Development of Student Worksheet Oriented on PBL and Science Literacy to Improve Students' Critical Thinking Skills on Buffer Solution Material

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ABSTRACT

This research intends to create a student worksheet that can be used to help students enchance their critical thinking skills. Validity, practicality, and effectiveness are taken into consideration when evaluating the viability of a student worksheet. The validity of the student worksheet is evaluated by specialists. Practice was based on student responses supported by activities during learning. Meanwhile, effectiveness was based on improving students' critical thinking skills in terms of classical learning completeness, N-gain, and non-parametric statistical tests. This research employed the Research and Development method devised by Borg and Gall, with 18 students from grade XI SMAN 20 Surabaya serving as research subjects. The research instruments used were validation sheets, response questionnaires, student activity observation sheets, and pretest and posttest question sheets. The results indicated that the student worksheet was usable. The evaluation results show the validity of the student worksheet, which received a score mode of 5 with a very good category. The practicality of student worksheet is seen from the positive response of students with a range of 88.9%-100% which is categorized as very practical. It is also supported by activities that are more relevant than irrelevant activities. The effectiveness of student worksheet is shown by the 89% completion of classical learning, medium and high N-gain criteria with successive percentages of 38.89% and 61.11%, and hypothesis tests with Sig. < 0.05 values.

Keywords: Development; student worksheet; PBL; science literacy; critical thinking skills.

INTRODUCTION

Learning activities, as defined by Law of The Republic of Indonesia No. 20 of 2003 governing the National Education System, are a sequence of interactions between students and teacher that take place in the learning environment. The existence of these behaviors and interactions is inseparable from the object studied, namely the subject.

There are various kinds of subjects taught at the Senior High School (SMA) level, one of which is chemistry. The content of the material discussion in it is contextual, abstract, and complex. This causes obstacles for students to understand chemical materials, one of which is in buffer solution material (Alighiri et al., 2018).

The application of the concept of buffer solution material is relevant to problems in the real world (Agam et al., 2022). These various problems can be solved by applying the concept of buffer solution material through training in science literacy questions. Broadly speaking, science literacy is the ability to apply scientific concepts as an effort to solve everyday problems (Wardani and Mitarlis, 2018).

One of the skills involved in science competence is critical thinking (Rahayuni, 2016). In other words, it takes critical thinking skills to complete science literacy exercises. Facione (2013) revealed indicators as part of critical thinking skills, some examples such as interpretation, analysis, and explanation.

Based on preliminary research at SMAN 20 Surabaya reveals that students' critical thinking skills are very low. The critical thinking skills test results show an average percentage of students' ability to solve interpretation questions of 41.67%, analysis indicator questions of 43.05%, and explanation indicator questions of 45.83%.

The low critical thinking skills in students are also proven through the results of Indonesia's

PISA assessment for the last 18 years. Indonesia has been in the bottom 10, far behind many other countries since its first participation in 2000 to 2018 (Hewi, 2020).

There are several factors that cause insufficient critical thinking skills, one of which is that students in learning activities are unprepared to tackle contextual problems that need reasoning and creativity (Asniar et al., 2022). To accomplish this learning, it is required to develop a teaching material in the form of a student worksheet that contains actual problems and practice questions which require ability to think critically to solve.

Currently, the student worksheet used in schools mostly only contains a general summary of the material. This results in participants being only memorizing the material, making it easy to forget. Students will struggle to solve questions that differ little when they are trained with them (Astuti et al., 2018).

Through the above problems, efforts are needed to improve critical thinking skills through a learning process that encourages students to actively find and explain information from various sources, then apply the concept as a solution to solve a problem, one of these is the use of a problem based learning (PBL) model. The PBL model contains various problem situations to students that are authentic and meaningful (Arends, 2012). This learning process also fosters student learning independence through the difficulties offered. Investigation and problem-solving activities in learning play a role in constructing students' critical thinking skills (Astuti et al., 2018).

The description described above is the background of this PBL-oriented and science literacy student worksheet development research. If a student worksheet meets the qualifying criteria for validity, practicality, and effectiveness, it is expected that it can be used to increase students' critical thinking skills.

RESEARCH METHODS

Types and Methods of Research

This research was a type of development research using Research and Development (R&D) methodologies by Barg and Gall (Sugiyono, 2015).

Research Subjects

The participants in this research were 18 students of grade XI MIPA 1 SMAN 20 Surabaya.

Data Sources

In this research, primary data was collected through validators, observers, and students.

Research Design

Data was collected through limited trial activities using one group pretest posttest design. The trial was conducted in a single group without any comparison class. Students are given an initial test (pretest) before treatment is applied. Furthermore, treatment in the form of learning activities is applied with the application of developed student worksheet. After the treatment is applied, a final test (posttest) is given to students.

Table 1. One Group Pretest Posttest Design

Research Design		
O_1	X	O_2

Information:

O_1 = test results before the application of PBL-oriented student worksheet and science literacy (pretest scores)

X = application of PBL - oriented student worksheet and science literacy

O_2 = test results after the application of PBL-oriented student worksheet and science literacy (posttest scores)

Place and Time of Research

Student worksheet trial research was limited to SMA Negeri 20 Surabaya, located at Jalan Medokan Semampir Indah No. 119, Medokan Semampir, Sukolilo District, Surabaya, East Java. The research activity will be carried out on May 22-26, 2023.

Data Collection Techniques

In order to assess the viability of student worksheets to increase students' critical thinking skills, appropriate data collection techniques are needed. In this research, several kinds of data

collection techniques were employed, including validation, observation, tests, and questionnaires.

Research Instruments

The viability of student worksheet is reviewed from aspects of validity, practicality, and effectiveness. The validation instrument sheet is used to validate the authenticity of student worksheet based on the validity aspect. On the other side, the response questionnaire, which is supported by observation sheets of student activities, is used to assess the practicality aspect. Meanwhile, the effectiveness of student worksheet is measured through pretest and posttest question sheets.

Data Analysis

The collected data is then processed by descriptive-quantitative analysis methods, which are in the form of numbers and reinforced by descriptions in the form of data descriptions.

a. Analisis of Validation Sheets

The scores given for each aspect of the assessment on the validation sheet are in accordance with the likert scale, which is in the range 1-5 (Riduwan, 2016).

Table 2. Likert Scale Categories and Ranges on the Validation Sheet

Assessment Categories	Score
Very good	5
Good	4
Good enough	3
Not good enough	2
Bad	1

The data of validation results is analyzed by calculating the score mode of each assessment with the following conditions:

1) If a score mode of ≥3 is obtained on the assessment aspect, then the aspect is declared valid.
2) If the <3 score mode is obtained on the assessment aspect, then that aspect is declared invalid. Therefore, revision and revalidation are needed (Lutfi, 2021).

b. Analysis of Student Response Questionnaires

The response questionnaire contains a number of positive and negative statements. Students respond in the form of "Yes" or "No", according to the Guttman scale.

Table 3. Scores and Assessment Criteria for Student Response Questionnaire Answers

Answer	Positive Statement Score	Negative Statement Score
Yes	1	0
No.	0	1

The response to the response questionnaire statement item is analyzed by calculating the number of positive responses of students in percentage form using the equation:

$$\text{Response (\%)} = \frac{\sum \text{Answer score obtained}}{\sum \text{Maximum score}} \text{x} 100\%$$

In positive statements, a positive response is the number of students who respond "Yes". While. In negative statements, a positive response is the number of students who give a "No" response. The student questionnaire analysis results are then evaluated in accordance with Table 4.

Table 4. Intervals and Score Criteria for Student Response Questionnaires

Interval	Kriteria
0% - 20%	Impractical
21% - 40%	Less practical
41% - 60%	Quite practical
61% - 80%	Practical
81% - 100%	Very practical

Based on the criteria in the table above, student worksheet is considered practical if it receives ≥ 61% positive response from students (Riduwan, 2016).

c. Analysis of Student Activity Observation Sheets

Analyzing student activity observation sheets requires calculting the percentage of relevant and irrelevant activities in learning activities using the following equation:

$$\% \text{ Time} = \frac{\sum \text{Frequency of activity that appears}}{\sum \text{Overall activity frequency}} \text{x} 100\%$$

If the number of relevant activities is more than the number of irrelevant activities, the student worksheet is said to be practical (Riduwan, 2016).

d. Analysis of Pretest and Posttest Scores

The analysis of pretest and posttest scores is carried out through the completeness of learning outcomes, N-gain calculations, normality tests, and hypothesis tests.

1) Completeness of Learning Outcomes

Individually, students are said to have completed learning if they achieve a minimum completeness score according to the provisions of the school. While classically, learning completeness is achieved when ≥ 85% of students have met the minimum completeness score. The completeness of classical learning is calculated using the equation:

$$\% \text{ Completeness of classical learning} = \frac{\sum \text{Students with } \geq \text{KKM grades}}{\sum \text{Students taking the test}} \text{x} 100\%$$

(Afrita, 2021)

2) N-gain score

The N-gain score is calculated to measure whether or not student's critical thinking skills have improved. The following equation is used to get the N-gain score:

$$(\text{g}) = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Max score} - \text{Pretest score}}$$

The N-gain calculation data from the students will subsequently be categorized as shown in Table 5.

Tabel 5. N-gain Score Category

Nilai *N-gain*	Kategori
$0{,}7 < (g) < 1$	High
$0{,}3 \leq (g) \leq 0{,}7$	Medium
$0 < (g) < 0{,}3$	Low

The developed student worksheet has been declared effective if N-gain score is obtained which is categorized as medium or high (Hake, 2002).

3) Normality Test and Hypothesis Test

The prerequisite test must be met before entering the hypothesis test is the normality test with the help of the SPSS application. This test is designed to detect whether the distribution of data obtained is normal or abnormal (Sugiyono, 2015).

When a Sig. value of > 0.05 is obtained in the normality test, it indicates that the data is dispersed normally, so the Paired Sample T-test hypothesis (t-test) is carried out. However, if the resulting Sig. value < 0.05, it means that the data is abnormally distributed. Thus, another alternative hypothesis test was carried out, namely the Wilcoxon Signed Rank Test. If a Sig. value of > 0.05, the hypothesis test results indicate that H_0 is accepted and H_1 is rejected. If the value of Sig. < 0.05, then it is concluded that H_1 is rejected and H_1 is accepted.

RESULTS AND DISCUSSION

Research Results

The results of this research are in the form of PBL-oriented student worksheet products and science literacy developed through the stages of development research (R & D) according to Borg and Gall (Sugiyono, 2015). There are ten stages of research according to Borg and Gall. However, this research is only limited to the limited product trial stage, which is described further bellow:

1. Preliminary Study Stage

a. Potential and Problems

In this section, data collection activities or information needed as material for student worksheet design are carried out. The data or information is obtained through literature studies and field studies.

b. Data Collection

At this stage, diagnostic tests and questionnaire dissemination are carried out on students. Through diagnostic tests, it is known that sudents are poorly trained to implement critical thinking skills in the learning process. Meanwhile, the majority os students regard buffer solutions to be difficult content, according to the results of the response questionnaire.

2. Development Study Stage

a. Product Design

The development stage of student worksheet begins with designing the design to the content

and other supports contained in the student worksheet. Design of student worksheet is carried out as attractive as possible starting from the cover design, layout, content, to the layout in student worksheet. The developed student worksheet products are arranged according to the syntax of the PBL learning model accompanied by exercises on science literacy questions. So at this stage Draft 1 was produced.

b. Product Design Review and Revision

Draft 1 at the product design stage is then reviewed process. This stage aims to obtain suggestions and inputs that can be used as material for improving student worksheet products, resulting in Draft 2.

c. Product Validation

Draft 2 was then validated by three validators consisting of a chemistry teacher at SMAN 20 Surabaya and two chemistry lecturers at Surabaya State University. The validity of student worksheet is reviewed using the criteria of content, construct, and presentation. student worksheet is considered valid if it obtains a score mode of ≥ 3 in each aspect (Lutfi, 2021).

d. Product Design Revision

After the validation process, then revisions were made to the student worksheet following the suggestions and inputs provided by the validators.

e. Product Trials

After repairs, student worksheet trial activities were carried out on a limited basis. This activity was carried out on students of grade XI MIPA 1 SMAN 20 Surabaya who had received buffer solution learning materials. There were a total of 18 students that were the subjects of this research consisted of six students from high, medium, and low class groups. There are 6 people each. Student worksheet trial activities were carried out during four meetings described in Table 6.

Table 6. Student Worksheet Trial Activity Schedule

Number.	Day, Date	Time	Activity
1.	Monday, 22 May 2023	13.30 – 14.15	Pretest
2.	Tuesday, 23 May 2023	10.30 – 12.00	1st meeting of student worksheet trial
3.	Thursday, 25 May 2023	13.30 - 15.00	2nd meeting of student worksheet trial
4.	Friday, 26 May 2023	08.15 – 09.15	Posttest and dissemination of student response questionnaires

Discussion

1. Validity

One of the eligibility criteria for student worksheet is assessed from the aspect of validity which is reviewed based on the criteria of content, construct, and presentation. The content's validity involves the compatibility of student worksheet with the material, curriculum, indicators, and learning objectives. Construct validity includes the suitability of student worksheet with the learning model and skills to be achieved. While the presentation criteria, including linguistic and graphic components. The validation results are ordinal data which is then analyzed using the determination of the mode of each aspect of the assessment. The results of student worksheet validation are described in Table 7.

Table 7. Student Worksheet Validation Results

Number.	Assessment Aspect	Score Mode	Category
1.	Content	5	Very good
2.	Construct	5	Very good
3.	Presentation	5	Very good

Based on Table 7, each aspect of the student worksheet assessment as a whole obtained a score mode of 5 at the validation stage with a very good category. student worksheet is considered valid if it obtains a score mode of ≥ 3 in each aspect (Lutfi, 2021). So that student worksheet can be declared to have met the validity criteria. Student worksheet is suitable to be used as teaching material to improve students' critical thinking skills on buffer solution material.

2. Practically

The practicality aspect is evaluated based on the student responses to the developed student worksheet. Students respond to statements in questionnaires distributed via google form links. The response questionnaire includes various positive and negative statements with the answer "Yes" or "No". Student worksheet is declared practical if a percentage of positive responses is obtained of ≥ 61% (Riduwan, 2016).

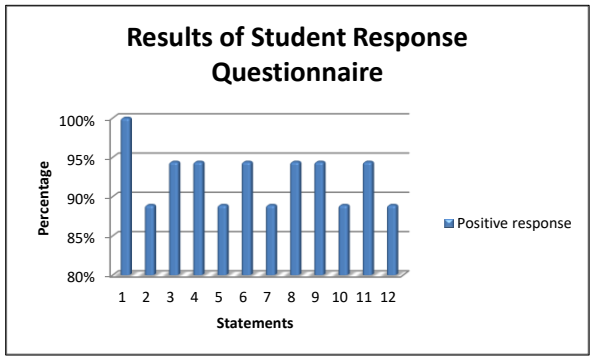

Figure 1. Percentage graph of student response questionnaire results

In Figure 1, it can be seen that the overall statement in the response questionnaire obtained a percentage of ≥ 61% with a range of 88.9%-100% which is categorized as very practical (Riduwan, 2016).

Student responses are also supported from activities during learning activities by applying student worksheet oriented to PBL and science literacy. Student worksheet is said to be practical if it contains a higher percentage of relevant activities than irrelevant activities during learning activities (Riduwan, 2016).

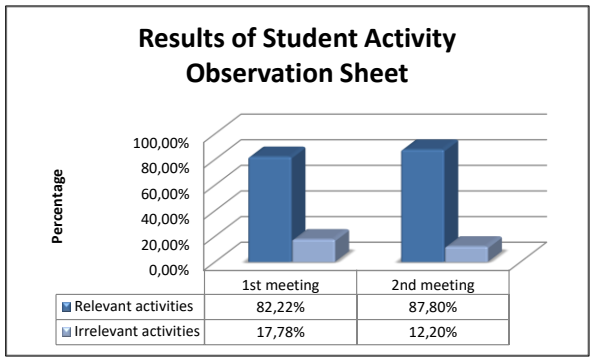

Figure 2. Percentage graph of student activity observation sheet results

In Figure 2 it is known that at both meetings a greater percentage of relevant activities than irrelevant activities were obtained. In the first meeting, 82.22% of activities were relevant to learning and increased in the second meeting, which was 87.80%. In addition, there was a decrease in the emergence of irrelevant student activities. At first in the first meeting by 17.78% to 12.22% in the second meeting. This decrease is caused by students who have begun to get used to the learning carried out.

The student worksheets might be declared practical during the learning process using what has been done, because relevant activities are higher than irrelevant activities (Riduwan, 2016). Thus, student worksheet is feasible to be used as an effort to improve students' critical thinking skills on buffer solution material.

3. Effectiveness

The effectiveness aspects of student worksheet are reviewed based on the pretest and posttest scores. The pretest results are test scores before the implementation of student worksheet. Meanwhile, posttest scores were obtained after implementing PBL-oriented student worksheet and science literacy trial activities.

On the pretest and posttest question sheets, a reading of the phenomenon is presented which is then developed into five points of description questions tailored to the domain of science literacy and indicators of critical thinking skills. Critical thinking is one of the abilities needed for scientific competence (Rahayuni, 2016). In other words, it takes critical thinking skills to complete science literacy exercises. In this research, there are three indicators of critical thinking skills measured, namely interpretation, analysis, and explanation.

The domain of science literacy used in the preparation of pretest and posttest questions is the domain of context, knowledge, and competence. Each of these domains of science literacy is related to each other.

The phenomena presented are forms of context domains that are personal. The phenomena presented are used to answer the questions given. While the pretest and posttest question items contain two domains of science literacy. These domains are knowledge, content, and competence to explain phenomena scientifically. The content knowledge domain is

knowledge about the natural world (in the form of chemical concepts) used to explain phenomena (OECD, 2019). The competence domain and the critical thinking indicators of analysis, interpretation, and explanation have a connection between them (Zahroh and Yuliani, 2021).

In this research, aspects of student worksheet effectiveness were measured through learning completeness, N-gain calculation, normality test and hypothesis test. The test is based students' pretest and posttest scores.

a. Completeness of Learning Outcomes

Individually, students achieve learning completeness if they can obtain a minimum score in accordance with school regulations, which is 70. In line with this, the completeness of classical learning is achieved if as many as ≥ 85% of students have reached a score of 70.

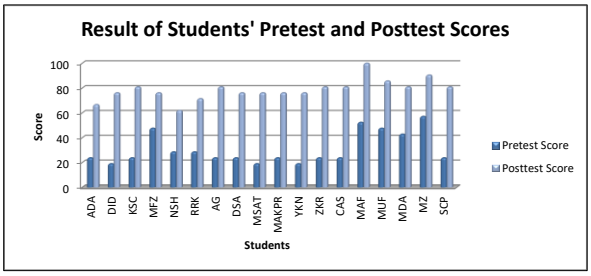

Figure 3. Graph of students' pretest and posttest scores

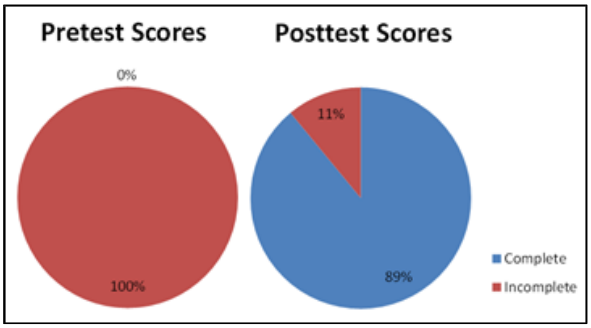

Figure 4. Classical completeness diagram of students

Through Figures 3 and 4, none of the students achieved individual completeness before implementing student worksheet oriented towards PBL and science literacy, so that classical learning completeness was 0%. Meanwhile, based on the posttest scores obtained after applying the student worksheet, it can be seen that there are only 2 of all students who do not achieve minimum scores, so that classical learning completeness is 89% obtained. Thus, student worksheet is said to be effectively used as an effort to improve students' critical thinking skills.

b. N-gain Score

In addition to being assessed from the completeness of learning, the increasing of students' critical thinking skills is also measured by the results of the N-gain calculation. Individually, student are said to experience improved critical thinking skills if they obtain N-gain with categories medium ($0{,}3 \leq (g) \leq 0{,}7$) or high ($g > 0{,}7$) (Hake, 2002).

Table 8. N-gain results in students' critical thinking skills

Number.	Students	N-gain Score	Category
1.	ADA	0,58832	Medium
2.	DID	0,7059	High
3.	KSC	0,75	High
4.	MFZ	0,63631	Medium
5.	NSH	0,53339	Medium
6.	RRK	0,66667	Medium
7.	AG	0,75	High
8.	DSA	0,66667	Medium
9.	MSAT	0,68753	Medium
10.	MAKPR	0,75	High
11.	YKN	0,7059	High
12.	ZKR	0,75	High
13.	CAS	0,75	High
14.	MAF	1	High
15.	MUF	0,72719	High
16.	MDA	0,66661	Medium
17.	MZ	0,77788	High
18.	SCP	0,75	High

Table 8 shows that N-gain score were obtained in the medium and high categories of 38.89% and 61.11% respectively. It can be concluded that student worksheet is effectively used to improve students' critical thinking skills on buffer solution material.

c. Normality Test and Hypothesis Test

There is a significant difference between students' critical thinking skills before and after the developed student worksheet trial can be known through hypothesis testing. Before

entering the hypothesis test, a normality test is first carried out on the data obtained.

Tests of Normality

	Shapiro-Wilk		
Statistic	Statistic	df	Sig.
,298	,794	18	,001
,278	,870	18	,018

a. Lilliefors Significance Correction

Figure 5. Pretest and Posttest Value Normality Test Results

The pretest Sig. value in Figure 5 is 0,001, and the posttest Sig. value is 0,018. Both Sig values are < 0.05, indicating that the data distribution occurred abnormally. To overcome this, another alternative hypothesis test was carried out in the form of the Wilcoxon Signed Rank Test. The following hypothesis have been proposed:

1) H_0 = there is no statistically significant difference between the pretest and posttest scores of students.
2) H_1 = there is a statistically significant difference between the pretest and posttest scores of students.

Test Statistics[a]

	posttest - pretest
Z	-3,763[b]
Asymp. Sig. (2-tailed)	,000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Figure 6. Wilcoxon Signed Ranked Test Results

Through the hypothesis test, the value of Sig. < 0.05 was produced. Therefore, it is possible to conclude that H_0 is rejected and H_1 is accepted. This shows a significant difference in students' pretest and posttest scores. Thus, PBL-oriented student worksheet and science literacy developed are effectively used as an effort to improve students' critical thinking skills.

CONCLUSION

Based on the research, it can be concluded that student worksheet oriented on PBL and science literacy is worthy of being used as teaching material to improve students' critical thinking skills on buffer solution material.

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