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Socio-Scientific Issue Application in the PBL Model: Is that Effective in Improving Chemical Literacy?

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Abstract: Science education, especially chemistry, emphasizes the application of science to solve problems encountered in daily life to foster chemical literacy skills. This study aims to prove the impact of socio-scientific issue (SSI) application in the problem-based learning (PBL) model on student's chemical literacy ability on acid and base materials. This study employed a quasi-experimental method through a pretest-posttest nonequivalent control group design. Its population consisted of 11th-grade science students from one of Surakarta's public high schools in the 2023/2024 academic year. It used class XI.6 as the control class and class XI.7 as the experimental class. The sample was established using the cluster random sampling technique. Based on the analysis of the hypothesis test carried out with the independent sample t-test, the Sig. value is 0.000. The mean chemical literacy score in the experimental class is 72, whereas that in the control class is 62. The enhancement of chemical literacy in the experimental class is 63% (quite effective), while that in the control class is 50% (less effective). This proves that the effect of SSI application in the PBL Model on students' chemistry literacy ability was more significant than the PBL without SSI application.

Keywords: acid and base, chemical literacy, problem-based learning, socio-scientific issue

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INTRODUCTION

Science literacy refers to an individual's ability to link scientific concerns and ideas with an object to solve a problem (OECD, 2017). This ability allows individuals to apply science concepts in life to solve problems through decision-making based on scientific evidence (Handayani et al., 2018). This skill becomes a benchmark of the country's growth. Based on the evaluation of the PISA literacy test in 2018, Indonesia achieved a mean science literacy score of 396, whereas in 2022l Indonesia obtained a mean score of 382 (OECD, 2023). These results indicate the science literacy of Indonesian students has decreased and is in the low category because it is below the universal average of 485 (Haetami et al., 2023). Science literacy skills can be developed through various sciences, one of which is chemistry (Celik, 2014). Therefore, chemical literacy is an essential part of science literacy (Cigdemoglu et al., 2017).

The ability to understand how science and technology relate to each other to explain chemical phenomena and make environmental changes for the better is known as chemical literacy (Schwartz et al., 2006). Moreover, chemical literacy can be described as the student's ability to identify, evaluate, connect, and communicate chemical events using scientific reasoning to solve real-world problems (Perkasa & Aznam, 2016). A person is defined as having chemical literacy ability if he or she can understand chemistry and connect it to the environment and social life, understand the ideas, rules, concepts, and fundamental ideas of chemistry, and can apply their scientific process skills (Ad'hiya & Laksono, 2018). The poor science literacy scores of Indonesian students based on the PISA 2022 literacy test results can imply that students' chemical literacy skills are also weak (Fadly et al., 2022).

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The main factors that can affect students' low chemical literacy are the limited variety of learning models and learning context teacher uses (Puspitasari et al., 2024). In the 21st century, learning is encouraged to involve science materials that cover multi-disciplinary socio-scientific issues (Morris, 2014). However, the teaching strategy that teachers often use tends to be through reading material activities carried out by students (Yaumi et al., 2019). The teaching activities conducted by the teacher by providing apperception and problem orientation to students are not contextual enough with their lives, so they cannot participate in the learning process (Phandini et al., 2023). They grasp science only as a concept and cannot apply the knowledge to their daily lives (Fortuna & Fitria, 2021). Therefore, the low chemical literacy skills of students must be overcome immediately. Increasing students' chemical literacy can also be done by giving a contextual problem (Husniyyah et al., 2023).

A socio-scientific issue (SSI) is a social issue that contains a scientific component, including various other disciplines and interests, and is controversial, so it requires moral judgment (Evagorou et al., 2012). SSI has the potential to be implemented as a framework for teaching science in schools, can be integrated with real problems, and can be used as a basis for students to investigate science content (Rostikawati & Permanasari, 2016). The application of SSI can also make learning activities more interesting and relevant to students because of the correlation between science learning and its real-life and real-society applications (Chen & Xiao, 2021). Chemical literacy will be fulfilled if students have chemical knowledge and apply it to solve real-life problems (Yaumi et al., 2019). Hence, SSI is appropriate to be used in teaching to encourage students' chemical literacy (Cian, 2020).

Socio-scientific issues can be applied to several learning models, especially the problem-based learning model. This model allows students to learn and share experiences to solve real problems, thus stimulating the development of students' ways of thinking (Natalia DS, 2017). The problem orientation presented in this model encourages students to actively participate in the teaching-learning process. The analytical skills and curiosity of students can be linked through this problem orientation (Yulianti & Gunawan, 2019). This learning model has advantages, i.e. (1) enhancing science literacy and critical thinking abilities so students can face problems, (2) being able to encourage students to take part in learning activities so they can create their concepts, (3) facilitating scientific activities, (4) allowing students to evaluate their progress in learning, and (5) helping students to build communication skills (Nisa et al., 2021).

According to the conclusions of interviews performed with the chemistry teachers at one of the public high schools in Surakarta, acid-base materials are abstract materials, especially in the acid-base concept. Moreover, acid-base material requires reasoning and mathematical concepts, thus it makes students have difficulty understanding the material (Rezeki & Kamaludin, 2023). Moving on from this problem, acid-base material is the chemistry material chosen to be studied in the context of SSI learning in the PBL Model.

Acid-base material fulfills three standards of content selection based on PISA. First, it is actual and relevant to everyday life, authentic, and acid-base concepts related to process competencies (Nurisa & Arty, 2019). Furthermore, this content contains accurate, theoretical, procedural, and cognitive processes information, both abstract and tangible concepts, and abilities that are often used in life (Muntholib et al., 2020). Acid-base material can be explained through SSI as a learning context (Wiyarsi et al., 2021). Some issues contain the concept of acid-base material and can be explained through SSI as a learning context, such as acid rain, ocean acidification, global availability of clean water, water pollution, and food sovereignty in acidic soil. Thus, acid-base material was chosen to be taught through the SSI learning context in the PBL Model to develop students' chemical literacy skills.

According to the explanation above, the research problem is formulated as follows: "What is the effect of implementing socio-scientific issues (SSI) into the PBL Model on 11th-grade students' chemical literacy skills in acid-base materials?" Based on the problem formulated, this research aims to prove the impact of implementing SSI into the PBL Model on 11th-grade students' chemical literacy skills in acid-base materials.

RESEARCH METHOD

The quantitative descriptive method with a pretest-posttest nonequivalent control group design was used in this study. This study was held from January 2024 to June 2024. The population was all

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11th-grade students (XI.1 until XI.7) in one of the public high schools in the city of Surakarta in the 2023/2024 academic year, consisting of 254 students.

The sample of this research consists of 36 students of XI.6 and 37 students of XI.7. The sample was established using the cluster random sampling technique through normality and homogeneity test using the results of the final semester summative assessment (PSAS) chemistry scores in the 2023/2024 school year. The two classes used as the sample in this study are the experimental class (XI.7) that received the application of SSI in the PBL learning model, and the control class (XI.6) that received treatment without the application of SSI within the same model.

The instruments used in this study are teaching modules, student worksheets, and a chemical literacy test. Each instrument was validated by two experts and confirmed valid and they were appropriate for use. The test consisted of 11 essay questions and was tested for reliability, difficulty level, and discrimination power using ANATES software.

Based on the ANATES software results, 11 questions are questions with a medium level of difficulty in different categories of discrimination power: four questions are sufficient, five questions are good, and two questions are very good. The reliability results show that the pretest (r = 0.88) and posttest (r = 0.91) questions have been reliable in the very high category. The test questions were prepared using chemical literacy indicators according to Shwartz (2006) in the form of content aspects, chemistry in context, high-order learning skills (HOLS), and attitudes/affective as shown in Table 1.

Table 1. Chemical Literacy Indicators

No.	Chemical Literacy Aspects	Indicator
1.	Content	a. conducting scientific inquiry, making generalizations, and proposing theories to describe the phenomena of the universe b. recognizing that chemistry describes macroscopic phenomena in the form of the molecular structure of matter c. knowing that chemistry investigates the dynamics of processes and reactions d. knowing and describing life in terms of the chemical structure and processes of the living system
2.	Chemistry in Context	a. understanding the importance of chemical knowledge in explaining everyday phenomena b. using chemical understanding in solving problems
3.	High-Order Learning Skills (HOLS)	a. asking questions and seeking information about chemical issues b. analyzing the pros/cons of a problem
4.	Attitude/Affective	showing interest in chemistry-related issues.

Descriptive and inferential statistical techniques were applied for this data analysis. Data such as pretest and posttest results of students' chemical literacy skills that have been obtained were analyzed for percentage achievement of chemical literacy skills and N-Gain score.

$$\text{Percentage achievement of chemical literacy} = \frac{\text{student scores}}{\text{highest score}} \times 100\%$$

The N-Gain score test was used to identify the effectiveness and improvement of students' chemical literacy skills after they were given different treatments. The N-Gain score formula is as follows:

$$\text{N-Gain score} = \frac{\text{score after treatment} - \text{score before treatment}}{\text{highest score} - \text{score before treatment}}$$

According to Hake (1998), the N-Gain scores are classified into three categories, namely low, medium, and high, as shown in Table 2.

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Table 2. N-Gain score category

Gain factor (g)	Category
More than 0.7	High
From 0.3 to 0.7	Medium
Lower than 0.3	Low

The effectiveness of the n-gain score can be known from the percentage of N-Gain according to Sukarelawan et al., (2024). The percentage of the N-Gain score is presented in Table 3.

Table 3. Percentage of N-Gain score category

N-Gain Percentage (%)	Category
Lower than 40	Not effective
From 40 to 55	Less effective
From 56 to 75	Quite effective
More than 76	Effective

This study used the independent sample t-test with the IBM SPSS 26 software to test the hypothesis. This test uses the difference between the pretest-posttest scores of the experimental and control classes (gain score). This test can be used if the data are normally distributed and homogeneous. A normality test is needed to check normal data distribution. The normality test used is the Sapiro-Wilk test with the help of IBM SPSS 26 software. A homogeneity test is needed to determine the distribution of homogeneous data. The homogeneity test used is Levene's test with the help of IBM SPSS 26 software.

According to Arends (2012), the learning syntax in the PBL Model is orientating problems, organizing students to learn, guiding individual and group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process. This study implements SSI as a learning context in the PBL Model, and it is presented in Table 4.

Table 4. The implementation of SSI in the PBL Model

PBL Model Syntax	Process of Socio-scientific Issue (SSI) Implementation	Chemical Literacy Aspects
1st Phase: problem orientation	The teacher introduces the SSI to the students as a real problem that is relevant to chemistry.	Content and Chemistry in Context
2nd phase: organizing students to learn	The teacher organizes the students to recognize the presented SSI as a learning assignment related to chemical ideas, while the students can group according to the instructions given by the teacher and follow the teacher's directions to solve the problem in groups.	Content and Chemistry in Context
3rd phase: guiding individual and group investigations	Students gather knowledge about the SSI linked to chemical topics, with the teacher participating as a facilitator.	Higher-Order Learning Skills (HOLS) and Chemistry in Context
4th phase: developing and presenting work results	SSI becomes a topic of discussion during the learning in the class. Students can communicate the outcomes of their SSI discussion in class, with the teacher participating as facilitator and mediator.	Content, Chemistry in Context, and Higher-Order Learning Skills (HOLS)
5th phase: analyzing and evaluating the problem-solving process	Students can solve and find a solution to SSI as a learning context by analyzing and evaluating it with their teacher.	Attitude/Affective

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The selection of SSI in this learning fulfills several criteria, namely authentic, relevant, providing opportunities for evaluation, having the potential for open discussion, and connected with science and technology (Stolz et al., 2013). The SSIs used from the first meeting to the fourth meeting were acid rain, Japanese nuclear waste pollution, and food sovereignty on acidic soil in Indonesia.

The SSIs used in the chemical literacy test were acid rain, ocean acidification, the impact of leachate water pollution, the impact of nickel mine waste pollution, and leakage in the household product industry. The use of this issue is in line with previous research on the context of SSI that can be used in learning acid-base topics, namely acid rain (Rahayu, 2019), environmental pollution (Genisa et al., 2020), biodiversity (Wiyarsi & Çalik, 2019), global warming, household products, medical drugs, and ocean acidification (Fadly et al., 2022).

FINDINGS AND DISCUSSION

Data Description

The findings show that there are substantial differences in chemical literacy skills between the experimental and control groups. The difference in ability can be seen from the mean score of chemical literacy skills, N-Gain values, percentage of N-Gain values, and the percentage of chemical literacy skills aspect. The mean score of chemical literacy ability can be seen in Figure 1.

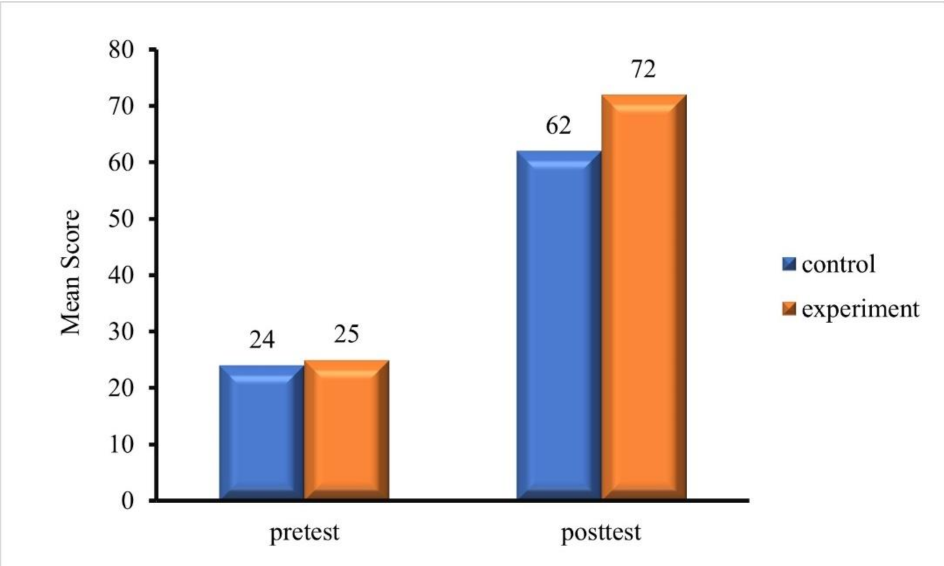

Figure 1. The mean score of chemical literacy ability

Figure 1 shows that the pretest results of the experimental and control classes have almost the same mean value and standard deviation, which indicates that the two groups started at almost the same level of ability. Furthermore, based on the post-test results, the experimental class has an average chemical literacy score of 72 while the control class's average score is 62 (Figure 1). The N-Gain score and percentage of the N-Gain score can be seen in Table 5.

Table 5. N-Gain score and percentage of n-gain score

Class	Mean score		N-gain score	Criteria	Percentage of N-gain score	Category
	Pretest	Posttest				
Control	24	62	0.50	Medium	50%	Less effective
Experiment	25	72	0.63	Medium	63%	Quite effective

Table 5 shows that the experimental class n-gain score of 0.63 is higher than the control class n-gain score of 0.50. Based on the N-gain criteria, the score obtained is in the medium category. Based on the interpretation of the N-gain effectiveness percentage, the experimental class has a percentage of 63% (quite effective), while the control class has a percentage of 50% (less effective). This shows an increase

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in chemical literacy in the moderate category and the application of SSI in the PBL Model is quite effective in improving students' chemical literacy skills in acid-base material.

This difference is due to the teacher using SSI as a learning context that connects the material with real-life applications in the experimental class. SSI as a learning context presented in the experimental class could make students observe the problem through various points of view and use the material concepts, and they had to solve the problem so that students in the experimental class had better abilities than control class students. This is because SSI has the main characteristics that can improve chemical literacy skills as follows: (1) it uses relevant and controversial problems, and it requires evidence to make decisions to solve the problem; (2) it uses scientific and social issues that serve to encourage students to engage in communication, discussion, debate, and reasoning; (3) it includes ethical aspects both implicitly and explicitly; and (4) it emphasizes student character building as a long-term learning goal (Zeidler, 2014).

Student's chemical literacy achievement

This study uses a conceptual definition from Shwartz et al., (2006), where chemical literacy is an awareness of the fundamental features of matter, chemical processes, chemical rules and theories, and the widespread use of chemistry in everyday life. Individuals with chemical literacy skills must comprehend the fundamental concepts of chemistry. According to Shwartz et al., (2006), chemical literacy is composed of four components, i.e. chemical knowledge (content), chemistry in context, higher-order learning skills (HOLS), and attitudinal or affective aspects. The percentage achievement of students' chemical literacy skills can be seen in Table 6.

Table 6. Percentage achievement of students' chemistry literacy

The chemical literacy skills aspect	Control Class Achievement (%)		Experiment Class Achievement (%)	
	Pretest	Posttest	Pretest	Posttest
Content	18.11	66.72	11.66	73.82
Chemistry in context	20.83	73.96	16.89	91.89
Higher-order learning skills (HOLS)	31.94	57.81	37.95	65.99
Attitude/Affective	26.74	46.88	34.12	58.11
Mean	24.41	61.34	25.15	72l.45

Table 6 shows that the achievement of the content aspect in the experimental class of 73.82% was superior to that in the control class of 66.72%. This difference in achievement occurred because the teacher used SSI as a learning context to attract students in the experimental class so that they could actively explore SSI content related to acid-base material. The application of SSI in teaching and learning activities makes students actively participate through developing, sharing, and applying their knowledge to overcome issues connected to the SSI (Wiyarsi et al., 2021).

The achievement of the chemistry in context aspect in the experimental class of 91.89% was superior to that in the control class of 73.96%. The high achievement in the experimental class was because the teacher linked chemical concepts with SSI as a learning context so that students in the experimental class could understand chemical concepts more easily. SSI, as a context utilized in learning, incorporates issues connected to life, which helps students understand the learning context (Gul & Akcay, 2020).

The achievement of the higher-order learning skills (HOLS) aspect in the experimental class of 65.99% was higher than that in the control class of 57.81%. The high achievement in the experimental class was because the teacher used SSI as a discussion topic in the learning process. SSI as the context of the problem to be solved provides students with space to have a discussion (Qamariyah et al., 2021).

The attitude aspect is the aspect that shows the lowest achievement compared to other aspects. According to the results of the interview, students stated that the chemical literacy questions on the aspect indicators have a fairly high difficulty level and require a high level of reasoning so some students

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can do it but some cannot (Yani & Afrianis, 2022). The achievement of the attitude aspect of the experimental class of 58.11% was superior to the control class of 46.88%. The high achievement in the experimental class was because the teacher sharpened the students' ability to take action to overcome the problems that occur by considering various aspects of life. This is in line with previous research which states that the application of SSI can develop students' critical attitude toward scientific information so that they can apply the knowledge they already have to the environment and society (Tidemand & Nielsen, 2017). The application of SSI can also increase students' awareness as part of the environment where students must participate in protecting it (Rery & Rahmasari, 2023).

Students' chemical literacy skills enhancement

The results of this study also revealed that students who studied using the application of SSI in the PBL Model had increased chemical literacy skills. The results of the improvement of students' chemical literacy skills can be shown in Figure 2.

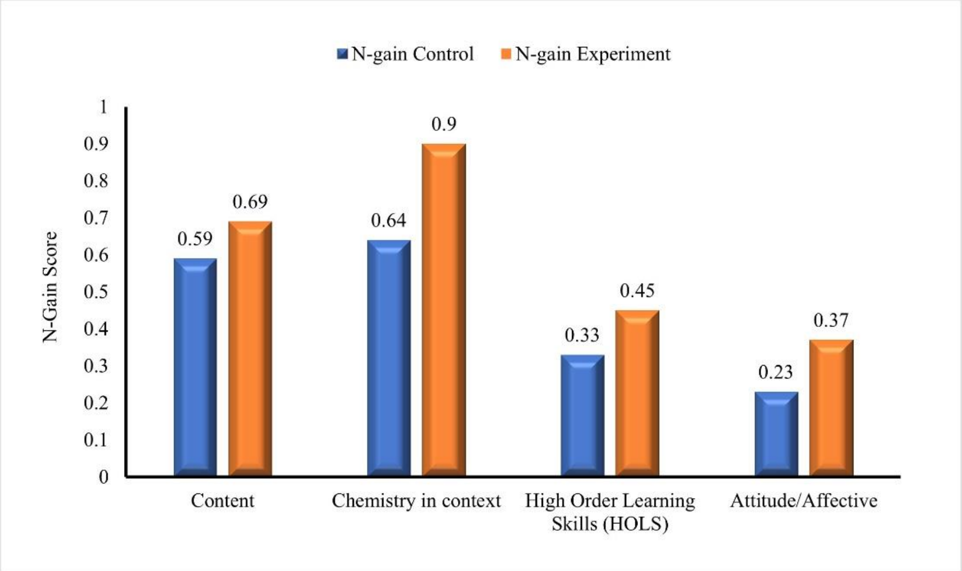

Figure 2. Chemistry literacy aspects enhancement

Figure 2 shows that the aspect of chemistry in context is the aspect that has the highest enhancement compared to other aspects, both in the experimental and control classes. This is because the aspect of chemistry in context is the aspect that teachers emphasize through the application of SSI during the teaching process.

Prerequisite test

The difference in pretest-posttest scores (gain score) between the experimental and control classes must be examined for normality and homogeneity before testing the hypothesis. The normality test results are shown in Table 7.

Table 7. Normality Test

Variable	Class	Sig.	Decision	Conclusion
Difference between pretest and posttest scores of Chemical literacy ability (Gain Score)	Control	0.129	H_0 rejected	Normal Data
	Experimental	0.190	H_0 rejected	Normal Data

Based on the normality test results of the Sig. > 0.05, the data are normally distributed. Based on the homogeneity test results, the Sig. > 0.05 (0.107), the data have been distributed homogeneously (Table 7).

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Hypothesis Test

According to the analysis of the prerequisite tests, the data were normally distributed and homogeneous, which allowed for hypothesis testing using the independent sample t-test. This test was carried out using IBM SPSS 26 software and the results can be seen in Table 8.

Table 8. Hypothesis test result

Variable	Sig.	Decision
Chemical literacy ability	0.000	H_0 rejected

According to the hypothesis test results, the value of Sig. is < 0.05 (0.000), so the application of SSI in the PBL Model affects chemical literacy skills (Table 8). Thus, the result of this study shows that implementing socio-scientific issues (SSI) into the PBL Model affects students' chemical literacy skills. This finding is in line with research conducted by Fadly et al. (2022) and Wiyarsi et al. (2021) that socio-scientific issue implementation in learning activities has a significant impact on students' chemical literacy. This can be explained by Jean Piaget's cognitive development theory, Bruner's learning theory, and Vygotsky's social constructivism theory.

The findings of this study support Jean Piaget's cognitive development theory which states that high school students including children over 11 years old enter the formal operational level. The theory also states that children are curious and strive to understand the world around them so they try to learn from their environment (Rabindran & Madanagopal, 2020). Students at this level can know the form of argument and can think abstractly. The learning model used in this study, which is the PBL Model, can encourage students to research, integrate theory with practice, and explore knowledge through a problem in-depth (Rézio et al., 2022). On the other hand, the application of SSI in the PBL Model also plays a role. Socio-scientific issue application in the PBL Model can present issues that require students' understanding to be able to provide ideas (Minin & Fauziah, 2022).

The findings of this study support Bruner's learning theory which claims that the process of learning is carried out through three stages, i.e. (1) the information acquisition process, (2) the information transfer process, and (3) the process of evaluating the relevance and accuracy of knowledge. The PBL Model used in this study allows students to actively participate during the learning process. Learning stages in the form of information acquisition can be carried out at the PBL stage, which guides individual and group investigations. The student’s role at this stage is that students can conduct discussions in groups to obtain information, while the teacher mobilizes students to find information. High-ability students can play a supporting role in the group. Medium-ability students can be rewarded for their efforts, while low-ability students can receive help and encouragement from friends to increase their motivation (Luo, 2019). The information transfer stage is carried out at the stage of developing and presenting work. The role of students at this stage is that they carry out presentation activities to communicate the results of their discussions, while the teacher assists students in organizing these activities. The stage of evaluating the relevance and accuracy of knowledge is carried out at the stage of analyzing and evaluating the problem process. At this stage, the student’s responsibility is to reflect during learning, while the teacher has to guide students in reflecting on and evaluating the process and results of the investigation they have done.

The findings also support Vygotsky's social constructivism theory where children learn more effectively and efficiently when they work together with their classmates in a supportive environment and with teacher direction. This research uses the application of SSI in the PBL learning model which has the potential to make students become active learners so that they can develop their knowledge through interaction during the learning process. The interaction that occurs in the learning process involves three components, which are educators (teachers), students, and the context of the problem to be solved. SSI as the context of the problem to be solved provides students with opportunities to discuss (Qamariyah et al., 2021). Socio-scientific issue implementation in education also encourages active participation in discussions, debates, and dialogue among students so that it opens opportunities to restructure students' perception of their knowledge idea (Cahyarini et al., 2016).

Contribution and Relevance of Research Results to the Future

The results of this study have the potential to be applied in learning chemistry in materials other than acid-base, such as petroleum (Nurhadi, 2022), organic chemistry (Ambrogi & Eilks, 2023), and chemical kinetics (Rery & Rahmasari, 2023). The results of this study also show that students who learn using the application of SSI in the PBL Model have better chemical literacy skills compared to students who learn without applying SSI. This was shown by students in the experimental class who connected and used their knowledge to solve real-world challenges. Students are focused on overcoming problems from various aspects of life, such as knowledge, culture, and morals by applying SSI to learning (Li & Guo, 2021). Therefore, the findings of this study can support national education in Indonesia in the 21st century, where the goal of education during this period is not only to provide extensive knowledge to students, but also to cultivate scientific attitudes, noble values, and commendable attitudes in social life that focus on science, mathematics, and humanities (Afandi et al., 2019).

CONCLUSION

This study reveals that using SSI in the PBL Model affects chemical literacy skills with Sig. <0.05 which is 0.00. The experimental class had a higher average posttest score for chemical literacy abilities (72 points) than the control group (62 points). The experimental class's improvement in chemical literacy abilities was 0.63 (medium), with a percentage of 63% (very effective), whereas the control class's gain was 0.50 (medium), with a percentage of 50% (less effective). This study also found that the aspect of chemistry in context had the highest achievement aspect, with an increase of 0.90 (high) in the experimental class and 0.64 (medium) in the control class. The subsequent study is expected to investigate internal student factors or other factors that can affect students' chemical literacy skills, especially when applying SSI in the PBL Model.

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