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Implementation of the STEM-PBL Approach in Online Chemistry Learning and its Impact on Students' Critical Thinking Skills

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ABSTRAK

Kimia merupakan salah satu cabang ilmu pengetahuan yang sangat penting karena berkaitan dengan fenomena yang sering terjadi dalam kehidupan sehari-hari. Pada pembelajaran kimia siswa diajak untuk mempelajari materi serta perubahannya. Pembelajaran kimia dinilai sangat abstrak karena tidak bisa dilihat secara langsung menggunakan mata telanjang. Hal ini menyebabkan sebagian besar siswa SMA beranggapan bahwa kimia merupakan mata pelajaran yang sulit. Keterbatasan pembelajaran pada masa pandemi Covid-19 mempengaruhi berbagai kemampuan yang dimiliki siswa. Siswa menunjukkan keterampilan berpikir kritis yang kurang yaitu belum mampu menganalisis dan memberikan solusi pada soal sederhana. Tujuan penelitian ini adalah untuk mengembangkan keterampilan berpikir kritis siswa melalui penerapan pendekatan STEM-PBL pada pembelajaran online. Metode penelitian ini menggunakan metode deskriptif kualitatif dengan instrumen lembar observasi dan soal tes. STEM terintegrasi dalam PBL menjadi salah satu solusi untuk meningkatkan keterampilan berpikir kritis siswa. Hasil penerapan STEM-PBL menunjukkan peningkatan keterampilan berpikir kritis siswa dalam memecahkan permasalahan kehidupan sehari-hari. Siswa juga mampu mendesain alat untuk memecahkan masalah dan mengintegrasikan berbagai disiplin ilmu.

ABSTRACT

Chemistry is a very important branch of science because it deals with phenomena that often occur in everyday life. In chemistry learning, students are invited to study the material and its changes. Chemistry learning is considered very abstract because it cannot be seen directly by the naked eye. It causes most high school students to think that chemistry is difficult—limitations of learning during the Covid-19 pandemic affected various abilities possessed by students. Students lack critical thinking skills, namely, the inability to analyze and provide solutions to simple problems. The purpose of this research is to develop students' critical thinking skills through the application of the STEM-PBL approach to online learning. This research uses a qualitative descriptive method with observation sheet instruments and test questions. STEM integrated into PBL is one of the solutions to improve students' critical thinking skills. The results of the application of STEM-PBL show an increase in students' critical thinking skills in solving everyday problems. Students can also design tools to solve problems and integrate various disciplines.

1. INTRODUCTION

Chemistry is a very important branch of science because it deals with phenomena that often occur in everyday life. In chemistry learning, students are invited to study the material and its changes. Chemistry learning is considered very abstract because it cannot be seen directly by the naked eye. It causes most high school students to think that chemistry is difficult (A. Agustina, 2017; Zakiyah, Ibnu, & Subandi, 2018). Redox and electrochemical reactions are topics that are considered difficult by students because they have submicroscopic aspects of understanding the events of electron capture and release (Harianto, Suryati, & Khery, 2019) coupled with the current pandemic, which affects various sectors of people's lives, including

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the education sector. This situation is a new challenge for students and teachers to be able to continue to carry out learning and solutions in understanding chemistry material and other subjects.

The Indonesian education system has also undergone many changes to adapt to the situation and reduce the spread of the Covid-19 virus. The teaching and learning process originally face-to-face at school became distance learning using available technology (Lutfi, Aini, Amalia, Umah, & Rukmana, 2021; Nadeak, Juwita, Sormin, & Naibaho, 2020). In reality, this change in the learning system is a new challenge for students and teachers at school. Many difficulties are faced with online learning (Hernanda, Kumalasani, & Danawati, 2021; Sholichin, Zulyusri, Lufri, & Razak, 2020). Constraints to the availability of learning media, lack of mastery of science and technology, internet networks, and even the mentoring process are becoming increasingly difficult (Dian Primasari & Zulela, 2021). Amidst the many obstacles in online learning, students must continue developing the skills needed in this century.

One of the important student abilities to pay attention to in online learning is the ability to think critically. Critical thinking is the ability everyone has to be able to analyze ideas or ideas in a more specific direction to gain knowledge and understand relevant information by evaluating evidence (Effendi, Herpratiwi, & Sutiarso, 2021; Kurniati, Khairil, & Darwin, 2019). Critical thinking skills can help students solve existing problems, such as questions or real-life problems. Critical thinking can guide students in connecting learning materials with their daily lives (Kurniati et al., 2019; Satwika, Laksmiwati, & Khoirunnisa, 2018). This ability helps students identify and analyze problems and then find and implement solutions to these problems (Suryaningsih & Koeswanti, 2021).

However, several research results show that students' ability to think critically (identify problems, formulate problems, create hypotheses, process data, and draw conclusions) is still lacking (Muharni & Mustami, 2019). During the online learning period, students' thinking skills also decreased because students only got material files and assignments without any practice in the lab (Purwanto et al., 2020; Sholichin et al., 2020). Based on the results of observations at a private school in Yogyakarta, when learning chemistry, it was found that students were still unable to think critically in the learning process. Students could not complete and solve simple questions given by the teacher, and some answered that they did not know when asked questions. During the first week of teaching activities, students were given essay questions, and the average student score was 86.9, exceeding the Minimum Completeness Criteria set by the school. Even though the description test results showed that student learning outcomes were good enough, eight students were below the Minimum Completeness Criteria. They were unable to analyze the questions given. Students are not able to recognize which are redox reactions and which are not redox reactions, and students are also unable to distinguish between the two methods of equalizing redox reactions. Twelve students were above the Minimum Completeness Criteria with a score range of 80-95. However, they needed help writing down the steps for redox reaction balancing precisely and systematically. Some students can get an equivalent reaction or the correct final result, but the processing steps must be corrected. This fact is in line with the results of observations which show a lack of critical thinking skills, namely solving or answering questions given critically. If this situation continues, it will affect learning and student outcomes. The solution can be done to overcome this problem is that teachers must be able to choose and use appropriate approaches, learning models, and learning media.

One learning approach that encourages and trains students' critical thinking is applying the Science, Technology, Engineering, and Mathematics learning approach, also known as STEM education. STEM learning integrates science, technology, engineering, and mathematics learning which is very much needed in encouraging students' skills in the 21st century (Davidi, Sennen, & Supardi, 2021; Santoso & Mosik, 2019). In its implementation, STEM can be integrated with various learning models such as Problem Based Learning (PBL), Project Based Learning (PjBL), Discovery Learning, and Inquiry-Based Learning (Putri, Pursitasari, & Rubini, 2020; Setia Permana, Nyeneng, & Distrik, 2021). STEM integration with PBL provides opportunities for students to apply knowledge to existing problems or issues in solving problems (Farwati, Permanasari, Firman, & Suhery, 2017; Hasanah, Tenri Pada, Safrida, Artika, & Mudatsir, 2021). PBL also requires students to know to solve problems (Farwati et al., 2017). STEM-PBL is a solution to overcome the problem of the need for modern learning skills because it can train students' critical thinking as well as logical and systematic thinking. Students who can use their knowledge critically in solving problems are one of the competencies needed in this 21st era.

This study's results align with several previous studies, which showed that learning with the STEM approach improved students' critical thinking skills (Davidi et al., 2021). Subsequent research has shown that using the PBL model in the learning process in class can improve students' critical thinking skills (Effendi et al., 2021; Utami, Koeswati, & Giarti, 2019). Subsequent research has shown that the use of the STEM approach integrated with the PBL model is valid and feasible so that it is effectively used in the learning process (Arifin, 2020; Oktaviani, Anom, & Lesmini, 2020). Several studies have shown that the STEM learning model integrated with the PBL model can improve students' critical thinking skills to be suitable for learning. Previous research on using the STEM approach has been carried out a lot. However, there needs to research on using the STEM approach in online chemistry learning. For this reason, this research aims to develop students' critical thinking skills through the STEM-PBL learning approach in online learning.

2. METHOD

The method used in writing this article is descriptive qualitative. Data collection before application by conducting class observations and giving description questions to class XII IPA students in a Yogyakarta private high school. The data collection technique is to give STEM project assignments on Electrochemistry in groups. A guide rubric is given to make it easier for students to work on projects. The rubric also makes it easy to measure students' achievements. The scoring criteria for the rubric are provided in Table 1.

Table 1. Criteria for Assessing Electrochemical STEM Projects

CRITERIA			
SCIENCE:	**TECHNOLOGY**	**ENGINEERING*:***	**MATHEMATICS**
- Be able to explain the principle of the voltaic cell in the design. - Describe the chemical reactions that occur - apply an understanding of chemical properties to the materials and tools used.	- Design tools using today's technology (Ex, Canva, PPT, word, etc)	- Designing an innovative tool - Aesthetically appealing design - The tool Sin the design has the function of a problem solver and has an easy-to-use form.	- Write down the research steps. - Include calculations regarding tool design (size, weight etc.)

3. RESULT AND DISCUSSION

Result

The analysis of observational data and practice questions found problems with students' skills in critical thinking during online learning, available in Table 2, and Table 3.

Table 2. Data on Students' Critical Thinking Skills Problems in Online Learning

Indicator (Critical Thinking)	Analysis	Expectation	Problem (Evidence)
Able to provide innovative ideas/solutions to solve a problem	The teacher asks students to explain and give examples of how to practice the teachings of their religion to be able to understand chemical material in learning	Students can provide examples of the application of their religious teachings to be able to help understand chemical material in learning, especially during online	One student answered that they did not know, and three were confused by the teacher's questions.
Able to answer simple and complex questions clearly and precisely	The teacher gives two review questions regarding the molarity formula and what is the value of R in the osmotic pressure formula	Students can answer questions correctly, namely stating the molarity formula (M = mol/Volume) and 0.082 for the value of R	Two designated students answered did not know
Able to use the knowledge that has been learned to solve a systematic and structured problem	The teacher gives questions about equalizing redox reactions after studying the material.	Students can do the exercises correctly and correctly or fulfill the teacher's answer key.	Students still need help to answer the questions correctly, cannot identify redox reactions, and must help distinguish between the two requested methods. Students get the right final results, but the work

Indicator (Critical Thinking)	Analysis	Expectation	Problem (Evidence)
			steps need to be more systematic. Some don't even include work steps.

Table 3. Results of STEM-PBL Implementation Data Analysis

Critical Thinking Indicator	Code	Statement	Source
1. Able to provide innovative solutions or ideas to a problem (Engineering and Technology)	CT 1	- Designing an innovative tool - Aesthetically appealing design - The tool in the design has a function as a problem solver and has a form that is easy to use. - Design tools using today's technology (Ex, Canva, PPT, word, etc)	STEM Project Rubric Lesson plan teaching XII MIPA 3 second meeting Results of student designs in groups
2. Able to answer simple and complex questions clearly and precisely (Science)	CT 2	- Be able to explain the principle of the voltaic cell contained in the design. - Describe the chemical reactions that occur	STEM Project Rubric Teaching reflection 4 Mentors feedback
3. Able to use the knowledge gained in class to solve problems in everyday life and explain the relationship (Science and Engineering)	CT 3	- Apply an understanding of the chemical properties of materials and tools used.	STEM Project Rubric Design results and group reports Teaching reflection 4
	CT 4	- Write down the research steps. - Include calculations regarding tool design (size, weight, etc.)	STEM Project Rubric Design results and group reports Teaching reflection 4

Description:
CT = Critical Thinking Indicator

In its application, students are given a problem in everyday life and guidance regarding the steps they must do in STEM-PBL assignments. Students are divided into groups to ensure students can work together and discuss. In addition, in its implementation, STEM-PBL is often carried out in groups to find solutions to existing problems (Sari, Suhery, & Effendi, 2020). The steps for implementing STEM-PBL can be seen in Figure 1.

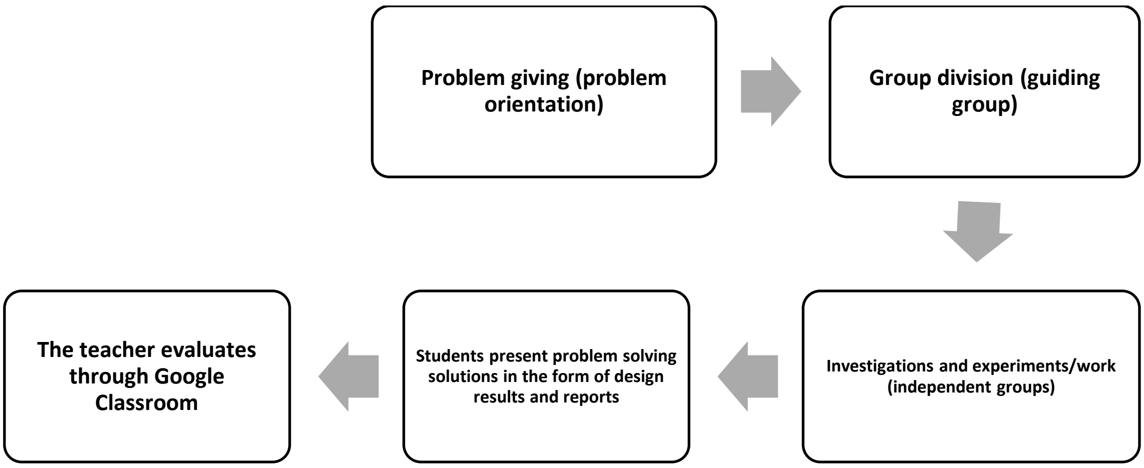

Figure 1. The Steps for Implementing STEM-PBL in Online Learning

The first stage is important and requires teacher creativity. At this stage, the teacher must be able to design or guide students to problems of everyday life. Problems that can encourage students to understand the concept of learning material. In the fourth stage, some findings show students' critical thinking skills. Through this stage, students can present the results of problem-solving solutions by fulfilling the objectives of the STEM disciplines.

In its implementation when carrying out research, STEM Education is applied as a learning approach and integrated with the Problem Based Learning learning model. At the time of observation, problems with students' critical thinking skills were found, so a pre-test was held in the form of a description of the material previously explained. The pre-test was held to reconfirm the observation results and facilitate the analysis of the results of STEM-PBL implementation. Figure 2 compares the average student scores between the pre-test before the implementation of STEM-PBL and the average student assignment scores after implementation.

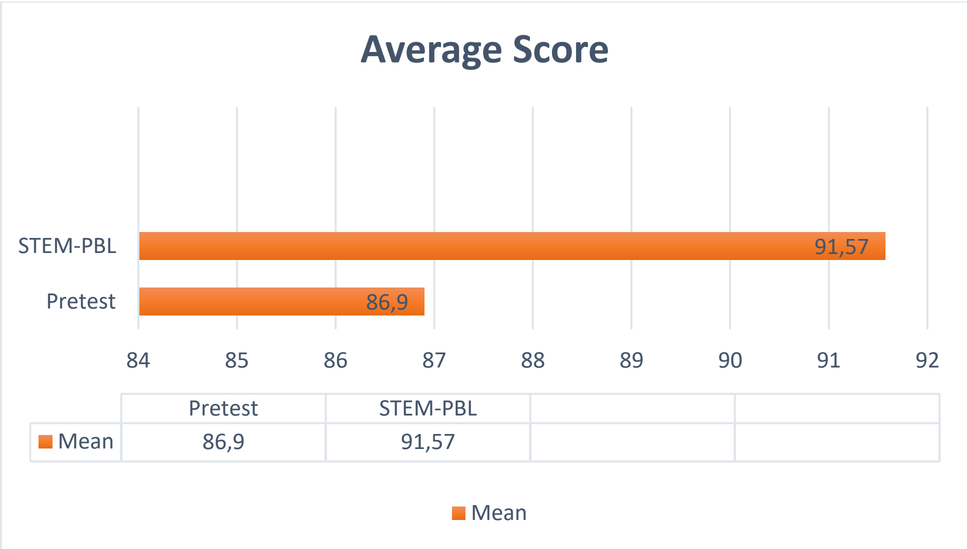

Figure 2. Graph of Comparison of the Average Score of the Research Class

The results of the average student score before the implementation of STEM-PBL were 86.9 to 91.57. Both results reached the Minimum Completeness Criteria limit set by the school. However, based on the results of observation and analysis of each student's answers, the problems that arise lead to indicators of critical thinking. Good learning outcomes, but students' critical thinking skills still need to be improved. Table 4 shows the results of implementing STEM-PBL on students' critical thinking skills. Following are the results of improving students' critical thinking skills per indicator.

Table 4. Data on Students' Thinking Skill Indicator Scores

Indicator	Group Score (rubric)						Average
	A	B	C	D	E	F	
CT 1	2	2	3	3	3	3	88.9
CT 2	2	3	3	2	3	2	83
CT 3	3	3	3	2	3	2	88.9
CT 4	3	3	2	3	2	3	88.9

Category: 1. Less; 2. Good; 3. Very good

CT 2 is fulfilled because it is given questions on applying STEM-PBL, which relates to students' daily lives. It is one of the uniqueness of STEM integration with PBL, where questions will be presented and packaged as an analysis of everyday life problems. It can encourage students to become more understanding, interested, and motivated to solve the questions the teacher gives.

Judging from CT 1, STEM-PBL can help students design a tool design that can solve a given problem. This success is inseparable from the characteristics of STEM-PBL, which uses everyday problems and engineering disciplines from STEM. In the engineering section, students are required to be able to produce a problem-solving product so that it will not stop at the problem analysis stage. Given the task of designing a problem-solving tool, design can challenge students' critical thinking about unique ideas and innovation to find solutions. The results of the STEM design of research class students on the Volta Cell material task can be seen in Figure 3.

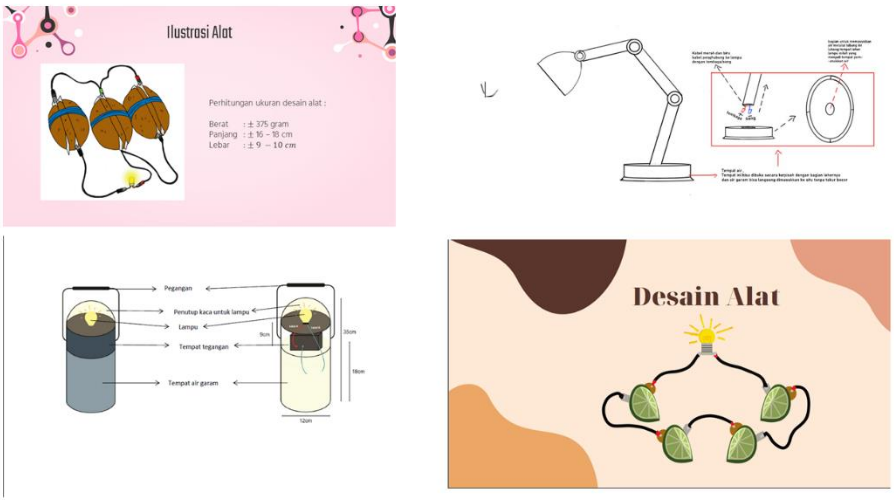

Figure 3. The Results of the Student's STEM-PBL Electrochemistry Tool Design

Tool designs are presented using existing technologies such as Powerpoint, Ms. Word, Canva, etc. Skills are needed in using technology so that they can produce good tool designs that follow the ideas they have. Thus, students must train themselves to study technological advances; this is the T principle in STEM: technology. Students are also encouraged to be able to master IT so that they can help solve existing problems.

In addition to designing a problem-solving product as the final result, STEM-PBL requires students to design products based on chemical principles. In the Science section, students must be able to explain chemical principles and concepts in their design tools. Therefore students need to explore the concept of material that can solve existing problems. CT 3 of critical thinking, using learned knowledge to solve problems. The results that the students gave showed that students were able to design a tool based on the principles of chemistry.

In implementing STEM-PBL, students also produce simple reports regarding the design of the tools they design. In addition to producing solutions, students also produce products in the form of reports and problem-solving tool designs. Report writing requires a variety of student skills, both in science, namely putting ideas into writing, and in mathematics, to write down the steps in a systematic and structured manner. Thus CT 4 is fulfilled based on the results of student reports which explain the research steps carried out in great detail.

Discussion

The results of the application data show that STEM with PBL integration encourages students to think critically in finding solutions to problems. Students can design a tool design that becomes a problem-solving solution. The tool is designed using existing technology, namely PowerPoint, word, and others. Students are not only limited to designing tools but can also explain how chemical concepts and reactions occur in their tool designs. Through STEM, students are trained to be able to think critically, students can have the ability to solve problems, and be active, and there is an increase in the student's Competency-Based Curriculum (Fadlina, Artika, Khairil, Nurmaliah, & Abdullah, 2021; Fithri, Tenri Pada*, Artika, Nurmaliah, & Hasanuddin, 2021; Isatunada & Haryani, 2021).

Through the activities, STEM can develop students' truth-seeking and open-mindedness (Hacioglu & Gulhan, 2021). STEM can improve students' critical thinking skills by using the California Critical Thinking Disposition Inventory (CCTDI) to determine the effect of STEM education on students' critical thinking skills. It is evidenced by the results of students who can answer the questions and integrate their knowledge to solve problems in everyday life and relate them to the subject matter concepts. Applying STEM-PBL to questions by making them analyze everyday life problems can improve students' critical thinking skills (Hasanah et al., 2021; Setia Permana et al., 2021).

Students can compile detailed STEM project research reports. The report contains reasons for choosing tools and materials, the chemical processes, assembling the tools, and the complete set of tools. They are indirectly preparing reports to train students before conducting research. They must know in advance about tools and materials that are effective in becoming solutions to problems that occur. Students must also explore chemical processes, such as what happens to tools and materials when assembled into a problem-solving tool. STEM can train students in critical and scientific thinking, especially in problem-solving research (R. Agustina, Huda, & Nurmaliah, 2020; Debora & Pramono, 2021). What's more, the implementation carried out by integrating STEM with Problem Based Learning through PBL can improve students' problem-solving skills (Fauzan, Gani, & Syukri, 2017; Jayadiningrat & Ati, 2018).

A comparison of the results of implementing PBL-STEM and PBL, which was carried out online, showed an increase in students' critical thinking skills in STEM-PBL and no significant increase in the application of PBL alone. The fundamental difference between the two applications is that the process of problem analysis and solutions in STEM-PBL is carried out in-depth by integrating various disciplines (Putri et al., 2020). In PBL alone, problem analysis and solutions are generally carried out without integrating them into various disciplines.

Besides being able to design a tool design based on chemical principles, students can also compile a simple report based on the STEM rubric that the teacher has prepared. In line with previous research, STEM-based rubrics could improve students' thinking skills in working on the questions given (Ardianti, Sulisworo, Pramudya, & Raharjo, 2020). In the results of its application, students can design tool designs and utilize technology such as PowerPoint to present their results. Thus, in addition to students' ability to solve problems and provide innovative solutions, STEM-PBL can also develop the ability to master technology. STEM-PBL improves students' thinking skills up to the master thinker category (Parno et al., 2019). Subsequent research has shown that using the PBL model in the learning process in class can improve students' critical thinking skills (Effendi et al., 2021; Utami et al., 2019). Other research shows that using the STEM approach integrated with the PBL model is valid and feasible to use effectively in the learning process. Other research shows that the STEM approach integrated with the PBL model is valid and feasible for effective learning (Arifin, 2020; Oktaviani et al., 2020).

The advantage of integrating STEM and PBL in the implementation stages and processes is that STEM-PBL is more complex and emphasizes various disciplines. It is because, in STEM, students are encouraged to be able to integrate the material concepts they have with other disciplines. Thus, when given a problem in everyday life following PBL principles, students will try to solve it by using existing knowledge and explaining its relationship with other material concepts. Applying STEM-PBL can generally meet the indicators of students' critical thinking because STEM-PBL integrates several disciplines. While producing the final product, students are involved in multidisciplinary knowledge (STEM). When students elaborate (STEM) in stages to design problem-solving products, from the PBL perspective alone, they have gone through a thinking process that can stimulate critical thinking. Meanwhile, students must consider each stage carefully when going through STEM syntax or rubrics. Thus the stimulus to be able to think critically will be even greater.

4. CONCLUSION

The conclusion from the application of STEM-PBL in online learning can improve students' critical thinking skills. Students can design tool designs with electrochemical principles, compile research reports and provide solutions to problems. Critical thinking indicators can be fulfilled through STEM-PBL characteristic steps. Research using the STEM-PBL approach is very good if it is continued to the stages of making tools for solving everyday problems because aspects of creativity can be further developed.

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