Development of Problem-Based Learning (PBL) Oriented Student Worksheets to Improve Students' Critical Thinking Skills on Redox Reaction Material

Salsa Nur Indarwati*, Harun Nasrudin**

* Chemistry Education Department, Universitas Negeri Surabaya
** Correspondence author, Universitas Negeri Surabaya, harunnasrudin@unesa.ac.id

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Abstract- This research aims to produce student worksheets oriented to Problem-Based Learning (PBL) to improve students' critical thinking skills on redox reaction material that is feasible in terms of validity, practicality, and effectiveness. This research is a Research and Development (R&D) study using the 4D development model, which was limited to the development stage and a limited trial with 25 students from Senior High School 1 Sooko Mojokerto. The results showed that the content validity of the student worksheets scored 4, and the construct validity also scored 4, both categorized as very valid. The practicality of the student worksheets, based on relevant student activities in the first and second meetings, achieved a percentage of 93.33% and 95%, respectively, in the very practical category, supported by student response questionnaire results of 98.4 in the very practical category. The effectiveness of the student worksheets was assessed by measuring the improvement in critical thinking skills with normality tests for pretest and posttest scores, which yielded significance values of 0.063 and 0.521, respectively, indicating normal distribution since the significance values were greater than 0.05. Paired sample t-test analysis of the pretest and posttest data revealed a significance value of 0.000 < 0.05, indicating a significant difference between pretest and posttest scores in terms of critical thinking skills. The data were then analyzed using the n-gain score, with scores ranging from 0.33-0.81 in the medium and high categories, indicating that students' critical thinking skills improved and that the student worksheets is effective in improving critical thinking skills.

Index Terms- Student Worksheets, Problem Based Learning, Critical Thinking Skills, Redox Reactions

I. INTRODUCTION

Education continues to develop with the development of the curriculum, which is by the conditions of the educational unit. Curriculum, according to the Ministry of Education and Culture number 719/P/2020 is a plan and arrangement that includes objectives, content, learning materials, and methods used to help students achieve academic goals. Currently, the Indonesian government is implementing an independent curriculum which is regulated in the Ministry of Education, Culture and Research number 56/M/2022 as a result of the evaluation of the 2013 curriculum and in the context of restoring learning. The independent curriculum is motivated by certain circumstances that cause a lag in learning and the achievement of student competencies, so the government is trying to restore learning by implementing an independent curriculum.

Chemistry is a natural science component for senior high school students in the independent curriculum. The results of pre-research at Senior High School 1 Sooko Mojokerto by taking 31 students as samples stated that as many as 87.09% of students thought chemistry subjects were difficult because many terms were not understood and abstract. Chemistry lessons are difficult for students to understand because chemical concepts are so complex and abstract that they require strong reasoning and understanding to solve problems (Priliyanti, et al, 2021). Complex concepts can be mastered if the basic concepts have been understood. Chemistry has sequential concepts, students will have difficulty understanding the next topic if they do not understand the basic concepts. Abstract concepts are concepts that are not visible so they need to be connected to concrete things to be more easily understood by students. This is related to chemical representation. Chemical representation is divided into three levels, namely the macroscopic level (observable), sub-microscopic (particles that make up the substance), and symbolic (substance identity) which provides complementary information in the cognitive process. According to Priliyanti, et al (2021), chemical representation levels can increase students' conceptual understanding and thinking skills. Therefore, to help improve students' thinking skills in learning chemistry, skills by 21st-century skills are needed.

21st-century skills are the skills needed to face modern challenges, problems, and life (Redhana, 2019). These skills commonly known as the 4Cs include critical thinking, collaboration, creativity, and communication. The 4C skills then evolved into 6C skills with the addition of two skills namely character, and citizenship. The 6C skills are needed for students to gain understanding independently.
Critical thinking is a skill that involves cognitive processes and encourages students to think according to their abilities and think deeply about problems. According to Facione (2015), critical thinking indicators include interpretation, analysis, evaluation, inference, explanation, and self-regulation. Critical thinking is related to higher-order thinking such as analyzing and evaluating (Juliyanika & Batubara, 2022). It involves thinking skills such as recognizing problems, analyzing problems with various possible solutions, determining cause and effect, and drawing rational conclusions based on observation, experience, and learned reasoning. Critical thinking is an important component of learning, yet Indonesian students are still lacking in this skill. Based on the results of the Trends in International Mathematics and Science Study (TIMSS) in 2015, Indonesia was in 44th position out of 49 countries with an average score of 397, far below the TIMSS average score of 500 (Syamsul & Novaliyosi, 2019). According to the 2018 Program for International Student Assessment (PISA) results, Indonesia is in the 72nd position out of 78 countries, with a score of 379 (Khasanah & Sumarni, 2021). This is relevant to the results of pre-research conducted on students in Grade 12 Science Class 7 Senior High School 1 Sooko, the results of skills in stating problems, formulating problems, and variables (interpretation) were 51%, stating hypotheses and drawing conclusions (inference) was 45%, compiling data and analyzing data (analysis) were 56%, and stating concept relationships (evaluation) were 24%. The results show that students' critical thinking is still low. Thus they have not been able to analyze all ideas to solve a problem.

Critical thinking in the learning process is done by students to answer questions using ideas and concepts. Critical thinking skills play an important role in learning because they allow us to solve problems by producing better solutions. Relevant to Setiana idea (2019) critical thinking skills are the process of making logical decisions. Critical thinking is one of the important goals in 21st-century chemistry education, although most students still have relatively low critical thinking skills (Manik, et al, 2020). Lack of understanding of the concept of critical thinking is a problem in itself, especially in learning chemistry.

Chemistry concepts are related to each other, if there is an error, it will be difficult to understand the concept of the next material. Based on the results of pre-research, 74.19% of students think that redox material is material that is difficult to understand because students do not understand the concept of redox reaction material. Redox reactions are material with a gradual concept and will be deepened in electrochemical material. Redox material is material that has stages of equalizing reactions that use changes in oxidation numbers (Nugrohadi & Chasanah, 2022). Students will have a good understanding if they can solve problems by linking the concept of redox reactions with things that happen in real life. With problem-solving, students can more easily receive an understanding of redox reaction material.

Problem-solving can be improved using a problem-based learning model. One of the problem-based learning models is the PBL model. This model allows students to experience real experiences and encourages them to actively participate in class (Tyas, 2017). The PBL learning model has five syntaxes which include 1) orienting students to the problem, 2) organizing students to learn, 3) guiding individual/group investigations, 4) developing and presenting work, and 5) analyzing and evaluating the problem-solving process. PBL helps students learn material concepts that are associated with authentic problems so that they can solve problems and find ideas gained from their life experiences. This is a step towards improving thinking skills because during the learning process, a phenomenon is given and students learn to find better solutions. The use of the PBL model aims to increase students' creativity and critical thinking in the learning process (Antara, 2022). In learning chemistry, critical thinking skills can be improved by using teaching materials. Teaching materials are tools used by teachers in teaching students in the classroom (Zakaria, et al., 2020). Teaching materials as a supporting factor for the success of teaching teachers to students to be more directed in understanding a chemical concept. Student worksheets are one of the teaching materials that can be used in the learning process so that learning activities become more effective and efficient.

The results of the interview with the teacher of Senior High School 1 Sooko showed the lack of utilization of student worksheets in the chemistry learning process so it was felt that it did not improve the critical thinking skills of students. Student worksheets used by teachers only contain titles, learning objectives, materials, questions, and practicum steps. In this case, students are not accustomed to sharpening their critical thinking by producing solutions in solving a problem. Therefore, teaching materials for student worksheets must be made to improve students' critical thinking skills.

Previous studies explained that the development of student worksheets can improve students critical thinking skills in chemistry. Relevant to Rusdiana idea (2021) the development of problem-solving-oriented student worksheets can improve the critical thinking skills of grade XI students on chemical equilibrium material. Furthermore, research from Nonik (2021) states that the development of PBL-oriented student worksheets can improve critical thinking skills in hydrocarbon material. Then research from Amnia'ul (2021) states that the development of PBL-based student worksheets can improve critical thinking skills on buffer solution material.

Based on the description above, the presentation of student worksheets can be innovated by combining student worksheets with learning models. The PBL model is appropriate in this research because it helps students improve critical thinking skills by providing phenomena that are related to the real world to help find solutions.
II. LITERATUR REVIEW

Student Worksheets

Student worksheets are printed teaching materials containing tasks that must be done by students (Ramadhan N., 2022). Student worksheets are teaching materials that contain material coverage, summaries, and instructions for implementing the learning process that must be carried out by students who refer to the basic competencies that have been determined and must be achieved (Prastowo, 2012). Student worksheets are used to maximize understanding and facilitate learning for students to solve problems related to the material provided either independently or in groups according to the indicators of competency achievement. The development of student worksheets is designed based on the conditions and environment of students so that in understanding the concept of material students can find their ideas by linking in everyday life.

Problem-Based Learning Model (PBL)

Problem-based learning model is a learning model that emphasizes solving a problem related to daily life. According to Warsono (2017), the PBL model is a learning model that teachers do in teaching students with a focus on solving real problems. In PBL model learning, students can explore real experiences in learning because the problems used in this model are authentic. Authentic problems are problems that must be faced in everyday life and do not cause new problems for students (Hidayah, 2019). The PBL model has learning characteristics that are carried out with group activities in finding solutions to solve problems from existing problems (Mayasari, et al., 2022). The PBL learning model consists of five stages, namely (1) orienting students to the problem; (2) organizing students to learn; (3) guiding individual/group experiences; (4) developing and presenting work; and (5) analyzing and evaluating the problem-solving process (Arends, 2013).

Critical Thinking Skills

Critical thinking is one of the higher-level skills related to analyzing and evaluating to make decisions and solve problems needed in 21st-century skills (Rahardhian, 2022). In this case, critical thinking skills must be systematic and specific in dealing with a problem faced by exploring the problem carefully, and thoroughly, and identifying all information to find solutions or problem-solving strategies. The focus of this critical thinking is being able to decide by using thinking skills to get the best solution or result. Critical thinking skills have indicators consisting of interpretation, inference, analysis, evaluation, explanation, and self-regulation (Facione P. A., 2015).

Redox Reaction Material

Redox events are events in which two types of reactions occur, namely reduction and oxidation. The concept of redox can be explained from various points of view. Among them are seen from the transfer of oxygen, the rise and fall of oxidation numbers, and the transfer of electrons (Sukmawati, 2020). Electrochemical cells are chemistry that occurs in electrodes due to electron transfer based on redox reactions and electrolyte solutions (Andriani & Gazali, 2024). Electrochemistry has electrodes that are divided into cathodes and anodes. The cathode is where the reduction reaction occurs, while the anode is where the oxidation reaction occurs. Electrochemical cells are divided into two, namely voltaic cells and electrolysis cells. Voltaic cells are electrochemical cells that convert chemical energy into electrical energy with redox reactions that take place spontaneously, electrolysis cells are electrochemical cells that convert electrical energy into chemical energy with redox reactions that take place not spontaneously.

III. METHODS

This research uses a type of development research or Research and Development (R&D) adapted from Ibrahim (2014). The 4-D development model has stages including define, design, develop, and disseminate. However, this research was only carried out up to the develop stage. The define stage has five steps, namely front-end analysis, student analysis, concept analysis, task analysis, and learning objectives analysis. The design stage has two steps, namely format selection, and making the initial design according to the format that has been chosen to produce draft I. The last stage, namely develop, has steps, namely review by 1 chemistry education lecturer, namely the supervisor, revision and producing draft II student worksheets, validation is carried out by 2 chemistry education lecturers and 1 chemistry teacher, and the results of validation produce draft III, limited trial stage, analysis, and report preparation (Ibrahim, 2014). The development research design is as follows.
In this study, it was tested on 25 students of Grade 12 Science Class 7 at Senior High School 1 Sooko Mojokerto. The limited trial used a one-group pretest-posttest design. One group pretest-posttest design is a research activity that is tested twice, namely before using PBL student worksheets called pretest and after using PBL student worksheets called posttest (Sugiyono, 2013). One group pretest-posttest design can be described as follows.

Table 1. One Group Pretest-Posttest Research Design

<table>
<thead>
<tr>
<th>Pretest</th>
<th>Treatment</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_1$</td>
<td>X</td>
<td>$O_2$</td>
</tr>
</tbody>
</table>

Description:
- $O_1$ = Pretest score
- X = Treatment using problem-based learning-oriented student worksheets
- $O_2$ = Posttest score

Data analysis used in this study includes analysis of review data, validation, results of student response questionnaires, student activity observations, and critical thinking skills tests. The review data was obtained from the assessment of one supervisor through the review sheet provided. The results of the review are in the form of suggestions and input used to improve PBL oriented student worksheets so that they can achieve validity. Validation data was obtained from the assessment of three validators, namely two chemistry education lecturers and one chemistry teacher of Senior High School 1 Sooko Mojokerto through the validation sheet. Validators gave an assessment based on a Likert scale.
Table 1. Likert Scale

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very less valid</td>
<td>1</td>
</tr>
<tr>
<td>Less valid</td>
<td>2</td>
</tr>
<tr>
<td>Valid</td>
<td>3</td>
</tr>
<tr>
<td>Very valid</td>
<td>4</td>
</tr>
</tbody>
</table>

(Sugiyono, 2015)

The validation data was used to describe the feasibility of the students' worksheet on the validity criteria. The validation data obtained was analyzed by determining the mode of each aspect. The score that often appears or becomes the mode is the validity value of the student worksheets developed. Student worksheets are said to be valid if they get mode ≥ 3 (Lutfi, 2021).

Practicality data analysis was obtained from student response questionnaires and student activity observations. The student response questionnaire is used to measure the practicality of PBL-oriented student worksheets. The response questionnaire is used to find out the responses of students after using PBL student worksheets. The response questionnaire sheet contains 15 statements including 11 positive statements and 4 negative statements which will be analyzed based on a Guttman scale.

Table 2. Guttman Scale

<table>
<thead>
<tr>
<th>Statements</th>
<th>Answer</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>Yes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Positive</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
</tr>
</tbody>
</table>

(Riduwan, 2015)

The data obtained will be analyzed by calculating using the following formula.

\[ P = \frac{F}{N} \times 100\% \]

Description:
- \( P \) = Percentage of Respondents' Answers for Each Item Statement (%)
- \( F \) = Frequency of Respondents' Answers for Each Item Statement
- \( N \) = Number of Respondents

The percentage results are interpreted in the table criteria below.

Table 3. Percentage Criteria for Student Response

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>81 ≤ x ≤ 100 %</td>
<td>Very practical</td>
</tr>
<tr>
<td>61 ≤ x ≤ 80 %</td>
<td>Practical</td>
</tr>
<tr>
<td>41 ≤ x ≤ 60 %</td>
<td>Practical enough</td>
</tr>
<tr>
<td>21 ≤ x ≤ 40 %</td>
<td>Less practical</td>
</tr>
</tbody>
</table>

(Arikunto, 2013)

Based on these criteria, the student worksheet is said to be practical if the percentage of results obtained is ≥ 61% with practical and very practical criteria. Response questionnaire data is supported by student observation data. The student activity observation sheet is used to observe relevant and irrelevant student activity activities in the learning process at a frequency of once every three minutes. The data obtained was analyzed by calculating the percentage of student activity with the formula below.

\[ \text{Activity percentage (\%)} = \frac{\sum \text{frequency of activity that occurs}}{\sum \text{overal activity frequency}} \times 100\% \]

The percentage results of students' activities are interpreted in Table 4. Students' activities are said to be practical if the percentage of relevant activities is ≥ 61% with practical and very practical criteria.

Analysis of effectiveness data obtained from pretest and posttest scores used to determine the improvement of critical thinking skills. The pretest and posttest data obtained will be analyzed and calculated using the n-gain score as follows.

\[ n\text{-gain score} = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}} \]

The results obtained are interpreted in the criteria table below.
Students' critical thinking skills are declared to have increased and PBL student worksheets are declared effective if the n-gain score $\geq 0.30$ with medium to high categories. Data on pretest and post-test scores were also analyzed using the t-test. The first step is to do a normality test using SPSS to ensure that the data is normally or abnormally distributed. The normality test used in this study used Shapiro-Wilk because the sample in this study was small scale (<50 data). The basis for making data distribution decisions $\alpha = 0.05$, if the significant value $>0.05$ then it is declared normally distributed. If the data is normal, then proceed with the paired sample t-test. The basis for decision-making is the sig value. (2-tailed) $< 0.05$ then $H_1$ is accepted, and if the sig value. (2-tailed) $> 0.05$ then $H_0$ is accepted.

IV. RESULT AND DISCUSSION

Research and Development (R&D) adapted from Ibrahim (2014) begins at the define stage, which is the stage to define the needs of the learning process. The define stage includes front-end analysis, student analysis, concept analysis, task analysis, and learning objectives analysis. The front-end analysis was conducted by analyzing the applicable curriculum at Senior High School 1 Sooko Mojokerto, which uses the revised K-13 curriculum for grade 12, and the independent curriculum for grades 10 and 11. The student analysis aims to examine the characteristics and cognitive development so that there is compatibility with the developed student worksheets. Students of Senior High School 1 Sooko Mojokerto have critical thinking skills that are still relatively low as evidenced by the results of pre-research critical thinking skills tests including indicators, interpretation, inference, analysis, and evaluation. Concept analysis is done by systematically compiling concept maps on redox reaction materials. Task analysis is the stage of identifying the tasks given to students when learning takes place by connecting the PBL learning model with critical thinking skills on redox reaction material with the sub-material of increasing and decreasing oxidation numbers, and electrolysis cells. Analysis of learning objectives is carried out by making learning objectives by the learning outcomes of phase F of the independent curriculum with redox reaction material.

The second stage is the design stage which includes format selection and initial design of student worksheets. Format selection is done by compiling the components of the student worksheets adapted from Pranowo (2012). The preparation of the format includes cover, title, general instructions, instructions for the worksheet, concept map, introduction, summary of material, and stages in the PBL model that are linked to the critical thinking skills of students, and bibliography. The initial design was carried out by designing and designing PBL student worksheets so that this stage obtained the first draft.

The third stage is the development stage including review, validation, and limited trials. The development stage is described as follows.

Product Review

PBL student worksheets are produced from stage two, namely in the initial design so that draft I is produced. There are two student worksheets developed, the first student worksheets with the sub-material of increasing and decreasing oxidation numbers, and the second student worksheets with the sub-material of electrolysis cells. The learning model used is the problem-based learning model with the stages of orienting students to the problem, organizing students to learn, guiding individual or group investigations, developing and presenting work, and analyzing and evaluating the problem-solving process. The PBL model student worksheets is linked to critical thinking skills which include indicators, interpretation, inference, analysis, and evaluation. The following is the design of the PBL-oriented student worksheets.

![Figure 1. Cover of Student Worksheets](image-url)

The cover of the student worksheet is presented with different images that are adjusted to the sub-material developed. On the cover page, there is the title of the student worksheet and a description of the model used, the model used is the PBL model. The difference in cover images aims to make it easier for students to distinguish the title of the worksheet. On the cover page, there is the title of the student worksheet and a description of the model used, namely the PBL model. At the top right, there is a student worksheet number that shows the sub-material developed, namely number 1 shows the sub-material of increasing and decreasing oxidation numbers, and number 2 shows the sub-material of electrolysis cells. In addition, there is also the identity of the authors and supervisors on the cover of the student worksheet. At the bottom, there is a place to fill in the class, group, and group member names, as well as a description of the class of student worksheet users.
Figures 2 and 3 are the design of the draft student worksheet by the results of the analysis in the previous stage. PBL student worksheets were produced in draft I, and then reviewed by the supervisor to collect input and provide suggestions for improving PBL student worksheets. The aspects reviewed in this student worksheet include content and construct. The results of the revised review resulted in draft II.

Product Validation

The revised student worksheet in the form of draft 2 was then validated by two chemistry education lecturers and one chemistry teacher at Senior High School 1 Sooko Mojokerto which included content and construct validity using a validation sheet. Content validation includes (1) the suitability of student worksheets with CP and ATP, (2) the PBL learning model, and (3) critical thinking skills. The construct validity criteria include (1) graphic criteria including news and images related to the material, and (2) linguistic criteria including clarity of information related to the use of simple sentences and easily understood by students. The assessment on the validation sheet was carried out by the validator by checking the available column with an assessment score in the range of 1-4. The validation data obtained was analyzed by determining the mode of each aspect. The score that often appears or becomes the mode is the validity value of the student worksheet developed. Student worksheets are said to be valid if they get mode \( \geq 3 \) (Lutfi, 2021). The following are the results of content and construct validation as follows.

<table>
<thead>
<tr>
<th>Validity</th>
<th>Worksheet 1</th>
<th>Worksheet 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Construct</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Based on the validation results above, the mode on the content criteria is 4 with a very valid category, so that from these results prove that the content contained in the student worksheet is by the learning objectives, the stages of the PBL model, and the indicators of critical thinking. This is by Hirza, et al (2023) learning objectives are prepared based on learning outcomes and the flow of learning objectives, this preparation must be by the provisions of ABCD (Audience, Behavior, Condition, Degree). Also, relevant to the research of Purwati, et al (2016) critical thinking refers to the ability to analyze and evaluate information obtained from observation, experience, reasoning, and communication to determine whether the information is reliable or not, so that valid and reasonable conclusions can be drawn.

In the construct criteria, a mode of 4 is obtained with very valid criteria, so that from these results it prove that the PBL student worksheet meets the criteria for grammar and language. Relevant to Andyani, et al (2023) the cover design of the student worksheet is made attractive because the initial part will represent the content of the material. Also relevant to Ayunda & Azhar's research (2023) student worksheets must use language that is easy to understand so that students understand the material and questions given. The validation results prove that the student worksheets developed are feasible based on the validity criteria, so they can be continued to the next stage, namely the limited trial stage.

Limited Trial

This stage is carried out after the developed student worksheet is completed in the improvement process in the form of draft III and declared valid. This stage was tested on 25 XII-grade students with the condition that they had received redox reaction material. Limited trials were conducted at Senior High School 1 Sooko Mojokerto in Grade 12 Science Class 7. Data collection was carried out for three meetings. The first meeting was taking pretest scores, the second meeting involved the use of student worksheet 1 with the sub-material of increasing and decreasing oxidation numbers, and the third meeting involved the use of student worksheet 2 with the sub-material of electrolysis cells, taking posttest scores, and filling out student response questionnaires. At the limited trial stage, practicality and effectiveness data were obtained.

Practicality

Practicality is the condition or criteria of the product developed in terms of ease of use. Practicality in this study was used to determine the feasibility of student worksheets developed through student response questionnaire sheets and student activity observation sheets. The following is a discussion of student activity data and student response questionnaires.

Student Response
The response questionnaire was used to find out the responses of students after using PBL-oriented student worksheets. The response questionnaire sheet contains 15 statements consisting of positive and negative statements. Students fill in the response questionnaire sheet by choosing the answer "Yes" or "No". Students will get a score of 1 if they answer "Yes" to a positive statement, and answer "No" to a negative statement. Response questionnaire data is said to be practical if the percentage obtained is ≥ 61% with practical criteria. The results of the student response questionnaire obtained a percentage of 98.4% with a very practical category obtained from the average number of all statements so that the student worksheet developed was feasible based on practicality criteria. Relevant to the research of Rochmatin & Muchlis (2023) the student response questionnaire on PBL-oriented student worksheets obtained a percentage of 88.9%-100% with a very practical category.

**Student Activity**

Observation of students' activities aims to determine all students' activities during the learning process (Ningtiyas & Nasrudin, 2021). In this study, students' activities were observed every three minutes. Students' activities were observed by six observers with each observer observing 1 group each.

In Figure 4, it is obtained that the relevant activity data for the first meeting and the second meeting get a greater percentage than irrelevant activities. Relevant activities increased in the second meeting from a percentage of 93.33% to 95%. As for the decrease in irrelevant activities of students at the second meeting from a percentage of 6.67% to 5%. This decrease was due to students being more orderly during the learning process. Student worksheets are categorized as very practical because the percentage of relevant activities obtained is > 61%. This is relevant to Anjarwati & Nasrudin's research (2022) that student activity is declared good if relevant activities are more significant than irrelevant activities. Also supported by research by Ramadhani & Muchlis (2023) activities observed while using student worksheets at meetings 1 and 2 get an average percentage of 90% and 95.60% so the percentage of relevant activities is higher than irrelevant activities at each meeting.

**Effectiveness**

The effectiveness of this study was reviewed from the critical thinking skills test sheet. The critical thinking test sheet was used to measure the improvement of students' critical thinking skills both before and after using PBL-oriented student worksheets. The research design uses a one-group pretest-posttest design, which means that research activities are tested twice, before treatment is known as the pretest, and after treatment is known as the posttest (Sugiyono, 2013). The pretest-posttest questions were presented with the same questions and contained 9 essay questions tailored to critical thinking indicators including interpretation, inference, analysis, and evaluation. Pretest and posttest data were tested for normality to ensure that the data were normally or abnormally distributed. The normality test used in this study used Shapiro-Wilk because the data used was less than 50 data (Muhun & Nasrudin, 2021). The basis for making data distribution decisions α = 0.05, if the significant value > 0.05, it is declared normally distributed and if the significant value ≤ 0.05, the data is declared not normally distributed (Putri, et al., 2023). The data obtained based on the Shapiro-Wilk normality test is presented in the following table.
Based on the normality test above, the pretest-posttest significance value is 0.063 and 0.521 so the data is said to be normal because the significance value is ≥ 0.05. Relevant to Ningtiayas & Nasrudin's research (2021) the results of the normality test show that the pretest score has a significance level of 0.093 and the post-test is 0.067, meaning that the data scores obtained are normally distributed. Normally distributed data is then analyzed using the paired sample t-test to test whether there is a difference in the average of two paired samples, these two samples mean the same sample but have two data. The hypothesis proposed is H₀ = there is no significant difference between the critical thinking skills of students on the pretest and posttest, and H₁ = there is a significant difference between the critical thinking skills of students on the pretest and posttest. The basis for decision-making is the Sig value. (2-tailed) < 0.05 then H₁ is accepted, and if the Sig value. (2-tailed) > 0.05 then H₀ is accepted. The data obtained from the paired sample t-test test results are presented in the following table.

### Table 7. N-Gain Score Results for Each Indicator

<table>
<thead>
<tr>
<th>No.</th>
<th>Critical Thinking Indicators</th>
<th>Pretest (%)</th>
<th>Posttest (%)</th>
<th>N-Gain score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Interpretation</td>
<td>58.7</td>
<td>94</td>
<td>0.85</td>
<td>High</td>
</tr>
<tr>
<td>2.</td>
<td>Inference</td>
<td>49.3</td>
<td>64.7</td>
<td>0.3</td>
<td>Medium</td>
</tr>
<tr>
<td>3.</td>
<td>Analysis</td>
<td>52</td>
<td>88</td>
<td>0.75</td>
<td>High</td>
</tr>
<tr>
<td>4.</td>
<td>Evaluation</td>
<td>40</td>
<td>63.3</td>
<td>0.39</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Based on the table above, the n-gain value on critical thinking skills obtained scores ranging from 0.3-0.85 in the moderate to high category. This proves that each indicator of critical thinking skills has increased from the pretest and posttest. This proves that PBL-oriented student worksheets can improve students' critical thinking skills. Students are more critical in identifying problems, formulating problems, making hypotheses, analyzing experimental data, and evaluating so that the developed student worksheets effectively improve students' critical thinking skills. Relevant to the research of Suci & Nasrudin (2018) critical thinking skills are very important for students to have through a scientific approach as used in the PBL learning model. It is also supported by Dewi & Azizah's research (2019) that the critical thinking skills of students have increased as evidenced in the n-gain score which has a score range of 0.529-0.901 with moderate to high categories.

### V. CONCLUSION

Based on the results and discussion of the research, it can be concluded that PBL-oriented student worksheets can improve students' critical thinking skills and are suitable for use. Feasibility on validity criteria in terms of content and construct validity obtained a mode of 4 very valid categories. Practicality criteria are reviewed from student activities and student responses. In the student's response, it gets a percentage of 98.4% with a very practical category, and in relevant student activities at meeting 1 and meeting 2 respectively, namely getting a percentage of 93.33% and 95.00% with a very practical category. The effectiveness criteria are reviewed based on the
improvement of critical thinking skills. The results of the paired sample t-test test obtained a sig. value of 0.000 < 0.05, so there is a significant difference between the critical thinking skills of students on the pretest and posttest. The results of the n-gain test by obtaining scores ranging from 0.33-0.85 in the moderate to high category, so that the student worksheets developed effectively improve students' critical thinking skills.

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AUTHORS

First Author – Salsa Nur Indarwati, Chemistry Education Department, Universitas Negeri Surabaya, salsa.20026@mhs.unesa.ac.id. 
Correspondence Author – Harun Nasrudin, harunnasrudin@unesa.ac.id, +62 815-1525-7040