JPPIPA 9(10) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

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

Learning Challenge: Solar Cell Technology in PjBL- STEM Learning Using Jigsaw Strategy to Enhance the 21st Century Skills of 9th Graders

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Received: August 28 2023
Revised: October 19, 2023
Accepted: October 25, 2023
Published: October 31, 2023

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DOI: 10.29303/jppipa.v9i10.5126

Abstract: Project-based innovative, creative, and integrative learning is currently an option in preparing 21st-century skills for students and accommodating the implementation of the Merdeka Belajar Curriculum. Research has been conducted through the application of PjBL-STEM learning with a Jigsaw strategy through the theme of environmentally friendly technology with the utilization of solar cells in grade 9 to improve critical thinking skills and communication skills. This research was conducted using a pseudo-experimental method with a pre-posttest control group design using inferential analysis methods to test critical thinking skills while testing communication skills using descriptive analysis. The research subjects were junior high school students totaling 62 people. The results showed that PjBL-STEM learning with the Jigsaw strategy can train students to argue, draw conclusions, deduce, and build basic skills, tactics, and strategies better than the control class. The Jigsaw strategy causes students to become more confident and trained to discuss more intensely with both the initial group and the expert group. This led to an increase in students' communication skills much better than the control class students whose learning was guided by the inquiry method.

Keywords: Jigsaw strategy; PjBL-STEM; 21st Century skills

Introduction

Education plays an important role in improving the social life that develops in society in its implementation by preparing a more innovative education system and increasing graduate competency. The application of 21st-century skills in the world of education is a solution to encourage economic growth and country competitiveness in the era of Industrial Revolution 4.0 (Zubaidah, 2017). In its implementation, education is also expected to strengthen the Sustainable Development Goals, namely eradicating poverty, protecting the planet, and ensuring prosperity for all (Shiroishi, 2018). For this reason, children must have 21st-century skills from an early age and in the future, which will become the basis for ushering the nation's generation into a future full of challenges. Critical thinking is a 21st-century skill that encourages a person to think at a higher level beyond basic observations, facts, and memorization to direct students from low-level thinking to high-level thinking, namely from knowledge to understanding, from application to analysis, and from evaluation until synthesis. In interviews conducted by Richardson et al. (2017), high-level thinking skills or critical thinking are widely used by various groups ranging from public policymakers, scientists, and researchers, to.practitioners.

Critical thinking skills and communication skills are currently very necessary, especially in expressing one's ability to have a conversation, express ideas or opinions clearly, and motivate and convey information to others. According to Nugraha et al (2022) Natural Sciences (IPA) is a science that not only studies theory but trains how to communicate the theory that has been studied by carrying out an activity. Mahanal (2019) stated that the serious challenge for the world of

How to Cite:
Widiawati, R., Permanasari, A., & Ardianto, D. (2023). Learning Challenge: Solar Cell Technology in PjBL- STEM Learning Using Jigsaw Strategy to Enhance the 21st Century Skills of 9th Graders. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8846–8851. https://doi.org/10.29303/jppipa.v9i10.5126

education is to prepare students to become workers who are able to adapt to new tasks and processes that can be solved by training in high-level thinking skills. 21st century skills are also one of the learning innovators that must be mastered today.. One learning that can improve 21st-century skills is project-based learning (PjBL) which trains students to share ideas, negotiate and resolve conflicts, and effectively communicate in presenting work or student learning (Boss et al., 2013; Buck Institute for Education, 2019). all of which are solutions that can train someone to be critical, creative and innovative.

In fact, many students have low 4Cs abilities, for example, based on the 2012 PISA results, Indonesia was ranked second from the bottom with an average score of 382 below the average PISA score of 501 (OECD, 2017). Low thinking skills are one of the reasons why science learning is needed which can train students to think critically or at a higher level. Apart from that, current learning is still teacher-centered, making it difficult for students to understand lessons (Erlinawati et al., 2019). So learning still does not meet the demands of the 21st century (Wagola et al., 2022). According to Permanasari in Ismail (2016), "STEM can train students to apply their knowledge to create designs as a form of solving problems related to the environment by utilizing technology." Holm (2011) further calls PjBL "student-centered teaching that occurs over a long period of time, from selecting contexts, planning, researching, producing products, presentations, and performances that answer real-world questions and respond to authentic challenges ".

PjBL-STEM learning with the Jigsaw strategy (Windale, 2022) aims to increase creativity, critical thinking, and the ability to collaborate and communicate. This learning model was taken to overcome the problems above. In line with several previous studies, experiment-based STEM activities are an effective way to develop creativity Stylianidou et al. (2018). Henriksen (2014) said that STEM is an important method for developing creativity because it is an interdisciplinary science where PjBL STEM involves students applying their knowledge through multidisciplinary STEM to create new products. PjBL STEM is able to solve real-life problems and has the potential to develop students' scientific creativity (Hanif et al., 2019). Researchers (Siew et al., 2015) stated that PjBL provides a mechanism for science teachers to develop their creativity when STEM is integrated into project-based learning. Bell et al., 2010; Shriki (2013) argues that project-based learning is useful in improving creative thinking. Christensen et al (2015) PjBL-STEM learning which is an practice interdisciplinary originating from real problems that span various disciplines of knowledge that can accommodate 21st century skills. Several studies show how the experience of designing and creating science-based prototypes helps teachers stimulate students' creativity (Mayasari et al., 2016; Siew et al., 2015).

Based on the explanation above, the aim of this research is: To obtain a PjBL-STEM learning model with Jigsaw strategies and information about improving 21st-century skills (critical thinking abilities and communication skills) in students after learning PjBL-STEM through environmentally friendly technology materials.

Method

The method used in learning the PjBL-STEM model using the Jigsaw strategy for students' critical thinking and communication skills is using the Quasi-Experimental method with a Pretest-Posttest Control Group design adopted from Seel (2012) and Frankel et al (2012). This design uses two classes, namely the control class and the experimental class.

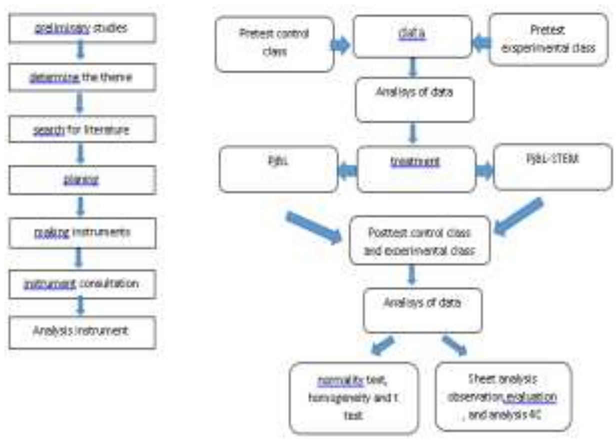

Figure 1. The design of the study

The experimental class carries out learning using the PjBL-STEM learning model, while the control class carries out learning using the inquiry learning model with the 5M approach. The research instruments used include 1) question sheets using essay questions for students' critical thinking skills through pre-test and post-test. 2) Observation sheet to assess communication skills. Data analysis is a very important part of research because the data analyzed can answer research problems by conducting hypothesis testing. In this research, researchers used class IX students at MTs Negeri 6 Cianjur for the 2022/2023 academic year as Environmentally Friendly Technology subjects. All students in the class were taken as respondents from all groups. Sampling was carried out using a purposive sampling technique, namely taking two classes considering, among other things, that they had the same knowledge abilities. Of the two classes, one class is the control class and the other class is the experimental class. The design of this research is shown in Figure 1.

Result and Discussion

The learning model that has been developed with the Jigsaw Strategy PjBL-STEM model syntax includes 4 stages as proposed by Windale (2022). Based on the results of the research conducted, either through observation or through data analysis, it shows an increase in students' 21st-century skills. The assessment was carried out using 2 classes, namely the experimental class with PjBL-STEM learning with the Jigsaw strategy and the control class using inquiry. The results of learning in the experimental class showed that PjBL-STEM with a jigsaw strategy has very potential and is efficient in improving 21st-century skills. As seen in the research results, the overall improvement of 21st-century skills is in a good category. This improvement is inseparable from the learning process that has been implemented in accordance with the learning steps. As we know PjBL_STEM with a jigsaw strategy has advantages in each of its stages that reflect some efforts to improve knowledge, skills, and attitudes. At each meeting, each learning step is carried out and followed well by students. The experimental class used the PjBL STEM model with the Jigsaw strategy which consisted of 4 syntaxes, while the control class applied the learning that had been done with the inquiry approach and followed the learning in the book compiled by the Ministry of Education and Culture. Learning in the experimental class or control class in this study conveyed the subject matter of Friendly Technology more precisely the use of solar energy (solar oven).

The implementation of PjBL-STEM learning with a jigsaw strategy is carried out with the first step, namely **Introducing the problem and context (Launch project**) scientific investigation or problem introduction where students are invited to see the surrounding phenomena regarding Environmentally Friendly Technology within the context of energy utilization in everyday life through the manufacture of solar cells which can improve students' critical thinking skills and communication skills. The jigsaw strategy in PjBL-STEM learning is applied in the next step, namely developing an understanding of the problem and background knowledge understanding and skills (Build Knowledge) or problem development. At this stage, students are formed into groups of origin and expert groups. Each member of the origin group is assigned to join an expert group with each expert group making one form of solar oven including a box, parabola, and a mixture of box and parabola. After students gain their knowledge in the expert group, they then return to the group of origin to be informed to the group of origin to discuss, and agree on what product will be made. The jigsaw strategy is very potential and efficient in improving 21st-century skills. As seen in the research results. The improvement of critical thinking and communication skills is in a good category. This improvement is inseparable from the learning process that has been implemented in accordance with the learning steps. As we know PjBL-STEM with a jigsaw strategy has advantages in each of its stages that reflect several efforts to improve knowledge, skills, and attitudes.

Step three Solving the Problem (Develop and critique) that is, each group of origin makes a project that has been agreed upon and determined by all members of the origin group about the shape of the solar cell to be made. The last step is presenting the Product and Evaluation at this stage testing the solar cells that have been made and presenting the products made in front of the class. Other groups evaluate and provide input on the products that have been made by each group. Earning stages with the integrated PjBL model of science, technology, engineering, and mathematics with a jigsaw strategy can be seen in Figure 2.

Figure 2. Stages of learning steps

Critical thinking

Based on the learning steps, the results of student critical thinking research showed that the average score of the experimental group was higher than the control group. Based on N-Gain calculations (Hake 1999) the increase in N-Gain in the control class and experimental class showed an increase of 15.47%. The results of the N-Gain increase can be seen in Figure 3.

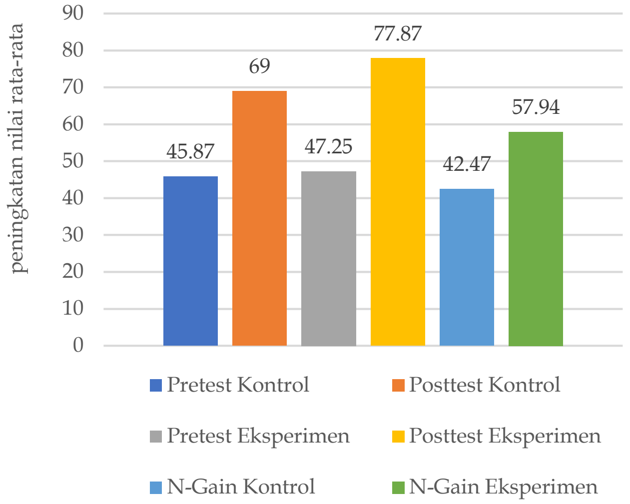

Figure 3. Average score improvement of control and experimental classes

To find out the overall N-Gain value on critical thinking indicators (Ennis in Munandar 1999) can be seen in Table 1.

Table 1. N-gain results for each indicator

Indicator	Average	
	N-Gain control	N-Gain experiment
Elementary Clarification	0.50	0.66
Building basic skills (Basic support)	0.32	0.56
Summarizing (inference)	0.43	0.61
Providing further explanation (Advance Clarification)	0.47	0.52
Strategy and tactics	0.43	0.58
Mean	0.43	0.58

Based on Table 1, it is obtained that there is an increase in the N-Gain value on each indicator between the control class and the experimental class with a moderate category. To prove the hypothesis, a statistical test with the T-test is carried out with the aim of seeing the significance value or how much influence the learning model has on the critical thinking skills of the two classes both in the control class and in the experimental class. Before conducting the T-test on the control class and experimental class, the normality test and homogeneity test were first carried out to determine whether or not the data generated was normal and homogeneous or not in each class. Table 2 is the result of the statistical test to prove the research hypothesis.

After the data is normally distributed, a homogeneity test is carried out which aims to find out whether the diversity of a variant is homogeneous or heterogeneous. The results of the homogeneity test are in Table 3.

Table 2. Normality Test Results

Group	Significance Value	Description
Control Post-test	0.065	Data is normally distributed
Experiment Post-test	0.062	Data is normally distributed

Table 3. Homogeneity Test Results

Group	Significance Value	Description
Control - Experiment	0.664	homogeneity

Based on Table 2 obtained a significance value of Sig. 0.664 > 0.05 then the result is homogeneous. After the normality and homogeneity tests were carried out, parametric tests were carried out with independent sample T-tests to prove the hypothesis test as in Table 4

Table 4. T-Test Results to Prove Research Hypothesis

Group	Significance Value	Description
Control - Experiment	0.664	homogeneity

Independent t-test results obtained Sig 2 tailed of 0.000 <0.05 with the assumption that there is an effect of learning with the PjBL model with a science, technology, engineering, and mathematics approach with a jigsaw strategy on students' critical thinking abilities

Communication

In addition to critical thinking skills, communication skills are also important. For this reason, researchers also assess communication through observation, which in its implementation is assisted by a fellow teacher to become an observer. The results listed on the observation sheet obtained results as in Table 5 below

Table 5. Recapitulation of Observation Data of Communication

Aspects	Mean	
	control	experiment
Speaking skills	70	85
Listening skills	65	83
Non-verbal communication skills	66	74

Based on Table 4, the observation results show that in the control class and experimental class, there is an increase in the average results in each aspect. In the communication aspect, the highest control class in the aspect of speaking skills is 70%, and the lowest is in the communication indicator of the non-verbal communication skills aspect of 66%. In the control class, the highest aspect was on communication involved in conversation 85% and the lowest was on the value of the non-verbal communication skills aspect 74%. Overall the results of the assessment of communication skills are at a good level.

The research results above, prove that the project-based learning model produces improvements in students' critical thinking skills. This is in line with research conducted by Afriana et al (2016) and Luthvitasari et al (2012) that PjBL learning can improve critical thinking skills. Apart from being able to improve critical thinking skills, the project-based learning model produces improvements in students' communication skills. This research is relevant to the research results of Ambarwati (2015), that students' abilities at aspects of communication skills through Project Based Learning to achieve classical completion. Kumalaretna (2017) also shows that students who receive model Project Learning achieve individual and classical completeness in various aspects mathematical communication skills.

Conclusion

The results of the analysis PjBL-STEM learning is able to improve 21st-century skills which are currently a priority in learning, especially in an independent curriculum that aims to balance the Industrial Revolution 4.0. Increasing 21st-century competencies applied to project-based learning with science, technology, engineering, and mathematics approaches significantly influences students' critical thinking skills compared to the model applied to the control class, namely the inquiry model. In the control class, the average N-Gain was 0.42, while in the experimental class, it was 0.58 both in the control class and in the experimental class are in the medium category but by looking at the effectiveness criteria, the experimental class is quite effective compared to the control class. PjBL-STEM learning also affects communication thinking skills as evidenced by an increase in students' ability to communicate at a good level.

Acknowledgments

Our thanks go to the big family of MTS 6 Cianjur. Thank you to the Ministry of Education, Culture, Research & Technology (Kemendikbudristek) for funding sources for research. Thank you to the Department of Science Education, Postgraduate School Pakuan University. Apart from that, a big thank you is also expressed to expert practitioners and students who have supported and supported until this research was completed.

Author Contributions

Conceptualization, R.W., and A.P.; methodology, R.W., and A.P; software, R.W.; validation, A.P., and D.A.; formal analysis, R.W.; investigation, R.W.; resources, R.W.; data curation, R.W., A.P., and D.A; writing—original draft preparation, R.W.; writing—review and editing, D.A., and A.P.; visualization, R.W.; supervision, A.P.; project administration, R.W.; funding acquisition, R.W. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat, Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi, Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, grant number DRTPM: 180/E5/PG.02.00.PL/2023

Conflicts of Interest

The authors declare no conflict of interest.

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