Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Application of E- worksheet Oriented on PBL Model to Improve Critical Thinking Skills on Acid-Base Material

Maharani Puspita Nur Azizah*, Muchlis

Chemistry Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Surabaya, Indonesia
*E-mail: maharanipuspita.20034@mhs.unesa.ac.id

Received: October 27, 2024. Accepted: November 28, 2024. Published: November 30, 2024

Abstract: Humans often interact with substances containing acids and bases daily. Learning in schools in grade XI, namely in phase F, one of the element achievements that students must complete is that students can use the concept of acids and bases in everyday life. Students are expected to have critical thinking and open minds through scientific work increasingly and, at the same time, strengthen the profile of Pancasila students, especially honest, objective, critical reasoning, creative, independent, innovative, collaborative, and globally diverse. The objective of the research will be to enhance students' critical thinking ability in E-worksheet learning-oriented Problem-Based Learning models within the subject matter of acid and base. The research design used is a descriptive quantitative approach with a pre-experimental design using a "Pretest-Posttest Control Group design ". The sample used in this research was 36 students in two classes XI of SMAN 1 Waru, Sidoarjo City. Data were collected using observation sheets, tests, and questionnaires. Two lecturers and a chemistry teacher validated the instruments to collect data. Data analysis used N-Gain to explain how much students' critical thinking skills increased. It was found that students' critical thinking skills increased significantly, with 63,9% of students in class XI-1 and 83,3% in class XI-5 obtaining N-Gain scores included in the high category, which falls into a high category. The results of the study confirm that E-worksheets oriented towards PBL are effective in developing critical thinking skills in chemistry among students, especially on the topic of acids and bases.

Keywords: Acids and Bases; Critical Thinking Skills; E-worksheet; Problem-Based Learning.

Introduction

Chemistry is a branch of science concerned with studying the composition, structure, properties, and changes of matter and the energy changes accompanying such transformations [1]. Chemistry is one of the sciences that studies the nature and characteristics of substances and elements found in nature. Chemistry is also closely related to everyday life phenomena [2]. By observing, experimenting, and critically analysing the substance interaction and transformation process, chemists intend to explain the minute details of such methods, which, in turn, explain the basics of our natural world.

In educational contexts, chemistry is regarded as one of the complex, abstract subjects that require considerable attention from students, especially on key and, at the same time, complicated subjects like acid-base. Acids and bases are abstract, yet their presence is felt in everyday life-from the sour taste of citrus fruits to the bitter nature of soap [3]. The high school level, especially at the eleventh-grade level, must bridge the gap between these two abstract concepts and their real-life applications. These are the current educational goals, as stated in the curriculum, in which the students had to apply these chemical concepts in solving real-world problems, thus developing critical thinking and analytical skills, which will be very helpful for scientific literacy [4].

However, even as understanding these concepts is essential, acids and bases are often cited among the topics students need help understanding. This difficulty comes about because the acid-base concept is abstract, contextual, and factual. Developing a conceptual view of acid-base requires abstract proton transfer and ionisation ideas that are not directly observable. Contextual acid-base characteristics require using indicators such as litmus paper and universal indicators to identify substances' acidic or basic nature [5]. It also relates to everyday experiences, such as the acidity of lemon juice and the basicity of baking soda. Factual characteristics of acids and bases include those related to everyday life; for example, oranges taste sour, and soap tastes bitter, in addition to the rusting of iron by strong acids such as HCl and H_2SO_4 [6]. The abstract, contextual, and factual characteristics of acid-base material require students to have the ability to formulate problems from a phenomenon, make analyses, and draw conclusions. Interpreting, analysing, and inferencing skills are 3 of the six critical thinking skills, according to Facione [7]. Students' critical thinking skills need to be improved by inviting students to see the relationship between the theory studied and the facts that can be attributed to existing experiments and data.

Acid-base material is one of the chemical materials that is closely related to everyday problems. Teachers can provide learning experiences to students by bringing up a real problem or phenomenon [8]. Acid-base material that emphasises daily life can be learned by using the PBL model. Suci & Harun [9] stated that to provide acid-base material to students, a learning method is needed that involves a lot of student activity in mastering the information or concepts

How to Cite:
Azizah, M. P. N., & Muchlis, M. (2024). Application of E- worksheet Oriented on PBL Model to Improve Critical Thinking Skills on Acid-Base Material. *Jurnal Pijar Mipa*, *19*(6), 1047–1051. https://doi.org/10.29303/jpm.v19i6.7970

being studied so that it will be more meaningful and more manageable for students to understand. Research conducted by Manullang [10] states that the Problem-Based Learning (PBL) model affects students' critical thinking skills on acid-base materials.

Preliminary studies conducted at SMAN 1 Waru showed that students felt that the acid-base material was one of the most complex topics in chemistry, with 83% failing to understand the concept well enough to apply classroom learning to everyday phenomena. Moreover, it was revealed that critical thinking skills in analysis and solving acid and base problems need to be better developed. It can be seen in the pre-test regarding essential thinking skills before the research conducted that 100% of students in class XI MIPA need to master more to pass grade 75.

Considering the enormity of the problem and the requirement to enhance students' awareness and critical thinking skills, it will be imperative to adopt instructional strategies that would make abstract concepts tangible and actively involve students in learning. One such strategy is the PBL model, which espouses student-centered learning through real-world problem-solving activities. According to Arends [11], PBL involves students in logical and critical analytical thinking, analogies and divergent thinking, creative integration and synthesis. PBL also enhances collaboration, critical thinking, and applying theoretical knowledge in problem-solving among students, as stated by Suprihatiningrum [12].

To facilitate more effective learning through PBL, the employment of E-worksheet-based digital learning tools has been suggested. E-worksheets can quickly provide students with an interactive and stimulating learning experience because they are supported by multimedia resources and interactive tasks that can be set for learners according to their needs, as stated by Syafitri & Tressyalina [13]. Previous studies have proven that integrating E-worksheets with PBL impressively improves students' critical thinking skills. Research conducted by Ayirahma & Muchlis [14] stated that E-LKPD, which adopted the PBL approach, effectively enhanced essential thinking skills in acid-base material. With all those promising results, 86% of SMAN 1 Waru Sidoarjo students reported never using such digital tools in their chemistry classes. This clearly shows the need for innovative instructional methods in classes to address such learning gaps.

This study aims to improve students' thinking skills by using the E-worksheet-oriented PBL model. Students' critical thinking skills on acid-base materials can be enhanced by using an E-worksheet oriented to the PBL model/ Critical thinking skills will be beneficial for students to understand acid-base material better and help face various problems because students must be actively involved in the learning process and can build their understanding. Similarly, the PBL model emphasises the process of thinking critically and analytically to formulate a problem independently, then collect data, make hypotheses and draw conclusions. In the PBL model, activities are also carried out that require students to practice critical thinking skills in solving problems related to daily life.

Research Methods

This research is a type of quantitative descriptive research. According to Sugiyono [15], quantitative descriptive research analysis is used to analyse data by describing or depicting the collected data as it is without intending to draw conclusions that apply to the public or generalisations. The research design used is pre-experimental with the "Pretest-Posttest Control Group design" method. This given approach is to be used since the assessment of the effectiveness of the E-worksheet oriented on the PBL model on students' critical thinking skills. This study tries to measure the improvement in students' abilities by comparing the pretest and the posttest scores in the control and experimental classes.

The respondents were 36 students in two classes from grade XI in SMAN 1 Waru Sidoarjo, selected using purposive sampling. Both classes were first given a pretest with the same test. Then, the experimental and control groups were given treatment, namely learning using an E-worksheet oriented to the PBL model. The chosen students were divided into two classes, namely XI-1 as the experimental class and XI-5 as the control class, consisting of 36 students in each class. The participants were chosen for the study because they had never experienced the E-worksheet model earlier; therefore, they would be appropriate in measuring its effectiveness in changing critical thinking skills.

The instruments used included a pretest and posttest to measure the students' critical thinking skills before and after implementing the E-worksheet-oriented PBL model. In the test, a few essay-type questions were prepared to check three crucial critical thinking skills: interpretation, analysis, and inference. Observation Sheet: Used for observing or recording the implementation of the E-worksheet by the PBL model by the teacher during learning. Student Activity Observation Sheet: This would be used to monitor and assess the relevance of the student activities during the learning process. Student Response Questionnaire: This shall elicit responses from the students concerning implementing the E-worksheet oriented on the PBL model and their engagement in learning. Two chemistry lecturers from Universitas Negeri Surabaya and one chemistry teacher from SMAN 1 Waru Sidoarjo validated all instruments to ensure their validity and reliability for data collection.

Data were collected through the following techniques. Pre- and post-testing: The student's critical thinking skills were measured before and after implementing the E-worksheet oriented on the PBL model. Pre-tests were done before commencing with the E-worksheet, oriented on the PBL model to see the beginning skills. At the same time, a post-test was conducted after implementing the E-worksheet oriented on the PBL model to measure an increase in these skills. Observation: The teachers were observed and recorded on structured observation sheets for their activities and that of the students throughout the learning process. This was necessary to ensure faithfulness in implementing the E-worksheet-oriented PBL model. A questionnaire was given to students at the end of the intervention to gather some information on their learning experience and perceptions of the E-worksheet oriented on PBL model implementation.

Data analysis was done using descriptive and inferential statistics as follows:

Descriptive Analysis: This outlined the implementation of the learning model and student activities. To this end, the percentage of the observed activities and responses that agreed with the expected outcomes for the E-worksheet, as instructed by the PBL model, was determined.
Inferential Analysis: In analysing the critical thinking improvement score pretest-posttest, calculations used the N-Gain formula. The N-Gain formula is as follows:

$$\text{N} - \text{Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum Score} - \text{Pretest score}}$$

The next test carried out is the t-test. The t-test is one of the tests used to determine whether or not there is a significant (convincing) difference between the two sample means (averages) [16]. Using the Minitab application, analysis was conducted by employing a t-test to see how the level of significance of the difference between pretest and posttest scores would behave in the experimental class and the control class. The right-sided t-test is conducted with the null hypothesis (H0), which reads “equal to”, and the alternative hypothesis (Ha), which reads “greater” [17].

Results and Discussion

The first hypothesis tried to establish how much improvement has occurred in students' critical thinking skills following implementing an E-worksheet oriented on the PBL model. The pretest and posttest scores were subjected to the N-Gain formula to determine the increase in critical thinking skills. Table 1 shows the N-Gain scores of students in class XI-1.

Table 1. Recapitulation of N-Gain Scores of Pretest and Posttest on Critical Thinking Skills in Class XI-1.

Student Name	Pretest Score	Posttest Score	N-Gain	Result
ARM	50	81	0.63	Medium
ANR	38	81	0.69	Medium
ARB	44	81	0.67	Medium
ANNF	25	88	0.83	High
ARH	50	81	0.63	Medium
AEA	56	100	1.00	High
AS	31	88	0.82	High
AMF	31	88	0.82	High
AMPS	31	94	0.91	High
BA	38	81	0.70	Medium
DRS	44	94	0.89	High
DAS	56	100	1.00	High
DF	38	81	0.70	Medium
DT	31	88	0.82	High
ELS	31	94	0.91	High
FSP	25	88	0.83	High
GBI	38	81	0.70	Medium
IR	31	88	0.82	High
JS	25	94	0.92	High
MFS	38	81	0.70	Medium
MAS	38	88	0.81	High
MRH	31	94	0.91	High
MTF	44	94	0.89	High
MZ	31	94	0.91	High
NH	44	94	0.89	High
NS	25	88	0.83	High
RA	38	81	0.70	Medium
RH	31	88	0.82	High
RSA	44	94	0.89	High
SNA	38	81	0.70	Medium
Total (Medium)	13 Students			36.1%
Total (High)	23 Students			63.9%

Table 1 shows a significant increase in the students' critical thinking skills, with 63.9% of students reaching the high category and 36.1% in the medium category. This demonstrates the effectiveness of the E-worksheet oriented on the PBL model in improving students' critical thinking skills. This happens because students have been trained to think critically when learning using the PBL model-oriented E-worksheet, which has been adjusted to include essential indicators of thinking of interpretation, analysis, and inference. E-worksheets cover systematic aspects of E-worksheets so that they can help participants and educators develop knowledge, initiative, problem-solving, and skills [18].

Table 2. Recapitulation of N-Gain Scores of Pretest and Posttest on Critical Thinking Skills in Class XI-5.

Student Name	Pretest Score	Posttest Score	N-Gain	Result
AS	38	88	0.79	High
AZF	44	88	0.78	High
ADT	38	81	0.70	High
BR	31	81	0.73	High
BSR	31	81	0.73	High
CNA	56	94	0.86	High
CARW	31	81	0.73	High
DD	56	81	0.57	Medium
DN	63	100	1.00	High
DMHP	31	88	0.82	High
GAS	38	88	0.80	High
KAMS	44	81	0.67	High
KKPS	38	81	0.79	High
MYA	44	81	0.67	Medium
MAP	38	88	0.80	High
MNF	50	100	1.00	High
MZT	44	88	0.78	High
NK	50	88	0.75	High
NNNM	31	88	0.82	High
NAL	44	81	0.67	Medium
OTA	38	81	0.70	High
PRTPEP	31	81	0.73	High
PNF	38	88	0.80	High
RCS	56	94	0.86	High
RPW	50	94	0.88	High
RIS	56	88	0.71	High
RR	44	88	0.78	High
SNA	31	88	0.82	High
SSR	25	81	0.75	High
SDA	38	88	0.80	High
Total (Medium)	6 Students			16.7%
Total (High)	30 Students			83.3%

From these results, the number of students who entered the high N-Gain category was 30 students (83.3%), while 6 (16.7%) entered the medium category. Each indicator of critical thinking skills of students in the

experimental class, namely class XI-1 and the control class, namely XI-5, increased. This is in Fisher's [19] opinion that critical thinking is an active thinking process that comes from oneself so that one can choose from several choices. The learning process with the PBL model will activate students in answering or solving every problem in the worksheet that presents issues related to daily life and impact increasing students' critical thinking skills during the problem-solving process [20]. Worksheets encourage students to learn actively and make learning easier [21]. This problem-based learning E-worksheet makes students learn more actively and directs students to discover concepts independently through learning activities [22]. This is by research conducted by Ayirahma & Muchlis [14] that an E-worksheet which adopts the PBL approach and uses it has been proven effective in improving critical thinking skills in acid-base material, as evidenced by a significant increase in N-gain. To determine whether the results of enhancing students' critical thinking skills in the control class XI-5 can strengthen the improvement in students' critical thinking skills in the experimental class XI-1, a difference test was carried out on the posttest in both classes using the right-sided t-test.

Test

Null hypothesis	H_0: μ_difference = 0
Alternative hypothesis	H_1: μ_difference ≠ 0

T-Value	P-Value
-0.42	0.675

Figure 1. Results of the Posttest t-test for Class XI-1 and Posttest for Class XI-5.

It can be seen in Figure 1 that the p-value obtained is 0.675 where the result is > 0.050, then the statistical hypothesis obtained is H0 is accepted, and Ha is rejected; it can be said that there is no significant difference in the posttest in both classes. This means that the posttest value of class XI-1 equals the posttest value of class XI-5. PBL is learning that uses real (authentic) problems that are unstructured and open as a context for students to develop problem-solving and critical thinking skills while simultaneously building new knowledge because the PBL model is a learning model that has the potential to connect many problems in everyday life [23]. The research conducted by Hayati & Nuriyah [24] also, the problem-based learning worksheet effectively trains students' critical thinking skills, with an effective percentage of 60%.

Conclusion

The research results showed that implementing an E-worksheet based on PBL could effectively improve students' critical thinking skills in material acid base. Such results align with increased students' critical thinking skills in experimental class XI-1 and control class XI-5. That experimental class XI-1 had 63.9% of the students in the category of high N-Gain; this means there is an outstanding improvement in critical thinking abilities after implementing an E-worksheet oriented towards the Problem-Based Learning (PBL) model. Meanwhile, control class XI-5 had a higher percentage, 83.3%. This indicates that the method of learning applied is very positive for both congruent classes with relevant results. Critical thinking is an active thinking process that originates from oneself so that the best choice can be obtained from several alternatives. Through the results of the right-sided t-test, the results of improving the critical thinking skills of students in control class XI-5 can strengthen the improvement of the critical thinking skills of students in class XI-1. The increased critical thinking skills for most students in both classes indicate that problem-based learning integrated with an E-worksheet helped students develop better analysis, interpretation, and inference skills. Therefore, it is the end; from this point, the implication of E-worksheet enhances students' critical thinking skills and provides tangible evidence that such an approach enhances learning outcomes of complex materials such as acids and bases. With results of significance in both classes, this learning model is suggested to be applied more widely in a chemistry education context for the better performance improvement of students' overall critical thinking skills.

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