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Development of Electronic Student Worksheet Inquiry-Based with Multiple Representations of Chemistry on Reaction Rate Material to Practice Students Critical Thinking Skills

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Abstract: This research aims to describe the feasibility of Electronic Student Worksheet Inquiry with Multiple Chemical Representations to Train Students' Critical Thinking Skills on Reaction Rate Material. The feasibility of e-worksheet is reviewed in terms of validity, practicality, and effectiveness. This research uses the Research and Development (R&D) method with the ADDIE model limited to the development stage. A limited trial was conducted in January 2024 on 32 students who received reaction rate material. The research results showed that the validity of the e-worksheet was declared valid based on the criteria for content validity getting mode four and construct validity getting mode 3. The practicality of e-worksheet was declared practical based on the results of the student response questionnaire, which showed a percentage of 98.4%. e-worksheet was declared effective based on the t-test results with a significance level 0.05, resulting in a t count of 68.50. Based on these results, it can be concluded that e-worksheet is suitable for use in practicing critical thinking skills on reaction rate material.

Keywords: Critical Thinking Skills; E-worksheet; Reaction Rate.

Introduction

In the 21st century, there is increasing competition in various fields of life, including education, especially science learning. In this regard, quality human resources must be able to compete [1]. Quality human resources are produced from quality education, so they have great opportunities to compete and overcome the problems they face. One of the 21st-century skills in science learning is chemistry learning, which can improve basic literacy, foster creative and critical thinking skills, and emphasize the importance of collaboration and communication in the younger generation [2]. Therefore, one of the efforts made by the government to improve students' skills in the 21st century is to improve the quality of Indonesian education.

Graduate competency standards are essential to support these efforts, as explained in Minister of Education and Culture Regulation Number 5 of 2022 on competency standards for high school graduates that "demonstrate the ability to analyze complex problems and ideas, conclude results, and convey arguments that support their thinking based on accurate data" [3]. Based on the competency standards for high school graduates, there is the ability to analyze problems, conclude results, and convey arguments based on accurate data, where each component is included in the indicators of critical thinking ability. This shows that critical thinking skills are essential in training students.

Critical thinking is an attitude where someone wants to think deeply and thoroughly about problems or other things within their experience's range [2]. However, facts in the field show that students' critical thinking abilities are not as expected. This can be seen from the results of the pre-research that has been carried out, based on the results of the critical thinking skills test on Tuesday, February 28, 2023, at SMAN 7 Surabaya. Critical thinking skills for interpretation were 29.4%, critical thinking skills for analytical were 18.3%, critical thinking skills for evaluation were 12.8%, critical thinking skills for inference were 13.9%, critical thinking skills for explanatory were 11%, and critical thinking skills for self-regulation were obtained from the results of the interview questionnaire teachers are still not optimal in implementing it. From the results of the pre-research, it can be seen that students' critical thinking skills are at shallow criteria. This is reinforced by the results of previous research conducted by Basuki & Novita, showing that critical thinking skills for interpretation were 7.5%, critical thinking skills for analysis were 40%, critical thinking skills for inference were 23%, and critical thinking skills for explanation were 0% [4]. In research conducted by Susilowati et al., critical thinking skills interpretation amounted to 54.87%, critical thinking skills analysis amounted to 46.56%, critical thinking skills evaluation amounted to 54.58%, critical thinking skills inference amounted to 49.24%, critical thinking skills explanation was 43.83% and self-regulation critical thinking skills was 60% [5]. Therefore, it can be concluded that students' critical thinking skills are at shallow criteria, so they still need to be trained in the learning process. Critical thinking skills are skillfully and actively interpreting and evaluating observations, communications, information, and arguments [6]. Critical thinking skills can be trained and applied in all subjects at school, including chemistry [7].

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Chemistry is a branch of Natural Science (IPA) that studies the structure, arrangement, properties, and changes in matter and the energy accompanying it. So far, many students still tend to experience difficulties in understanding chemistry lessons [8]. The results of the Decree of the Head of the Educational Standards, Curriculum and Assessment Agency No.008/H/KR/2022 of 2022 contain chemistry learning outcomes in the sub-material of factors that influence reaction rates [9]. Factors that influence the reaction rate are concentration, surface area, temperature, and catalyst. Critical thinking skills can be implemented in all chemical materials, one of which is the sub-material of factors that influence reaction rates because many applications in this sub-material are found in everyday life. Apart from that, the material studied in the sub-material on factors that influence reaction rates is in the form of understanding concepts. Understanding concepts is a student's ability to explain the material studied using their language [10]. Correctly understanding concepts is the basis for understanding other, more complex concepts [11]. Students who do not understand the concept correctly will form complex concepts, so understanding the concept becomes the basis for learning. Reaction rate material can be understood well if we pay attention to the interconnectedness of the three levels of representation to achieve effective learning; therefore, there is a need for teaching media with multiple chemical representations.

Multiple representation is a learning that uses various modes of representation to facilitate the connection of three levels of chemical representation (macroscopic, submicroscopic, and symbolic) [12]. Macroscopic representation is a concrete level that is visible, where at this level, students observe phenomena and facts that occur, either through experiments carried out or in everyday life. Microscopic representation is a concrete level that is invisible to the eye and is used to explain macroscopic phenomena. This representation is presented at the particle level, where matter is described as a composition of atoms, molecules, and ions. In contrast, symbolic representation represents macroscopic and microscopic phenomena using chemical equations, mathematical equations, graphs, reaction mechanisms, and analogies [13].

The teaching media used in schools can be student worksheets (LKPD). One form of interactive LKPD is the electronic Student Worksheet [14]. e-worksheet is a student practice sheet done digitally and carried out systematically and continuously over a certain period [15]. E-worksheet is an essential component in chemistry learning, and the use of e-worksheet can encourage students to be actively involved in the learning process. The advantage of e-worksheet is that it can simplify and narrow down space and time so that learning becomes more efficacious [16]. Apart from that, e-owrksheet can be used anywhere and at any time on a laptop or smartphone. In this research, we developed learning media in e-worksheet assisted by the live worksheets platform. Live worksheets are a platform assisted by electronic media that contains text, images, animations, and videos, which are more effective in preventing students from getting bored quickly [17]. With the e-worksheet assisted by the live worksheets platform, it can be easier to depict multiple chemical representations (macroscopic, microscopic, and symbolic) through pictures and videos.

E-worksheet and an appropriate learning model are also needed to train students' critical thinking skills. Based on previous research, the POGIL inquiry learning model positively influences students' level of activity and learning outcomes and can train essential thinking skills [18]. The POGIL (Process Oriented Guided Inquiry Learning) inquiry learning model is a learning model that prioritizes a learning process approach and is student-centred by encouraging student participation to be more active in the classroom [19]. The syntax of the POGIL inquiry learning model is orientation, exploration, conceptual formation, application, and closure [20]. According to Khulliyah & Fadhlan's research, the POGIL learning model can guide students in understanding a concept through the exploration, discovery, and application stages [21]. The stages of the POGIL inquiry learning model, which prioritizes the learning process, enable students to discover concepts independently to understand better what they are learning [22]. Discovering concepts based on events that occur in everyday life can train students' critical thinking skills [7]. Through learning using the POGIL inquiry model, students can carry out scientific processes such as identifying problem formulations, formulating hypotheses, collecting data, analyzing data, and making conclusions based on the results of experimental video observations. In this scientific process, students will also gain direct experience in identifying, analyzing, finding relationships, and discovering concepts independently so that the activities in this learning can enable students to be actively involved in the learning process and train their critical thinking skills.

The facts at SMAN 7 Surabaya after pre-research were carried out, where as many as 91.17% of students said that learning chemistry on reaction rate material was considered difficult to understand, and 55.88% of students said that one of the reasons the reaction rate material was considered difficult was because they lacked understanding—reaction rate concept. To support students' understanding of a concept, the sub-material of factors that influence reaction rates requires proof, which can be done by observing experiments in everyday life. Based on the problem description, this research is significant because students must have critical thinking skills in the 21st century. Hence, the researcher intends to conduct research by developing e-worksheet Inquiry learning media with Multiple Chemical Representations to train students' critical thinking skills on reaction rate material.

Research Methods

This type of research is development research (R&D). According to Sugiyono, Research and Development (R&D) is a research method used to produce specific products and test the effectiveness of the resulting products [23]. The research design used in this research is the ADDIE development model, which consists of the Analysis, Design, Development, Implementation, and Evaluation phases. This research will be limited to the Development stage with a trial process limited to 32 students in class XI IPA 4. The data collection techniques used were validation questionnaire methods, student response questionnaires, observations, and tests. The data

results were obtained from the quantitative data's validity, practicality, and effectiveness.

The validity of the e-worksheet was obtained based on filling in the validation sheet by two chemistry education lecturers and one chemistry teacher. Then, it was analyzed quantitatively descriptively with the criteria of the Likert scale according to the following table:

Table 1. Likert Scale

Value/Score	Statement
1	Invalid
2	Less Valid
3	Valid
4	Very Valid

[24]

The practicality of e-worksheet is obtained from filling out student response questionnaires. The measurement scale used for practicality is the Guttman scale, according to the following table:

Table 2. Guttman Measurement Scale

Statement	Answer	Value/Score
Positive	Yes	1
	No	0
Negative	Yes	0
	No	1

[24]

Data from students' response questionnaires were analyzed using percentage analysis as follows:

$$\%X = \frac{\text{sum of the scores obtained}}{\text{maximum score}} \times 100\%$$

Next, the practicality percentage results are interpreted according to the following table:

Table 3. Score Interpretation Criteria

Average Score	Criteria
76%-100%	Very Practical
51%-75%	Practical
26%-50%	Less Practical
0%-25%	Impractical

[23]

The results of the student response questionnaire to the developed e-worksheet are practical if the Percentage of assessment results is $\geq$ 51%. Student activity observation sheets also support practicality. On the student activity observation sheet, it is made in the form of positive questions according to the following table:

Table 4. Guttman Scale Observation Sheet

Question	Answer	Value/Score
Positive	Yes	1
	No	0

[24]

The Percentage of each student's activity is calculated using the following formula:

$$P\ (\%) = \frac{\text{sum of "yes" answers}}{\text{maximum score}} \times 100$$

The percentage results obtained from observing student activities are declared to support the feasibility of the e-worksheet being developed if the Percentage is $\geq$ 51% according to the interpretation criteria in Table 3.

The effectiveness of e-worksheet is obtained from the results of the pretest and post-test critical thinking skills. Each aspect of critical thinking skills is calculated using the following formula:

%) essential component of thinking skills =

$$\frac{\text{score obtained}}{\text{maximum score}} \times 100$$

The Percentage of each component of critical thinking is interpreted according to the following table:

Table 6. Score Interpretation Criteria

Percentage	Criteria
76%-100%	Very high
51%-75%	Tall
26%-50%	Low
0%-25%	Very low

[23]

Based on these criteria, each critical thinking component can be successfully trained if a percentage of 51% is obtained in the high category. Meanwhile, the pretest and post-test results were analyzed using the normality test and one sample t-test. The normality test uses SPSS based on decision-making; if the significance value is $\geq$ 0.05, then the data is usually distributed, while the sample t-test uses Minitab.

Results and Discussion

The research results show that inquiry e-worksheet with multiple chemical representations can train students' critical thinking skills on reaction rate material. The research results include validity, practicality, and effectiveness.

The validity instrument uses a validation sheet. On the validation sheet, there are content and construct validity criteria. Validation was carried out by two chemistry lecturers from FMIPA Unesa and one chemistry teacher from SMAN 7 Surabaya. The content validation criteria included (1) conformity of the e-worksheet content with learning indicators, (2) suitability of e-worksheet content with the POGIL inquiry learning model, (3) suitability of e-worksheet content with critical thinking skills, (4) suitability of e-worksheet content with multiple chemical representations. Meanwhile, construct validation criteria include: (1) presentation criteria, including images and videos related to the material; (2) linguistic criteria, including the accuracy of words or terms used in the e-worksheet; (3) design criteria include a combination of writing and image arrangement in the e-worksheet attractive and harmonious.

An electronic student worksheet is declared valid if it gets a mode score $\geq$ 3 from the three validators based on the interpretation of the Likert scale scores in Table 1 proposed by Riduwan (2016) [24]. The provisions for analyzing validity data by mode are if the aspects or indicators assessed by the validator obtain a mode on a score $\geq$ 3, it can be declared valid, while if the aspects or indicators evaluated by the validator obtain a mode on a score < 3, it can be declared less valid so that revisions and reassessments must be made until they reach the predetermined criteria, namely each aspect obtaining an assessment mode with a score $\geq$ 3.

Content validity contains items that assess how good the ingredients/contents in a product are? [25]. The content validity of e-worksheet has a mode of 4 with very valid criteria. This proves that the content of the material contained in the e-worksheet is by the sub-material learning objectives of factors that influence reaction rates, the POGIL inquiry learning model, components of critical thinking skills, and multiple chemical representations. Construct validity shows how much the instrument can reveal the theoretical construct to be measured. The construct validity of e-worksheet was obtained by a mode of 3 with valid criteria. This proves that the presentation and design in the e-worksheet being developed is attractive for use as a learning medium. Apart from that, the language used is also appropriate and consistent.

Table 7. Validation Results of e-worksheet

No	Statement	Mode
		Content validity
1.	The material in e-worksheet is following Learning Achievements (CP) and Learning Objectives Flow (ATP)	4
2.	Suitability of e-worksheet with the POGIL Phase 1 Inquiry Learning Model	3
3.	Suitability of e-worksheet with the POGIL Phase 2 Inquiry Learning Model	4
4.	Suitability of e-worksheet with the POGIL Phase 3 Inquiry Learning Model	3
5.	Suitability of e-worksheet with the POGIL Phase 4 Inquiry Learning Model	3
6.	Suitability of e-worksheet with the POGIL Phase 5 Inquiry Learning Model	4
7.	*e-worksheet* trains critical thinking skills in aspects of interpretation	4
8.	*e-worksheet* trains critical thinking skills in analytical aspects	4
9.	*e-worksheet* trains critical thinking skills in evaluation aspects	4
10.	*e-worksheet* trains critical thinking skills in inference aspects	4
11.	*e-worksheet* trains critical thinking skills in the explanatory aspect	4
12.	*e-worksheet* trains critical thinking skills in aspects of self-regulation	4
13.	*e-worksheet* represents the macroscopic level	3
14.	*e-worksheet* represents the submicroscopic level	4
15.	*e-worksheet* represents the symbolic level	3
		Construct validity
16.	Images and videos of the sub-material of factors that influence the reaction rate in the e-worksheet are visible	3
17.	The words or terms used in e-worksheet are correct and consistent	4
18	The combination of writing and images in e-worksheet is attractive and harmonious	3

The practical instrument uses a student response questionnaire to determine students' responses to e-worksheet Inkuri with Multiple Chemical Representations. Student activity observation sheets support it. A recapitulation of the student response questionnaire can be seen in the following table.

Table 8. Results of Student Response Questionnaire Data Processing

No.	Objective	Statement Number	Σ Positive Response	Average Percentage per Goal
1.	To find out about e-worksheet using the POGIL Inquiry learning model, you can form concepts in the sub-material of factors influencing reaction rates.	1	32	100%
2.	To find out if students can use e-worksheet to train critical thinking skills	2	32	100%
		3	32	
		4	32	
		5	32	
		6	32	
		7	32	
3.	To find out, e-worksheet can make it easier to understand the material with multiple chemical representations	8	32	100%
		9	32	
		10	32	
4.	To find out the ease of using e-worksheet	11	30	95.2%
		12	31	
5.	To determine the suitability of e-worksheet in terms of format	13	31	96.8%
		14	31	
Overall Average				98.4%

Based on the table above, it can be seen that the practicality of e-worksheet has a percentage of 98.4% in the convenient category. The student response questionnaire was also supported by an observation sheet on student activities, which was filled in by five observers from students majoring in Chemistry, FMIPA Unesa.

The effectiveness instrument uses critical thinking skills tests. The critical thinking skills test on reaction rate material has nine essay and self-regulation questions. The results obtained are according to the following table:

Table 9. Critical Thinking Skills Pretest and Post-test Data Processing Results

No	Skill aspect	Pretest (%)	Post-test (%)
1	Interpretation	41.99	98.04
2	Analysis	13.28	78.12
3	Evaluation	6.25	89.06
4	Inference	14.84	92.96
5	Explanation	4.68	79.68
6	Self Regulation	21.56	83.43

Based on the pretest results shown in Table 9, it is known that the scores obtained by students were relatively low. Therefore, learning was carried out using e-worksheet inquiry learning media with multiple chemical representations to train students' critical thinking skills to increase post-test scores.

The e-worksheet presents images of phenomena and experimental videos of factors influencing reaction rates, and students are asked to interpret them. This can train critical thinking skills in interpreting macroscopic representations so that the post-test score increases by 56.05%. Next, questions are presented on analysing factors that influence the reaction rate. Students are asked to create and explain a relationship graph based on the experimental video data table according to their understanding. This can train critical thinking skills for analysing symbolic representation, increasing post-test scores of 64.84%. In the e-worksheet, videos of collisions between particles are presented, and students are asked to evaluate the results of experiments based on videos of collisions between particles by explaining according to their understanding. This can train critical thinking skills in assessing microscopic representations, increasing the post-test score by 82.81%. Then, presented with inference questions on factors influencing reaction rate, students are asked to make conclusions based on the experimental video. This can train critical thinking inference skills so that the post-test score increases by 78.12%. In the e-worksheet, several experimental tools and materials are presented in everyday life, factors influencing reaction rates, and students are asked to carry out simple experimental activities in everyday life. This can train explanatory critical thinking skills that represent the macroscopic to obtain an increase in post-test scores of 75%. Next, several self-regulation questions are presented, and students are asked to check back on the learning they have done. This can train self-regulation critical thinking skills so that the post-test score increases by 61.87%.

Increasing all aspects of critical thinking skills in the post-test is done by Bruner's theory, which supports the POGIL inquiry learning model, namely that students must learn through themselves and actively participate in learning so that they can discover concepts independently [26]. Previous research shows that the POGIL inquiry learning model positively influences the level of activity and learning outcomes of students and can train critical thinking skills [18].

The pretest and post-test scores obtained are then calculated using the T-Test to determine whether there has been an increase in critical thinking skills. However, before carrying out the T-Test, the data must first be tested using the Shapiro-Wilk Normality Test to determine whether the data used is usually distributed. A normality test was carried out using SPSS. The results of the P-Value normality test (significance value) were > 0.05, which means the data was normally distributed, then the calculated t value > t table test results were obtained at 68.50 > 1.694; it could be concluded that H_0 was rejected and H_a was accepted, meaning The post-test score was found to be greater than the average pretest score, so it can be said that there was an increase in scores between before and after using e-worksheet. So, it can be concluded that inquiry e-worksheet with multiple chemical representations effectively trains students' critical thinking skills.

Conclusion

Based on the results of the research that has been carried out, the Inquiry e-worksheet with Multiple Chemical Representations to train students' critical thinking skills on reaction rate material is declared worthy in terms of several aspects, namely the Inquiry e-worksheet with Multiple Chemical Representations is declared valid in terms of the validation sheet score obtained from three validators with an assessment content validity getting mode four and construct validity getting mode 3. e-worksheet Inquiry with Multiple Chemical Representations was declared practical in terms of the results of the student response questionnaire with a percentage of 98.4% in the very practical category. e-worksheet Inquiry with Multiple Chemical Representations was declared effective in training students' critical thinking skills in analysing the t-test results with a significance level of 0.05 obtained t count > t table of 68.50 > 1.694 so that H_0 was rejected and H_a was accepted. This means that the post-test score was more significant than the average pretest score, so it can be said that there was an increase in scores between before and after using e-worksheet. Based on the research carried out, several suggestions are aimed at, namely e-worksheet Inquiry with Multiple Chemical Representations, which is only limited to the sub-material of factors that influence reaction rates so that in the future, it can be further developed into other material that contains indicators of critical thinking skills. In future research, if you use the live worksheet platform, you should use a PC or laptop to minimize obstacles during work.

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