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Development of Problem-Based-Learning (PBL)-Oriented Electronic Student Worksheets (e-Worksheet) to Improve Critical Thinking Skills of Class XI Senior High School Students on Factors that Influence Rate of Chemical Reactions Material

Sasmira Nur Hidayah[1], Utiya Azizah[2], Harun Nasrudin[3]
[1,2,3] Chemistry Department, Universitas Negeri Surabaya, Indonesia

ABSTRACT: Education system changes from time to time, and with these changes, the existing curriculum in Indonesia also continues to undergo several curriculum updates. The Merdeka Curriculum is the answer to the high level of competition that occurs in the 21st century. Factors that influence the rate of chemical reactions are one of the materials in chemistry phase F of the Merdeka curriculum, which has abstract characteristics and requires experimentation. Based on these characteristics, the problem-based-learning (PBL) learning model is suitable for use and can improve students' critical thinking skills. This research aims to determine the feasibility of developing a PBL-oriented student e-worksheet to improve critical thinking skills on factors that influence reaction rates. The method used in this research is R&D with a 4D model. The results obtained are that the student e-worksheet developed is feasible because the content and construct validity results obtained in mode 5 with a very valid category, then the practicality results obtained a response questionnaire score of 98.44%, which was supported by the results of the student activity sheets, and the effectiveness was obtained. From the data from the pretest and posttest results, which were analyzed using the SPSS Paired Sample t-Test, the results showed that there was an increase in students' critical thinking skills, namely with a significance value of 0.00.

KEYWORDS: Chemistry, Critical Thinking Skills, Development, Problem Based Learning, Reaction Rate, Student e-worksheet.

INTRODUCTION

The development of education in this century has had an impact on changes to the education system in Indonesia. One of the educational systems in Indonesia that must be changed is the learning process. This system experiences changes from time to time. With these changes, the existing curriculum in Indonesia continues to undergo several updates. The Independent Curriculum is the answer to the high competition that is occurring in the 21st century [1]. In the 21st century, there are skills that students must have, including (1) critical thinking and problem-solving skills; (2) the ability to create and update; (3) information and communication technology literacy; (4) contextual learning ability; (5) information skills and media literacy; and (6) the ability to communicate and collaborate [2]. Based on these skills, appropriate scientific disciplines are needed to develop students' skills in the 21st century. Chemistry is a science discipline that is suitable for training and improving students' skills in the 21st century [3].

Chemistry is a subject that discusses the laws of scientific and experimental activities [4]. According to the Minister of Education and Culture Decree No. 33 of 2022, one of the chemical materials that requires investigation through experimental activities is the material on chemical reaction rate factors. This material is contained in the chemistry learning outcomes in phase F of the Merdeka curriculum. This material has the characteristic of requiring experimental activities for the proof process [5]. This aterial in the learning process needs to be linked to phenomena in everyday life and has characteristics of abstract concepts, so that it needs direction on process skills to achieve learning goals [6]. Based on the characteristics of the material, an appropriate learning model is needed to be used.

The problem-based-learning (PBL) learning model is learning that is based on authentic problems and is suitable for application to material that has characteristics such as factors that influence the rate of chemical reactions. In problem-based-learning (PBL), there are five phases in its application, which include: (1) Problem Orientation: In this phase, students identify and explain information from phenomena related to factors that influence reaction rates. (2) Organizing for learning: In this phase, students have curiosity about how problems in everyday life regarding factors that influence the rate of chemical reactions can be solved. (3) Guiding individual and group investigations: In this phase, students make conjectures and hypotheses from the problems given, answer

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questions that lead to problem solving, fill in and analyze experimental data tables, and identify and obtain the information needed to support problem solving. (4) Develop and present work results. In this phase, students draw reasonable conclusions based on the data they have collected. (5) Analyze and evaluate the problem-solving process. In this phase, students evaluate how strong the arguments have been made [7]. This learning model requires you to have high-level thinking skills [8]. By challenging what they hear and reexamining particular ideas, critical thinkers can solve a variety of difficulties [9]. In the chemistry learning process, the material on factors that influence the rate of chemical reactions requires critical thinking skills because they need to relate concepts to each other [10]. The large number of previous studies using Facione's indicators prove that indicators including interpretation, inference, analysis, explanation, self-regulation, and evaluation can be applied to measure students' critical thinking skills [11]. Three skill indicators including interpretation, inference, and analysis are actually able to measure students' critical thinking skills [12]. There are four critical thinking indicators applied in this research that are adapted to the material and learning model used.

In fact, when in class, students' critical thinking skills are still low [13]. Based on the results of pre-research on students' critical thinking skills, which was carried out at state senior high school of 8 Surabaya, it was found that as many as 55.86% of students could not understand interpretation questions, 63.28% of students could not understand inference questions, 63.02% of students could not understand analysis questions, and 62.50% of students could not understand evaluation questions. This is also supported by the results of an interview conducted with one of the chemistry teachers at state senior high school of 8 Surabaya, who stated that the level of critical thinking skills of the students he taught was relatively low. To overcome this, appropriate learning media are needed because this media is a teacher's tool for expressing material to facilitate students' understanding and practice critical thinking skills [14].

Worksheet is a form of learning medium that can be used to improve these skills [15]. As time goes by, worksheet is oriented so that PBL can experience innovation presented in electronic form, known as the student e-worksheet [16]. This is also supported by pre-research results that state that 75% of students feel that electronic-based media is more enjoyable when used in the learning process, especially student e-worksheet media. The nature of this medium is flexible, which makes learning more effective [17]. One orientation that can be used in a student e-worksheet is PBL, which is defined as a worksheet that contains activity steps adapted to the phases or syntax of the problem-based-learning model [18]. Based on previous research, problem-based-learning-oriented e-worksheet is suitable for use in training critical thinking skills in terms of feasibility criteria [19]

From the background that has been explained, the research aims to development of electronic student worksheets (student e-worksheet) oriented to problem-based-learning (PBL) to improve critical thinking skills of class XI senior high school students on factors that influence the rate of chemical reactions feasible based on aspects of validity, practicality, and effectiveness. The final result of this product can later be saved using the general format, namely a liveworksheet, so that it can be accessed by anyone and anywhere.

METHOD

This research uses the Research and Development (R&D) method proposed by Thiagarajan and has 4 stages, or what is often referred to as the 4D model, namely define, design, develop, and disseminate [20]. This research is limited to the development stage only, namely by conducting limited trials.In this study, the research subjects were 20 students from classes 11-2 of state senior high school of 8 Surabaya who had received material lessons on factors that influence the rate of chemical reactions. The instruments used in this research include a validation sheet, which aims to determine the validity of the student e-worksheet; a response questionnaire sheet and student activity sheet, which aim to determine the practicality of the student e-worksheet; and a pretest posttest sheet, which aims to determine its effectiveness. student e-worksheet to improve students' critical thinking skills.

Previously, students were given pretest questions on critical thinking skills regarding factors that influence the rate of chemical reactions, then a limited trial was carried out by learning using PBL-oriented e-worksheets for three meetings and at the end of the lesson students would be given posttest questions on thinking skills. critical again. The pretest and posttest critical thinking skills questions take 2 phenomena which contain 4 indicators of critical thinking skills, namely consisting of 4 interpretation questions, 6 inference questions, 4 analysis questions, and 2 evaluation questions [11].

The data analysis technique used on the validation data was the Likert scale, then on the response questionnaire data using the Guttman scale, and on the pretest-posttest data, data analysis was carried out using a paired sample t-test to determine the increase in critical thinking skills.

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Validation results are declared valid if they obtain a mode with a value of 4 (valid category) or 5 (very valid), as in Table 1.

Table 1. Category of Validity

Value/Score	*Category*
1	Very Invalid
2	Invalid
3	Fairly Valid
4	Valid
5	Very Valid

Source: Riduwan, 2015

Furthermore, a student e-worksheet is declared practical if it obtains a practicality score percentage of ≥ 61% in the very practiclity category, as in Table 2. These results are also supported by the student activity observation sheet.

Table 2. Category of Practicality

Percentage (%)	*Category*
0 – 20	Impractical
21 – 40	Less Practical
41 – 60	Quite Practical
61 – 80	Practical
81 – 100	Very Practical

Source: Riduwan, 2015

Apart from that, the pretest-posttest results were analyzed using SPSS, including testing the normality of the data using the Shapiro-Wilk normality test. The data is normal if it obtains a significance value of > 0.05. After the data was declared normal, it was subjected to a paired sample t-test. The student e-worksheet being developed is declared effective if it obtains paired sample t-test results of <0.05 [20].

RESULSTS AND DISCUSSION

This research applies the stages in the 4D model proposed by Thiagarajan, namely Define, Design, Develop, and Disseminate. However, this research is only limited to the Develop stage [21].

A. Define

This stage consists of five analysis steps: initial and final analysis, student analysis, task analysis, concept analysis, and learning objective analysis [21]. This initial and final analysis includes an analysis of the curriculum used, namely the Merdeka curriculum, which includes one subject, namely chemistry. One of the materials in the chemistry subject is factors that influence the rate of chemical reactions, which, based on their characteristics, can be applied using the problem-based-learning model. Learning requires appropriate learning media, such as a student e-worksheet. At this stage of student analysis, an analysis of cognitive development and critical thinking skills was carried out, the results of which showed that students had cognitive development at the formal operational stage (age 16–18 years) so that they could think abstractly, and students' critical thinking skills were still relatively low at 4 indicators. In the concept analysis, a concept map of the material presented in the student e-worksheet will be produced. Task analysis aims to determine the tasks in the student e-worksheet that will be completed by students as a forum for improving critical thinking skills. And finally, in the analysis of learning objectives, learning objectives and the flow of learning objectives are formulated in the material on factors that influence the rate of chemical reactions based on phase F of the Merdeka curriculum.

B. Design

This stage includes (1) preparing a benchmark test for critical thinking skills based on the analysis of learning objectives. The criteria for this test are prepared in accordance with the 4 indicators of critical thinking skills proposed by Facione, namely interpretation,

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inference, analysis and evaluation [10]; (2) selecting media with the aim of helping students achieve learning goals, e-worksheet is the right media for practicing skills [22]; (3) selection of the student e-worksheet format used, the components in it refer to the Ministry of National Education and the topics are 1 main student e-worksheet and 4 student e-worksheet according to factors that influence the rate of chemical reactions [23]. e-worksheet 1 or main contains the identity and instructions for the e-worksheet being developed, e-worksheet 2 contains discussion topics regarding concentration factors, e-worksheet 3 contains discussion topics regarding surface area factors, e-worksheet 4 contains discussion topics regarding temperature factors, and e-worksheet 5 contains discussion topics regarding catalyst factors. The format of e-worksheet 1 or main includes several components, namely cover, foreword, instructions for use, instructions for sending, learning outcomes, learning objectives, details of critical thinking skills activities, summary of material, menu of options for going to e-worksheet for each rate factor. chemical reactions, and bibliography. Meanwhile, the other 4 e-worksheet (concentration factor, surface area factor, temperature factor, and catalyst factor) have the same format, namely covering cover, learning objectives, flow of learning objectives, and a series of activities that refer to the stages/syntax of the problem-based-learning model.[7]; and (4) student e-worksheet design activities, in this step an initial student e-worksheet design is produced in the form of student e-worksheet draft, namely a PDF file edited via the Canva application. The main e-worksheet cover can be seen in figure 1.

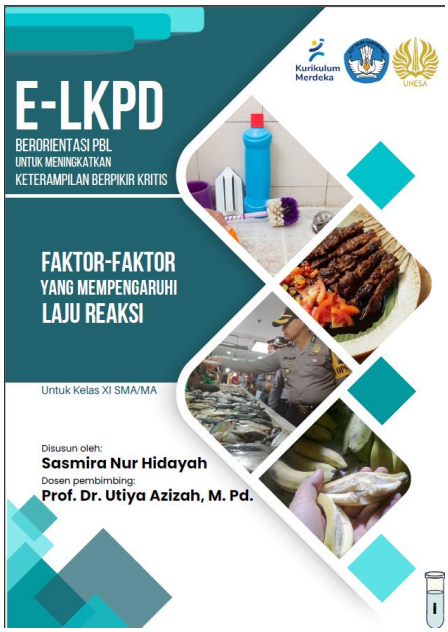

Figure 1. PBL Oriented e-worksheet Cover Appearance

C. Develop

This stage includes (1) creating a PBL-oriented student e-worksheet in the form of draft I, which is a realization of the previous stage and then uploaded to the liveworksheet web; (2) expert assessment was carried out on draft I of the student e-worksheet, including review by the supervisor and validation by 2 chemistry lecturers and 1 chemistry teacher; and (3) limited trials were carried out at state senior high school of 8 Surabaya class 11-2 for 3 meetings with a subject of 20 students. At this stage, data on the results of the response questionnaire and student activity will be produced, which will be used to determine practicality and data on pretest-posttest results. which is used to determine the increase in students' critical thinking skills.

D. Validity

Based on the validity data obtained, it can be seen that the results of the validation of the student e-worksheet developed in terms of content validation include 11 aspects of assessment that received mode 5 with valid categories, and construct validity consists of 3 criteria, namely (1) language criteria including 4 aspects of assessment that received mode 5 with a very valid category; (2) presentation criteria including 4 aspects of assessment with a mode of 5 with a very valid category; and (3) graphic criteria covering

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5 aspects of assessment that received mode 5 with a very valid category [24]. Overall, the student e-worksheet developed was declared very valid because it obtained mode 5 for both content and construct validity.

E. Practicality

The practicality of student e-worksheets is known from the results of the response questionnaire, which is supported by observation sheets of student activities during the learning process of applying student e-worksheets in the learning process in class. Student responses are students' opinions given on problem-based-learning-oriented e-worksheets using student response sheets [25]. Previous research states that e-worksheet is oriented towards practical problem-based-learning for use [19]. And then, the activities of each student in their group were observed by observers in three meetings. The purpose of the observation is to determine the suitability of the activity with the predetermined PBL model syntax [26]. These student activities include learning activities that are adapted to the phases or syntax of the PBL learning model and indicators of critical thinking skills, which include (1) students identifying problems and collecting information on phenomena (PBL phase 1, interpretation indicators); (2) students can formulate problems based on phenomena in student e-worksheet (phase 2 PBL, interpretation indicators); (3) based on information obtained through books/internet, students can make hypotheses (phase 3 PBL, inference indicators); (4) students process data from the results of experiments carried out and carry out data analysis that leads to problem solving (phase 3 PBL, analytical indicators); (5) students can make conclusions based on the experimental results and phenomena presented (phase 4 PBL, inference indicators); and (6) students check again how strong the arguments given regarding problem solving are when linked to the results of the experiment (PBL phase 5, evaluation indicators).

Figure 2. Process of Learning Activities in Class

Figure 3. Students Carry Out Experiments According to PBL-oriented e-worksheet

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Riduwan stated that learning media is said to be practical if a percentage of ≥ 61% is used on the Guttman scale [24]. Based on the data from the trial results, it can be seen that the percentage of response questionnaire results was 98.44%, with the very practical category supported by the results of observations of student activities. This shows that the PBL-oriented student e-worksheet developed is very practical to use to improve students' critical thinking skills.

F. Effectiveness

The effectiveness of the student e-worksheet is known from the pretest-posttest results of critical thinking skills on factors that influence the rate of chemical reactions. This test consists of 16 description questions containing 4 indicators of critical thinking skills which consists of 4 interpretation questions, 6 inference questions, 4 analysis questions, and 2 evaluation questions [11]. The pretest was carried out before learning using the student e-worksheet, and the posttest was carried out after learning using the student e-worksheet, and then the improvement was observed. The resulting data obtained is shown in Figure 4.

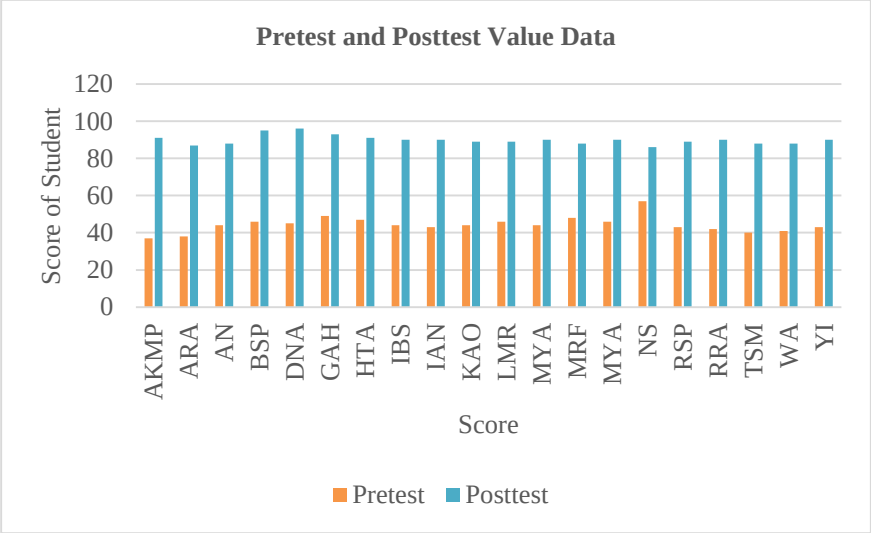

Figure 4. Pretest and Posttest Results Data

Based on Figure 4, it can be seen that initially, students got a low pretest score for critical thinking skills, then after implementing learning using PBL-oriented e-worksheets on the material of factors that influence the rate of chemical reactions, students got a high posttest score for critical thinking skills and there was a significant increase in scores. This is in line with previous research which states that problem-based-learning-oriented Worksheets can improve students' critical thinking skills [27].

The pretest and posttest data obtained were then analyzed using SPSS including a normality test and if the data was declared normal then it was continued with a paired sample t-test [20]. The results of the pretest and posttest normality test of students' critical thinking skills can be seen in Figure 5.

Tests of Normality

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Pretest	,150	20	,200*	,917	20	,086
Posttest	,234	20	,005	,898	20	,038

Figure 5. Test of Normality

The normality test was carried out with Shapiro-Wilk and obtained a pretest significance value of 0.086 and a posttest significance value of 0.038. The data was declared normally distributed because it obtained a significance value > 0.05 [20]. Because the data is

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normally distributed, the data can be tested using a paired sample r-test. The results of the paired sample t-test data on the students' pretest and posttest critical thinking skills are shown in Figure 6 below.

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pretest - Posttest	-45.55000	4.94682	1.10614	-47.86518	-43.23482	-41,179	19	,000

Figure 6. Paired Sample t-test

Based on the results of the paired sample t-test that was carried out, a significance value of 0.000 was obtained. The e-worksheet developed was declared effective for improving critical thinking skills because the paired sample t-test results were <0.05[20]. This is in line with previous research which states that problem-based-learning-oriented e-worksheets are effective for improving students' critical thinking skills [28]. The increase in students' critical thinking skills occurs because learning has been carried out using e-worksheets which contain work steps with learning stages using the problem-based-learning which can train students' critical thinking skills on material for each factor that influences chemistry including concentration, surface area, temperature, and catalyst [7]. In the e-worksheet for each material factor, there are student activities that apply four indicators of critical thinking skills, namely interpretation, inference, analysis and evaluation [11]. The PBL-oriented e-worksheet that was developed contains (1) In phase 1 of PBL: problem orientation, there are activities that train interpretation indicators in accordance with pretest posttest questions number 1 and 9; (2) In phase 2 of PBL: organizing students to learn, there are activities that train interpretation indicators in accordance with pretest posttest questions number 2 and 10; (3) In phase 3 of PBL: guiding individual/group experiences, there are activities that train inference indicators in accordance with pretest posttest questions number 3, 4, 11, 12 and analysis indicators in accordance with pretest posttest questions number 5, 6, 13, 14 ;(4) In phase 4 of PBL: developing and presenting the results of the work, there are activities that train inference indicators in accordance with the pretest posttest questions number 7 and 15; and (5) In phase 5 of PBL: analyzing and evaluating the problem solving process, there are activities that train evaluation indicators in accordance with the pretest and posttest questions number 8 and 16. Based on the results of the paired sample t-test and the discussion, it can be stated as an e-worksheet The PBL orientation was developed effectively to improve the critical thinking skills of class XI senior high school students.

CONCLUSSION

Based on the results of the research that has been carried out, it can be concluded that the PBL-oriented student e-worksheet to improve students' critical thinking skills on the factors that influence the rate of chemical reactions is feasible in terms of validity, practicality, and effectiveness. The validity results are viewed from the content and construct consisting of language, presentation, and graphic criteria, all of which obtained mode 5 with a very valid category. The practicality of the student e-worksheet is seen in the student response questionnaire, which obtained a percentage of 98.44% in the very practical category, supported by the results of the student activity observation sheets. And finally, the effectiveness of the student e-worksheet is seen from the results of improving critical thinking skills, which were processed using the paired sample t-test and obtained a significance value of 0.00, which means there is an increase.

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