JPPIPA 9(10) (2023)

Jurnal Penelitian Pendidikan IPA
Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Effect of STEM Integrated Problem-Based Learning Model on Students' Critical Thinking Skills on Electrolyte and Non-Electrolyte Solution Materials

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Received: August 19, 2023
Revised: September 1, 2023
Accepted: October 25, 2023
Published: October 31, 2023

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DOI: 10.29303/jppipa.v9i10.5163

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Abstract: This study aims to study the effect of problem-based learning integrated STEM and non-STEM learning models in improving critical thinking skills and their differences of learning process. The method used is a quasi-experimental design with a pretest-posttest non-equivalent control design. The population of all students in class X science with non-probability sampling was 36 students each. The instruments used were observation sheets, description questions, and questionnaires. The results showed that the average percentage of STEM-integrated problem-based learning implementation was 96.00% and 93.00% without STEM, both of which showed very good results. The average critical thinking ability of students in the STEM integrated problem-based learning class is 71% and 59% without STEM, this is shown by the average value of the STEM integrated problem-based learning classes is greater than without STEM. The linear regression test using STEM integrated problem-based learning has a positive effect on critical thinking skills 2.251, t-count > t-table (3.756 > 2.032), Ho is rejected Ha is accepted, and without STEM there is no effect on critical thinking skills, with a t-count <t-table (2.016 < 2.032). The results showed that the STEM-integrated problem-based learning model had a positive effect on students' critical thinking skills on electrolyte and non-electrolyte solution materials.

Keywords: Critical thinking; Electrolyte solutions and non-electrolyte; STEM integrated problem-based learning

Introduction

21st century learning is a big challenge for the world of education so that quality human resources are needed to face the 21st century. One of study that students should haves critically thinking and understanding (Akgunduz, 2016). Critical thinking ability is one of the 21st century skills that students need to in learning, especially in learning science (Kurniawan et al, 2023). The results of PISA 2018 show that the thinking skills of Indonesian students are still very low, which is ranks 58 out of 65 countries surveyed and based on previous research, the critical thinking skills of students in Indonesia are still relatively low (Hasanah et al, 2021; Sandi, 2021; Parenta et al, 2022). Based on the results of observations made in one of the schools in Cirebon City, it can be seen that the learning carried out is teacher centered which makes students only receive and listen to the material delivered by the teacher. Chemistry learning is carried out using the lecture method, reduced student interaction to improve critical thinking skills, two-way communication is less intertwined and cognitive perspective is limited.

The learning process is expected to encourage critical thinking in students. Learners sharpen their critical thinking when faced with everyday problems (Putri et al., 2020; Adhelacahya et al., 2023), in line with the implemented curriculum. The use of the currently implemented curriculum is the independent curriculum which is part of a new policy introduced by the Ministry of Education and Culture of the Republic of Indonesia (Marisa, 2021). Its application integrates classroom knowledge with everyday life (Arifin & Muslim, 2020), consisting of extracurricular, extracurricular, and

How to Cite:
Gusman, T. A., Novitasari, N., & Yulina, I. K. (2023). The Effect of STEM Integrated Problem-Based Learning Model on Students' Critical Thinking Skills on Electrolyte and Non-Electrolyte Solution Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8911–8917. https://doi.org/10.29303/jppipa.v9i10.5163

projects to strengthen the profile of Pancasila students (Nugrohadi & Anwar, 2022) that can answer current educational problems (Fahlevi, 2022). Critical thinking skills are central to the process of reflective thinking and the use of cognitive skills at the levels of analysis, evaluation, reasoning, and induction (Kisworo & Gusman, 2019).

The process of learning chemistry is interesting to study when discussing material that is interrelated with social and technological life which makes students able to think critically (Dywan & Airlanda, 2020). One of them is the material for electrolyte and non-electrolyte solutions which are microscopic, so students cannot visualize them properly (Fitriyani et al., 2019). There is a tendency in the process of studying chemistry as a product, to memorize concepts, theories, and laws. Chemistry learning has the aim and function of instilling a scientific attitude which includes a critical thinking attitude towards scientific statements that are not easily believed without observation, understanding chemical concepts, and their application in solving problems in everyday life (Rushiana et al., 2023).

Learning by using the problem-based learning model provides students with meaningful problems related to daily life that can be used as a means of investigation and investigation and opens up opportunities for students to be active in the learning process, think critically in solving problems, increase learning completeness, interest in learning and student achievement (Muchib, 2018). Science learning, especially chemistry, is closely related to technology (Ariyatun & Octavianelis, 2020), mathematics, and its application in life. This condition can be integrated very well into the science, technology, engineering, and mathematics (STEM) chemistry learning (Ariyatun & Octavianelis, 2020), in an interdisciplinary approach presenting an integrated learning paradigm in everyday life (Rukmansyah, 2020). One of the efforts to develop creativity in chemistry learning is by developing a chemistry learning creativity model (Sitorus, 2022).

STEM-integrated chemistry learning aims to improve cognitive abilities, foster a creative and innovative spirit, foster critical thinking skills, increase effectiveness (Nurhilyatuz Zulfa & Masykuri, 2022), and solve everyday problems by combining knowledge, skills, and attitudes of students, STEM learning prepares quality students to be competitive and ready to work in their respective fields (Fathoni et al., 2020). STEM learning helps today's generation of students to be more creative and innovative in the learning process (Ichsan et al., 2023; Adhelacahya et al., 2023). Its use is expected to make students more familiar with real-life science problems and be able to solve a problem that occurs.

The use of the PBL model will be more effective if it collaborates with the STEM learning model which will enable students to associate problems with science, technology, engineering, and mathematics. Research by Ariyatun et al. (2020) and Putri et al. (2020) that PBL-STEM learning is capable improve students' critical thinking skills. As well as research by Setyorini et al. (2021). PBL-STEM was able to improve concept mastery and critical thinking skills in energy matters. Previous researchers suggested using the PBL-STEM learning model because it received positive responses from students and not many studies have used the PBL-STEM learning model. In chemistry subjects, especially the material for electrolyte and non-electrolyte solutions, research has never been carried out using STEM-integrated PBL. The study aimed to determine the effect of the STEM-integrated problem-based learning model on students' critical thinking skills in the material of electrolyte and non-electrolyte solutions.

Method

In this research design, the approach used was quantitative because this study used numerical data that could be processed using statistical methods, while the type of research used was quasi-esperimental research (Quasi-Experimental Design) using one exsperimental and one control class that were not selected randomly. This research was conducted in the odd semester of the 2023/2024. This research was conducted at MAN 1 Cirebon City. The subject of this stufy were 36 students of class X Sciens 1 experimental class and class X Science 2 with a total of 36 students as the control class.

Table 1. Research Design

Class	Initial State	Treatment	Final State
Experiment	Y1	X1	Y2
Control	Y1	X2	Y2

Notes:
Y1 : Pretest adduction
X1 : Treatment with STEM-integrated problem-based learning
X2 : Treatment with not STEM
Y2 : Posttest adduction

The implementation of this research was preceded by the provision of a pretest first, the treatment was given in the form of learning using the STEM-integrated problem-based learning models for the experimental class and using the not STEM for the control class. At time of treatment, observations were also made based on observation sheets and questionnaires studies determine the improvement of students' critical thinking. After being given treatment, a posttest was held, for pretest and posttest in the form of 10 decription questions by using critical thinking indicators acvording to Ennis. The analysis technique used was descrptive analysis, non-test.

Result and Discussion

The research data was obtained in the form of observation sheets observed directly by chemistry teachers, answers to students' questions about critical thinking skills in a material, and answers to students' responses to learning models in class X IPA 1 and X IPA 2 at MAN 1 Cirebon City. The results of the implementation of the syntax of the learning model carried out are at a very good level, this is in line with research conducted by Mustofa et al. (2021), that the STEM-based problem-based learning model is effective with a score of 90%, these results are also in line with the research of Satriani et al. (2022) the implementation of learning is very good with a score of 3.6. This shows that each stage in learning has been done well. The STEM-integrated problem-based learning model makes students carry out learning activities in the form of analyzing problems, designing and making tools, interpreting the information received, and providing explanations (Putri et al., 2020). In learning, there is a phase of elaboration, cooperation, and collaborative interaction of students from the beginning of learning to the end of learning (Ariyatun & Octavianelis, 2020), thus making the learning process active, fun, and making a new experience for students.

The application of a STEM-integrated problem-based learning model has a good impact on students' critical thinking skills. The ability of students can be seen directly or in learning outcomes.

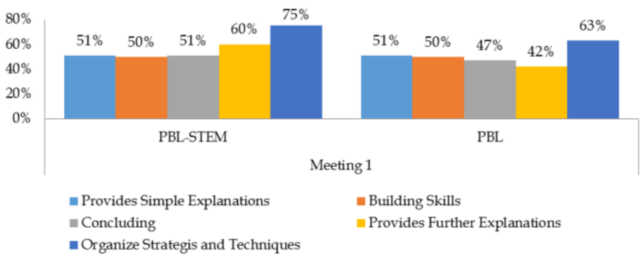

Figure 1. Results of critical thinking skills based on observation results meeting 1

Critical thinking skills based on figure 1 in both classes of students have not been able to work together with their groups in solving problems, connecting problems with some of the knowledge gained, providing an explanation, and drawing conclusions, making the teacher more dominant in its implementation, because students are not accustomed to the use of learning models so that it cannot be intertwined properly. The second meeting is needed to observe again so that the values in each indicator can be fulfilled properly.

Critical thinking skills based on figure 2 in both classes of students have been able to adapt well to the use of the applied learning model making students more dominant and able to be carried out properly. Learners are accustomed to solving problems that occur by discussing with their group friends and linking from various sources of literature, then providing an explanation of problem-solving and drawing a conclusion.

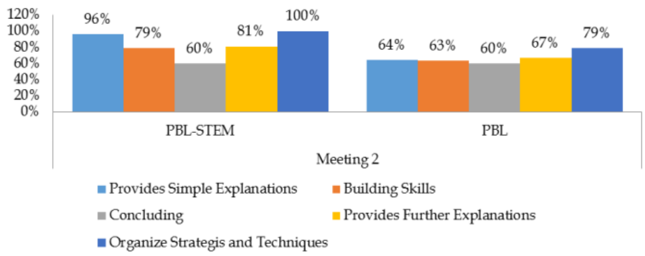

Figure 2. Results of critical thinking skills based on observation results meeting 1

Based on the implementation in two classes, the percentage value of each indicator has increased with the highest value on the indicator of organizing strategies and techniques, the ability of students to determine the right action according to the problems given by the teacher by looking for references from various sources of literature together with their group is well implemented. The learning process with STEM makes students able to organize strategies and techniques because students exchange ideas and determine the right actions in solving a problem (Hasanah et al., 2021), in line with research conducted by Marhamah et al. where the implementation requires students to be able to interact with their groupmates and exchange ideas both with the teacher, groupmates and other groups (Marhamah et al., 2020). Other indicators that get high scores provide simple and advanced explanations for problems that occur and build good basic skills by obtaining various sources of data from trusted sources. Learners can solve problems given by the teacher by interpreting them according to the data sources obtained. At the stage of providing explanations, students can provide simple and advanced explanations by clarifying the results obtained with various relevant sources (Ritonga & Zulkarnaini, 2021). As well as the lowest percentage in both classes, namely in the indicator of concluding the ability to conclude learners such as the ability to deduce, induce and consider the results given by some groups have not been able to do it well, due to some learners being too focused in their groups so that they pay less attention to their surroundings, this is in line with research conducted by Muchib (2018), that some learners do not listen well to learning material, which is caused by environmental factors, students in their groups were able to provide conclusions and convey them well (Putri et al., 2020), this is because PBL-STEM learning can invite students into real life to solve a problem with critical and logical thinking.

Based on the average value of the critical thinking skills test in both classes can be seen in figure 3.

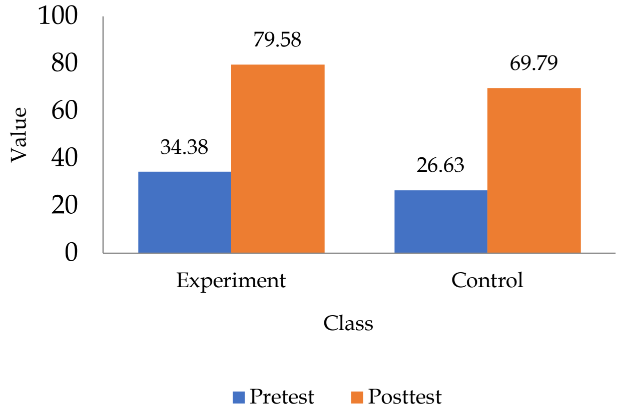

Figure 3. Mean of pretest posttest critical thinking ability

Figure 3 shows that the average score in the experimental class obtained a higher score than the control class. This can be interpreted that the application of the STEM-integrated PBL learning model can improve the ability of students in electrolyte and non-electrolyte solution material. In line with Topsakal et al. (2022) there are significants differencesbetween the two classes. The difference between the two is because there is a difference in the application of the learning model given. In the experimental class using the STEM-integrated PBL learning model where students identify problems given by the teacher, and solve problems by observing phenomena around to help design the product to be used. Problem solving carried out by students through products makes electrolyte test equipment by testing solutions around which makes the learning process more active and interesting. Students' achievement of critical thinking skills tests questions in terms of critical thinking sub-abilities according to Ennis from both classes in figure 4.

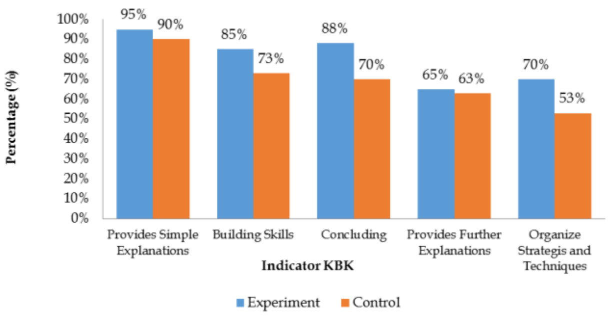

Figure 4. Achievement of critical thinking ability

The success of students in completing test questions in the experimental class was 86% while in the control class, it was 58%. This difference can prove that learning by using a problem-based learning model integrated with STEM is better and more effective in improving students' critical thinking skills when compared to STEM. In line with research conducted by Hasanah et al. (2021), that the acquisition of critical thinking skills in terms of answering average questions in the experimental group is greater than the control group, as well as Setyorini et al. (2021) that the percentage of the average value of the experimental class is 79.70% greater than the control class of 44.54%. This is because experimental classes that use STEM-integrated problem-based learning models centered on students, emphasizing students to be more active and independent and direct experiences of students in designing, making, observing directly, organizing strategies and techniques, and concluding a problem that occurs, able to acquire critical thinking skills of students in STEM-integrated PBL classes superior to those without STEM. That learning STEM have a positive impact on students' critical thinking abilities (Hacioğlu & Gülhan, 2021; Akcanca, 2020; Topsakal et al., 2022), becuase they are more wiling to solve problems, produce solutions, are confident and have hifhmotivation.

Before testing the hypothesis, a pre-requisite test is needed, namely the normality and homogeneity test, to find out the normality, homogeneity, linearity, regression test and the test of the coefficient of determination of students can be seen in table 2.

Based on table 2 shows that the data from both classes are normal, homogeneous, and linear. In the experimental class with the regression equation Y ˆ = 41.662 + 2.251x which means that every 1% increase in the application of the STEM integrated problem-based learning model will affect the critical thinking ability of students 2.251 with an influence of 29.3%, the value of the t-count > t-table is (3.756> 2.032). Because the value of t-count> t-table, then Ho is rejected and Ha is accepted. So it can be concluded that there is an effect of STEM integrated problem-based learning model on students' critical thinking skills. The control class with the equation Yˆ= 41.627 + 1.758x which means that every 1% increase in the application of the problem-based learning model will affect the critical thinking ability of students 1.758 with an influence of 10.7%, the t-count value (2.016 < 2.032). Because the value of t-count < t-table, then Ho is accepted and Ha is rejected, so it can be concluded that there is no effect of the problem-based learning model on students' critical thinking skills.

Table 2. Hypothesis Testing

Class	Normality	Homogeneity	Linearity	Regression Equation	R square	t_{count}
Experiment	0.10 (Normal)	0.28 (Homogeneous)	0.37 (Linear)	$\hat{Y} = 41.662 + 2.251x$	0.29	3.756
Control	0.11 (Normal)		0.28 (Linear)	$\hat{Y} = 41.627 + 1.758x$	0.11	2.016

The use of STEM integrated problem-based learning model is better in improving students' critical thinking skills. The difference in the achievement of students is due to differences in the treatment of learning models, where in PBL-STEM classes students do learning by solving problems, finding solutions from various reference sources, doing practicum, providing further explanation of the manufacture of tools as a solution and providing relevant conclusions to the results obtained. Whereas the control class uses a problem-based learning model where students only solve problems, find solutions from various reference sources, provide explanations, and make conclusions. So that the learning process can improve students' critical thinking skills. In line with research conducted by Ritonga et al. (2021), there is a difference in the average KBK between the experimental and control groups, where the experimental group with PBL learning guided by student worksheet STEM has a higher average value, due to differences in the application of learning models. Similarly et al. (2020), the average results of the experimental class and control class in the moderate category, but the experimental class has a higher value than the control class, because there are differences in pretest-posttest scores.

The improvement of critical thinking skills indicates that STEM-integrated problem-based learning has been proven to improve the quality of the learning process. Good understanding of the material from students is also due to an increase in students' critical thinking skills in solving problems about electrolyte and non-electrolyte solutions. Indicators of critical thinking variables ask questions, analyze, and evaluate the occurrence of significant differences before treatment and after treatment, so it can be concluded that the STEM-integrated problem-based learning model can improve students' critical thinking skills. This is because the repeated process can develop students' critical thinking skills, especially in applying concepts that make students able to remember and understand what is learned. STEM-integrated problem-based learning invites learners to a real situation in everyday life to solve a problem with critical and logical thinking and conclude the results in a relevant manner. The application of a STEM-integrated problem-based learning model can improve students' critical thinking skills in electrolyte and non-electrolyte solution learning materials.

Based on the results of the questionnaire given to students on the application of both learning models can be seen in figure 5.

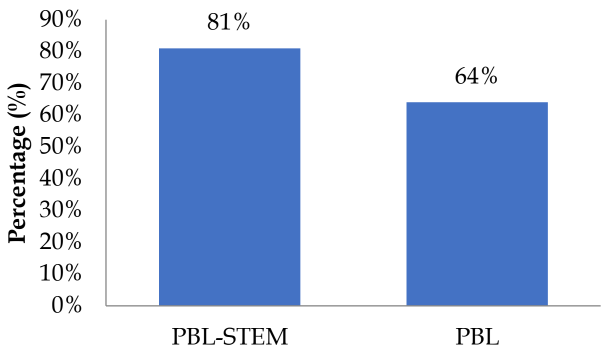

Figure 5. Students' response to learning

Students' responses to the use of STEM-integrated problem-based learning models with an average response of 81% with a very good response while without STEM obtained an average response of 64% with a good response. Based on the average results of students' responses to the two learning models the experimental class obtained a higher average than the control class. in line with Setyorini et al. (2021) and Perselia et al. (2020) that STEM-integrated problem-based learning is 92.48% in the very good category and without STEM is 78.42% good category. This is because STEM-integrated PBL learning is new, fun, able to increase motivation, and make students active in learning.

Conclusion

Based on the results of data analysis, it can be concluded that the use of a STEM-integrated problem-based learning model on the material of electrolyte and non-electrolyte solutions have a significant effect on the critical thinking skills of students in class X IPA 1 MAN 1 Cirebon City. The indicator of critical thinking such as provides simple explanations, building skills, concluding, provides further explanations, and organize strategic and techniques, are the cognitive results showed higher value than pretreatment class.

Acknowledgments
The author would like to thank the chemistry teacher of class X and the students of class X IPA 1 and X IPA 2 MAN 1 Cirebon City who have helped the author so that this research can run well.

Author Contributions
Conceptualization, N and TAG.; methodology, N and TAG.; software, N.; validation, TAG and IKY.; formal analysis, N.; investigation, N.; resources, N.; data curation, N.; writing—original draft preparation, N, TAG, and IKY.; writing—review and editing, TAG and IKY.; visualization, N.; supervision, TAG

and IKY.; project administration, N.; funding acquisition, N, TAG and IKY.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest

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