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The Analysis of Science Process Skills Using Virtual Chemistry Experiments (OLabs) on Reaction Rate Materials

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Abstract

Science process skills are a core component of chemistry learning because they train students to observe phenomena, analyze evidence, and communicate scientific explanations. Limited opportunities for school laboratory work make virtual laboratory media a practical alternative for supporting inquiry-based activities. This study analyzed students' science process skills in an experimental group and a control group and examined the effect of Online Labs (OLabs) virtual chemistry experiments on those skills. The research was conducted with Grade XI science students (XI IPA) at State Senior High School 1 Keritang in the 2021/2022 academic year on the topic of factors affecting reaction rate, using a mixed-method explanatory design. Quantitative data were collected through an essay pretest–posttest, while interviews were used to capture students' responses and strengthen interpretation of the quantitative results. The experimental group achieved a higher mean posttest score (74.84) than the control group (64.24). Hypothesis testing using SPSS showed Sig. (2-tailed) = 0.000 (< 0.05), indicating a significant effect of OLabs on students' science process skills. Indicator analysis showed the largest difference between groups on the grouping/classifying indicator (22.29). The findings indicate that OLabs-supported learning resulted in better science process skills than conventional instruction without OLabs.

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INTRODUCTION

Chemistry can be understood as both a product and a process, and this dual character should guide what counts as effective learning. Chemistry as a product refers to an organized body of knowledge containing chemical facts, concepts, and principles. Chemistry as a process highlights the skills and attitudes scientists use to obtain, test, and refine that knowledge (Miterianifa, 2013). Chemistry learning in schools becomes meaningful when students do not merely receive information but also practice scientific ways of working, such as asking questions, collecting evidence, and justifying conclusions. Chemistry instruction should provide direct learning experiences through the use and development of process skills and scientific attitudes, because these experiences help students link ideas to evidence rather than to memorization (Lutfi & Hidayah, 2019).

Science process skills provide a practical bridge between chemistry as knowledge and chemistry as inquiry. Science process skills equip students to carry out physical activities during discovery processes (hands-on activities), activate thinking processes (minds-on activities), and develop scientific attitudes (heart-on activities) (Ratnasari et al., 2017). These dimensions show that process skills involve more than manipulating equipment; they include reasoning, decision making, and readiness to evaluate ideas using evidence. Science process skills also involve intellectual, manual, and social skills that students use during learning. Indicators of science process skills include observing, formulating hypotheses, conducting experiments, planning investigations, controlling variables, interpreting data, making inferences, predicting, applying concepts, and communicating results (Fitriana et al., 2019). Learning experiences that explicitly target these indicators can support students in developing systematic thinking and more accurate explanations of chemical phenomena.

School observations indicate that science process skills are still not developed optimally in many contexts. Observations in several schools show that students' science process skills remain low (Puji Hartini, 2017). Learning that does not actively involve students can encourage passive reception of knowledge, leaving students habituated to lower cognitive domains and less accustomed to developing their thinking potential (Magfirah et al., 2019). Students may succeed on tasks that emphasize recall while still struggling to make predictions, justify claims, or interpret data. Chemistry learning should not override the process of discovering chemical concepts, because limited inquiry experiences can weaken students' ability to construct meaning and to connect theory with evidence (Lutfi & Hidayah, 2019). Strengthening science process skills is therefore an important goal in chemistry classrooms where conceptual understanding is expected to be developed through scientific activity.

Practicum experiences commonly provide the most direct setting for developing science process skills because experiments demand observation, measurement, variable control, and interpretation. Skills for conducting chemical experiments generally begin with practice and learning related to experimental activities in the laboratory (Kurniawati & Fatisa, 2019). Practicum, however, is rarely carried out in many schools due to obstacles such as unavailability of facilities, relatively expensive costs, limited allocation of learning time, difficulty in preparation before practicum, safety concerns, and limited support staff. Conditions that do not allow practicum, including situations during a pandemic, also restrict laboratory learning (Kurniawati & Fatisa, 2019; Lutfi & Hidayah, 2019; Sugiharti & Sugandi, 2020). Reduced practicum opportunities can limit repeated practice in key indicators such as controlling variables, interpreting results, and communicating findings, which may contribute to persistently low science process skills.

Learning media become increasingly important when real laboratory work cannot be implemented consistently. Media can help students understand abstract learning by clarifying content, facilitating learning, and creating engaging materials that motivate students and support the learning process (Siregar & Kurniawati, 2022). Media can also help teachers structure experiences that approximate inquiry, enabling students to observe phenomena, test predictions, and interpret outcomes in guided ways when physical resources are limited. Online practicum media offer an alternative pathway, and virtual laboratories are frequently proposed as a practical option to complement classroom learning (Sugiharti & Sugandi, 2020). Media-based inquiry still requires purposeful design so that students must think, explain, and communicate rather than simply follow steps or watch demonstrations.

Virtual laboratories are simulated experimental environments that do not require complete physical equipment. They can help students connect theory and practice through electronically programmed simulations that resemble real experiments, although certain limitations remain (Kurniawati, 2019). Virtual labs can reduce safety risks and costs, enable repeated practice without consuming materials, and provide flexible access for learning. They support procedural training and can also develop thinking processes when students are guided to identify variables, compare outcomes, explain patterns, predict results, interpret data, and communicate conclusions in scientific language (Fitriana et al., 2019). Online Labs (OLabs) is one virtual laboratory platform developed by Amrita CREATE at Amrita Vishwa Vidyapeetham, based on the idea that experiments can be taught online more efficiently and at lower cost (Nedungadi et al., 2017). OLabs offers structured simulations that mirror laboratory procedures and outcomes, allowing students to practice experimental sequences and reflect on results.

This study focuses on examining the benefits of using OLabs for students' science process skills at SMA Negeri 1 Keritang. The context of limited practicum opportunities makes virtual laboratory media a relevant alternative for facilitating inquiry-oriented learning (Sugiharti & Sugandi, 2020). The study is positioned to provide evidence about how OLabs use relates to indicators of science process skills, including observing, hypothesizing, experimenting, interpreting data, inferring, predicting, applying, and communicating (Fitriana et al., 2019). Findings from this work are expected to inform instructional decisions about how virtual laboratories can be integrated to support process skills and scientific attitudes in chemistry learning, particularly when conventional laboratory implementation faces persistent constraints (Kurniawati & Fatisa, 2019; Lutfi & Hidayah, 2019).

METHODS

The method used in this research is Mixed Method Research with explanatory design model research design (Kurniawati, 2019). This research begins with the first stage, namely collecting and analysing quantitative data, followed by the second stage, namely analysing qualitative data to help explain, or describe the quantitative results obtained in the first stage (Creswell, 2009). This research was conducted in the 2021/2022 school year in class XI IPA SMAN 1 Keritang with material on factors that affect the reaction rate. The samples in this study were 2 science XI classes with experimental and control classes. The experimental class is class XI IPA 4 and the control class is class XI IPA 3. The sampling technique used is simple random sampling. There are two stages of data collection techniques, namely, using test and interview methods. The indicators set in this study are as follows:

Table 1. Indicators of Science Skills

Indicators	Science Process Skills
1	Observation
2	Classification
3	Interpretation
4	Prediction
5	Hypothesise
6	Applying Concepts

The data analysis technique in this study used quantitative analysis including t-test to see the significant difference between the KPS results of experimental and control classes and n-gain test to see the effectiveness of learning using OLabs on students' science process skills on reaction rate material. While qualitative analysis is analysed through students' answers to questions that can indicate the ability of students' science process skills and analysis of students' responses from the results of interviews.

RESULT AND DISCUSSION

Students' science process skills are measured using the test method, namely by using a description test in the form of a pretest and posttest. The results of the description test can be seen in the following table:

Table 2. Pretest and Posttest Values of Science Process Skills

Description	Experiment Class		Control Class	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Highest Score	52.5	90	47.5	77.5
Lows Score	15	60	5	52.5
Mean	31.85	74.84	23.64	64.24

Table 2 indicates an increase in mean scores from pretest to posttest in both groups. The experimental group increased from 31.85 to 74.84, while the control group increased from 23.64 to 64.24. The mean difference between groups at pretest was 8.21 points (31.85 − 23.64), whereas the mean difference at posttest was 10.60 points (74.84 − 64.24). The difference between the pretest scores of the experimental class and the control class was 8.21 and the difference between the posttest scores of the experimental class and the control class was 10.6. This shows that there is an average difference between the experimental class and the control class. The difference in the average value of students' science process skills is due to learning activities carried out in the experimental class using virtual chemistry experiments online labs (OLabs) and in the control class the learning activities only use conventional methods. This shows that learning by using online labs (OLabs) can improve students' science process skills (Sugiharti & Sugandi, 2020).

An independent-samples t-test was conducted to examine whether the posttest difference between the experimental and control groups was statistically significant. The analysis was performed using SPSS V.23 after the normality test and homogeneity test were previously carried out, the significance value of the t test was 0.000 in this t test has criteria in accepting the hypothesis, namely if $t_{count} > t_{table}$ then (Ho) is rejected and (Ha) is accepted, whereas if $t_{count} > t_{table}$ then the null hypothesis (Ho) is accepted and (Ha) is rejected. For a significant value <0.05, Ho is rejected and Ha is accepted (Ismail et al., 2016). So from the data obtained significance of 0.000 <0.05, it can be said that Ho is rejected and Ha is accepted, so it can be concluded that there is a significant difference between the science process skills of students who learn using virtual chemistry experiments online labs (OLabs) learning media with the results of the science process skills of students who learn reaction rate material without using virtual chemistry experiments online labs (OLabs) learning media.

The N-gain test was used to evaluate the effectiveness of the virtual chemistry experiment media Online Labs (OLabs) in improving students' science process skills on the reaction rate topic. N-gain values were calculated for each student based on their pretest and posttest scores, and the results are presented in Table 3. The distribution of N-gain categories shows that the experimental group had 10 students (32.26%) in the high category and 21 students (67.74%) in the medium category. The control group had 1 student (3.03%) in the high category and 32 students (96.97%) in the medium category. These results indicate that OLabs-based learning produced higher learning gains than conventional instruction, suggesting that OLabs is more effective in improving students' science process skills.

Table 3 Calculation of N-gain Results

N-gain score	Category	Experiment Class		Control Class	
		SC	Percentage	SC	Percentage
(g > 0,7)	High	10	32,26%	1	3,03%
(0,3 ≤ g ≤ 0,7)	Medium	21	67,74%	32	96,97%
(g < 0,3)	Low	0	0%	0	0%

Mean N-gain values further support this conclusion. The experimental group achieved a mean N-gain of 0.63 (moderate), while the control group achieved 0.52 (moderate). The higher mean N-gain in the experimental group indicates a greater improvement in science process skills after learning the factors affecting reaction rate using OLabs. The N-gain percentage for the experimental group was 63.1% (moderately effective), while the control group corresponded to 52.0% (less effective). The result aligns with previous findings that OLabs can be quite effective for improving students' science process skills and helping students practice experimental procedures similar to real laboratory work (Bungkuran et al., 2021).

The essay test consisted of 10 items measuring six indicators of science process skills: observing, classifying, interpreting, predicting, hypothesizing, and applying concepts. Figure 1 presents the average posttest performance for each indicator in the experimental and control groups.

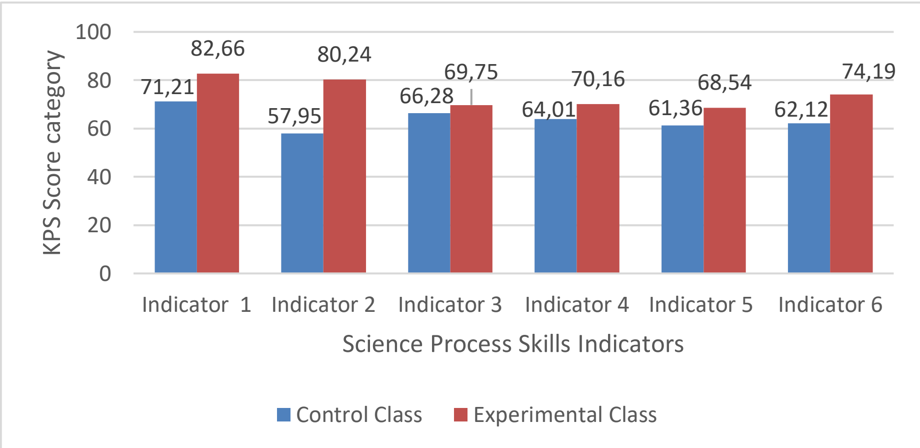

Figure 1 Average Posttest Scores of Experimental and Control Class KPS Indicators

Indicator-level analysis provides a clearer picture of how OLabs influenced specific components of students' science process skills rather than only showing overall score gains. The largest gap between groups occurred in the classifying indicator, with a difference of 22.29 points. Classifying tasks required students to organize and group information derived from images and experimental data, which aligns with the C4 level (analyzing) in Bloom's taxonomy. Students had to recall relevant prior concepts, interpret the context of the problem, identify relationships among variables, and then decide how the information should be categorized. Performance differences on this indicator suggest that OLabs learning offered advantages that were directly relevant to classification demands. Visual simulations in OLabs can make experimental relationships more explicit, helping students recognize patterns, compare conditions, and distinguish key features that support grouping and categorization. Such structured visual exposure can reduce cognitive load when students confront complex data representations, enabling them to focus on reasoning rather than struggling to imagine what happens in the experiment. Virtual laboratory learning also encourages deeper thinking about phenomena that are initially abstract, helping students integrate information when analyzing problems and generating more logical, evidence-based reasoning, which supports stronger science process skills (Elvanisi et al., 2018).

The pedagogical implication of this result is important. Classifying often functions as a "gateway" skill because it supports subsequent reasoning steps such as drawing conclusions, making generalizations, and constructing explanations. Students who can accurately classify observations or data are more prepared to justify why outcomes differ across conditions. OLabs potentially strengthens this gateway by providing repeated exposure to comparable experimental scenarios with clear visual cues. Repetition in virtual environments can be meaningful when students encounter similar experimental structures with varied variable settings, because this pattern can train them to notice which features matter for classification. Such experiences can be difficult to provide consistently through conventional instruction when hands-on practicum is limited, time is constrained, or materials are unavailable.

Indicator-level results also show the smallest gap in the interpreting indicator, with a difference of 3.47 points. Interpreting items were aligned with C3 (applying) and required students to make sense of results by reading data patterns and translating them into conclusions. Both groups achieved a "good" level on interpreting, which indicates that students could generally make basic sense of information provided in the test. The small gap suggests that OLabs did not create a large additional advantage for interpreting compared with conventional instruction, at least within the scope of the tasks used. One possible explanation is that interpreting data requires a specific set of habits: identifying trends, recognizing meaningful variation, and connecting patterns to underlying concepts. Students may not yet be accustomed to producing detailed interpretations, especially when practicum opportunities are infrequent. Students can often state general conclusions (e.g., "the rate increases") without explaining *how* the data support the claim or *why* the pattern occurs. Limited experience with practical data can lead students to rely on surface-level statements rather than evidence-linked reasoning.

This finding highlights a common challenge in science learning: interpreting is not only about "reading" data, but also about constructing an explanation that is consistent with evidence. Even when OLabs provides simulations and visual outcomes, interpretation skills may remain underdeveloped if instructional prompts do not explicitly require students to justify conclusions using data features (e.g., comparing slopes, identifying controlled variables, referencing specific changes). Virtual laboratories can support science process skills development and meaningful learning, but the extent of their impact depends on how learning activities are structured and how students are guided to reflect on evidence (Lutfi & Hidayah, 2019). Interpretation may therefore need stronger scaffolding than other indicators, such as structured worksheets, guiding questions, or reflection prompts that require students to connect patterns to scientific reasoning rather than to give broad conclusions.

The contrast between the strongest and weakest indicator gaps also suggests that OLabs may particularly support skills that depend on visualization and comparison (such as classifying), while skills that depend on argumentation from evidence (such as interpreting) may require more explicit instructional support. This does not mean OLabs is ineffective for interpreting, but it indicates that interpreting may not automatically improve through exposure to simulations alone. Instruction can leverage OLabs more effectively for interpretation by requiring students to (1) state a claim based on the data, (2) provide evidence from the simulation results, and (3) explain reasoning that links evidence to chemical concepts. Such structured reasoning aligns with meaningful learning goals and can help students move from general statements to more detailed, scientific interpretations.

Qualitative evidence from interviews strengthens the quantitative findings by explaining *how* students experienced the OLabs-based learning process. Students reported that learning with OLabs was more enjoyable, easier to follow, and more interesting, which helped them understand reaction rate content more effectively. These perceptions matter because affective factors such as interest and perceived clarity can influence attention and persistence during learning. Students who feel learning is engaging are more likely to concentrate, complete tasks, and revisit concepts when they encounter difficulty. Increased motivation can also reduce avoidance behavior and encourage students to explore "what if" questions within the simulation environment. Virtual laboratories can increase learning motivation because they make learning activities more engaging, and this engagement can translate into better learning outcomes (Lutfi & Hidayah, 2019).

Practical advantages of OLabs further support its feasibility as an instructional alternative. OLabs can be accessed via laptops or mobile phones without cost, making it flexible and efficient for classroom and independent learning. Reduced practicum time requirements are also beneficial because teachers can focus class time on discussion, analysis, and reflection rather than spending most of the session on logistical preparation (Bungkuran et al., 2021). Virtual laboratories also help address common barriers to conventional practicum, including costs of consumables, concerns about chemical hazards, and limited support personnel. Virtual chemistry environments can present learning at macroscopic, symbolic, and sub-microscopic levels, making them valuable for bridging representations in chemistry learning and providing an alternative tool for practical activities (Kurniawati & Fatisa, 2019b). This representation advantage is especially relevant to reaction rate topics because students often struggle to connect observable changes to particle-level explanations and symbolic representations. Simulations can help students "see" relationships more clearly and connect them to concepts.

Implementation constraints were also identified and should be treated as important considerations rather than minor technical issues. OLabs may not always provide complete tools or features for every experiment, which can limit the range of activities teachers can assign. Network stability can influence whether students can access simulations smoothly, and language barriers may reduce usability for some learners. Some simulations may also be inaccessible at certain times, creating inconsistency in learning experiences. These constraints imply that OLabs use requires contingency planning, such as providing alternative tasks, preparing offline supporting materials, or selecting simulations that reliably function under typical school internet conditions. Limitations also suggest that successful implementation depends on teacher readiness to integrate OLabs with clear learning objectives and guidance, rather than treating OLabs as a standalone replacement for instruction.

A broader implication of these findings concerns the relationship between virtual and real laboratory work. Physical laboratory activities remain essential because they build hands-on competence that cannot be fully replicated digitally, such as measuring with laboratory instruments, handling apparatus, and practicing safety procedures. Natural science education cannot be fully replaced by practice through monitors and keyboards (Kurniawati et al., 2019). Virtual laboratories should therefore be positioned as a complementary approach rather than a substitute. Integration between OLabs and real laboratories can create a balanced model: OLabs can be used to introduce experiments, train conceptual understanding, and prepare students to plan procedures before entering the laboratory; real practicum can then focus on developing manual skills, authentic measurement, and safety practice. This integration can also enhance efficiency because students who have "rehearsed" virtually may use laboratory time more productively and engage in deeper discussion about results. Such a blended approach supports both the inquiry process and the development of science process skills while maintaining the essential role of hands-on experiences.

Overall, the indicator-level results, interview findings, and implementation analysis suggest that OLabs can strengthen science process skills, particularly for indicators that benefit from clear visualization and structured comparison, while indicators requiring deeper evidence-based interpretation may need additional scaffolding in task design and reflection prompts. The findings also support OLabs as a feasible alternative under constraints, while reinforcing the importance of integrating virtual laboratories with real laboratory practice to maintain the full range of chemistry learning outcomes.

CONCLUSION

The study concludes that the use of Online Labs (OLabs) virtual chemistry experiments improved students' science process skills in the experimental group. The largest difference between the experimental and control groups appeared in the classifying (grouping) indicator with an average gap of 22.29 points, while the smallest difference occurred in the interpreting indicator with an average gap of 3.47 points. The experimental group also achieved a higher mean posttest score (74.84) than the control group (64.24), indicating better overall performance after OLabs-supported learning. Hypothesis testing using SPSS showed a sig. (2-tailed) value of 0.000 (< 0.05), confirming a significant effect of OLabs on students' science process skills and indicating that integrating OLabs into chemistry instruction has strong potential to enhance these skills.

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