh et al. (2023) who stated that teachers need effective

questioning strategies to stimulate students' curiosity and active participation. The results of cycle II shown in Table 3.

Table 3. Data on Students' Learning Activities in Cycle II

Learning Activity (Cycle II)	Average Learning Activity (%)
Delivering responses or opinions	78.05
Discussing in a study group	83.88
Asking questions	79.16
Watching the learning video	90.00
Working on questions in the E-worksheet	81.66
Total	82.55

Based on Table 3, students' average learning activity increased to 82.55%, which is included in the good category and has fulfilled the action success criteria. Statistical analysis using a paired sample t-test showed that the increase from Cycle I to Cycle II was statistically significant ($p < 0.05$). In addition, effect size analysis showed a large effect (Cohen's $d = 1.12$), indicating that the implementation of guided inquiry-based E-worksheet had a strong educational impact on student engagement. The comparison of learning activities between cycle I and cycle II shown in Table 4.

Table 4. Comparison of Learning Activities Across Cycles

Cycle	Mean (%)	Improvement (%)
Cycle I	60.38	-
Cycle II	82.55	22.17

The increase of 22.17 percentage points indicates that repeated inquiry practice, combined with reflective improvements in teaching strategies, significantly improved

students' classroom participation. From a constructivist perspective, this suggests that students gradually became more confident in social interaction, collaborative knowledge construction, and scientific communication (Gillies, 2020).

The improvement in students' learning activities from Cycle I to Cycle II indicates that guided inquiry-based E-worksheet successfully facilitated active engagement in chemistry learning. Recent studies have shown that inquiry-oriented digital learning environments significantly improve student participation, collaborative discussion, and classroom engagement in science learning. For example, Rusdiyana et al. (2024) reported that technology-supported inquiry learning enhances student engagement by encouraging active questioning, collaborative reasoning, and self-directed learning processes. Similarly, Siantuba et al. (2023) found that digital inquiry environments promote deeper student participation because learners are actively involved in constructing knowledge rather than passively receiving information.

The increase in group discussion and questioning activities also reflects the development of collaborative learning behavior. Recent evidence from Gillies (2020) showed that structured collaborative inquiry can improve students' communication skills, academic confidence, and willingness to participate in science discussions. In chemistry classrooms specifically, Beskara & Wiyarsa (2024) found that inquiry-based collaborative learning significantly improved student engagement and conceptual participation in chemical problem-solving tasks.

Furthermore, the increased use of videos and digital worksheets suggests that multimedia-supported learning positively influenced student motivation and attention. Recent

findings by de Carvalho (2023) indicate that interactive multimedia learning environments support active cognitive processing and improve student engagement in science education

3. 2. Students' Scientific Literacy Skills

At the end of the cycle, a test was conducted to see the scientific literacy skills of students after the action of applying E-worksheet based on guided inquiry. Data on individual completeness of students' scientific literacy skills shows in following table.

Table 5. Data on Individual Completion of Science Literacy Skills in Cycle I

Science Literacy Test Score	Number of Learners	Percentage
94 – 100	0	0
87 - 93	2	4.44
80 - 86	3	6.66
73 - 79	23	51.11
66 - 72	17	37.77
Total	45	100.00

Table 6. Data on Classical Completeness of Science Literacy Ability in Cycle I

Category	Number of Learners	Classical Completion (%)	Average value of scientific literacy skills (%)
Completed	28		
Not completed	17	62.22	73.71

Based on Tables 5 and 6, scientific literacy skills in Cycle I had not yet reached the action success criteria. Reflection results showed that students were still adapting to inquiry syntax and needed more intensive scaffolding during E-worksheet activities.

Table 7. Data on the Completeness of Each Indicator of Scientific Literacy Skills Cycle I

Indicator of Science Literacy	Ability Value (%)
Formulating scientific questions	78.33
Proposing a clear hypothesis	76.66
Solving scientific problems	60.00
Drawing the right conclusion	78.88
Average	73.46

The lowest achievement was found in the indicator of solving scientific problems. This indicates that students still experienced difficulty in applying reaction rate concepts to scientific contexts. Similar findings were reported by Chi et al. (2024), who stated that conceptual understanding strongly affects scientific problem-solving ability.

This finding is also consistent with recent international research in chemistry education. emphasized that many students experience difficulty in solving scientific problems because they tend to memorize chemical concepts without fully understanding how to apply those concepts in evidence-based reasoning and contextual situations. In chemistry learning, scientific problem-solving requires students not only to recall formulas or definitions but also to interpret scientific data, identify relevant variables, and evaluate possible explanations before drawing conclusions. Similarly, Chi et al. (2024) found that students' difficulties in chemistry problem-solving are often related to limited conceptual connections between macroscopic phenomena, symbolic representations, and molecular-level explanations.

Furthermore, recent studies by de Jong et al. (2023) revealed that inquiry-based learning environments supported by scaffolding can gradually improve students' ability to solve scientific problems by guiding them to analyze evidence systematically and justify their

reasoning scientifically. These findings suggest that the relatively low performance of students in Cycle I was likely influenced by their limited prior experience in inquiry-oriented problem-solving activities. After repeated exposure to guided inquiry tasks in Cycle II, students became more capable of connecting reaction rate concepts with scientific evidence, which contributed to the improvement of their problem-solving performance.

Table 8. Data on Individual Completion Science Literacy Skills in Cycle II

Science Literacy Test Score	Number of Learners	Percentage
94 - 100	22	48.88
87 - 93	13	28.88
80 - 86	4	8.88
73 - 79	0	0.00
66 - 72	6	13.33
Total	45	100.00

Table 9. Data on Classical Completeness of Science Literacy Ability in Cycle II

Category	Number of Learners	Classical Completion (%)	Average score of scientific literacy skills
Completed	39	88.84	86.66
Not completed	6		

Based on Tables 8 and 9, students' scientific literacy skills increased significantly in Cycle II compared to Cycle I. The average scientific literacy score increased from 73.71 in Cycle I to 86.66 in Cycle II, while the percentage of classical mastery also increased from 62.22% to 88.84%, indicating that most students had successfully achieved the predetermined learning success criteria. To examine whether this improvement was statistically meaningful,

a paired sample t-test was conducted between Cycle I and Cycle II scores. The analysis showed a statistically significant difference between both cycles ($p < 0.05$), indicating that the implementation of guided inquiry-based E-worksheet had a significant effect on students' scientific literacy performance. Furthermore, effect size analysis showed a large educational effect (Cohen's $d = 0.94$), suggesting that the improvement was not only statistically significant but also pedagogically meaningful in supporting students' scientific competence development.

Table 10. Data on Each Indicator of Scientific Literacy Ability Cycle I

No	Indicator of Science Literacy	Value (%)
1.	Formulating scientific questions	95.55
2.	Propose a clear hypothesis	86.11
3.	Solving scientific problems	81.66
4.	Drawing the right conclusion	91.11
Average		88.60

A more detailed analysis of each scientific literacy indicator showed that all indicators experienced improvement in Cycle II, particularly in the ability to solve scientific problems, which had previously shown the lowest achievement in Cycle I. This suggests that repeated exposure to guided inquiry activities gradually helped students become more capable of identifying relevant scientific information, analyzing experimental evidence, connecting chemical concepts to contextual situations, and making evidence-based conclusions. These findings indicate that students not only improved in procedural aspects of learning but also developed higher-order scientific reasoning skills that are essential in chemistry learning.

The improvement in students' scientific literacy appears to be influenced by three major pedagogical factors. First, students became increasingly familiar with the syntax of guided inquiry after repeated implementation across meetings. In Cycle I, many students were still adapting to the inquiry process, particularly in formulating scientific questions, proposing hypotheses, and interpreting evidence. However, after repeated engagement with inquiry activities in Cycle II, students demonstrated greater independence and confidence in completing each inquiry stage. This indicates that familiarity with inquiry procedures can reduce students' cognitive uncertainty and support more effective knowledge construction.

Second, the quality of collaborative discussions improved substantially in Cycle II. Students were observed to engage more actively in exchanging ideas, comparing answers, and evaluating evidence during group activities. This collaborative interaction enabled students to construct conceptual understanding socially and refine their reasoning through peer explanation and argumentation. Recent studies also support this finding. For example, Gillies (2020) reported that structured collaborative learning significantly improves student participation, scientific communication, and reasoning quality in science classrooms. Similarly, Beskara & Wiyarsi (2024) found that collaborative inquiry activities in chemistry learning enhance students' engagement and conceptual understanding through shared problem-solving experiences.

Third, more intensive teacher scaffolding during scientific investigations also contributed significantly to the improvement in scientific literacy. In Cycle II, the teacher provided more targeted support by approaching each group, identifying misconceptions, and giving guiding questions instead of direct answers. This scaffolding helped students focus on important scientific evidence, evaluate alternative explanations, and construct scientifically acceptable conclusions. Recent meta-analysis by Arifin et al. (2025) confirms that instructional scaffolding in inquiry-based science learning significantly improves

students' reasoning performance, conceptual understanding, and scientific literacy outcomes.

These findings support Muzafar & Ahmad (2025), who revealed that inquiry-based learning develops students' scientific reasoning through hypothesis testing and evidence evaluation. Internationally, these results are also consistent with Pedaste et al. (2015), who emphasized that inquiry learning improves scientific reasoning through structured investigation phases. Furthermore, recent studies by Siantuba et al. (2023) and also show that digitally supported inquiry environments can significantly enhance students' scientific literacy by facilitating active engagement, evidence-based reasoning, and independent knowledge construction.

From a broader perspective, the findings of this study are also aligned with the Organisation for Economic Co-operation and Development scientific literacy framework, which emphasizes that science learning should equip students with the ability to explain scientific phenomena, interpret data, and make evidence-based decisions in authentic contexts (OECD, 2023). Therefore, the improvement observed in Cycle II suggests that guided inquiry-based E-worksheet not only improved students' classroom performance but also supported the development of scientific competencies required in 21st-century chemistry education.

4. Conclusion

Based on the results and discussion, it can be concluded that the corrective action using E-worksheet based on guided inquiry on reaction rate material succeeded in increasing students' learning activities from cycle I to cycle II, increasing from 60.38% to 82.55% which is included in the good category. E-worksheet based on guided inquiry also succeeded in improving the science literacy skills of students. This is evidenced by the increase in the average

value of science literacy skills in cycle I, which was 73.71 with a percentage of classical completeness of 62.22% to 88.84 with a percentage of classical completeness of 86.66% with a very high category in cycle II. In addition, based on the average value of completeness for each indicator of science literacy skills, there was also an improvement from 73.46% in cycle I to 88.60% in cycle II which is included in the very high category. So that these findings show that E-worksheet based on guided inquiry can improve learning activities and science literacy skills of students on reaction rate material.

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