



The Effectiveness of Problem-Based Physics Learning to Improve High School Students' Science Process Skills

Maruf*, Ana Dhiqfaini Sultan, and Nurzyanti Jani

Physics Education Department, Faculty of Teacher and Training Education
Universitas Muhammadiyah Makassar, Makassar, Indonesia

*maruf@unismuh.ac.id

Abstract

This research aims to analyze the improvement in students' science process skills after applying the problem-based learning model to physics learning. Physics learning at the high school level, namely at Makassar National High School, experiences several deficiencies in the science process skills experienced by students. Choosing a problem-based learning model can support the delivery of material well. This research uses the problem-based learning model to analyze students' science process skills before and after being taught. The type of research used is quasi-experimental research. The population in this study was 32 students. The sampling technique uses purposive sampling with two classes. The level of science process skills of class X IPA 2 (experimental) students obtained an average score of 73.60 and class X IPA 3 (control) of 42.81. The results of the N-gain test analysis in the experimental class obtained an average value of 0.59 with medium criteria. The control class had an average N-gain value of 0.05 with low criteria, meaning there was an increase in both classes, so it can be concluded that there was a significant influence on students' science process skills after using the problem-based learning model. The research contribution is that the implementation of problem-based learning is very effective for improving physical science process skills.

Keywords: learning models; problem based learning; science process skills

Received : 3 January 2024

Accepted : 16 February 2024

Published: 4 March 2024

DOI : <https://doi.org/10.20527/jipf.v8i1.11544>

© 2024 Jurnal Ilmiah Pendidikan Fisika

How to cite: Maruf, M., Sultan, A. D., & Jani, N. (2024). The effectiveness of problem-based physics learning to improve high school students' science process skills. *Jurnal Ilmiah Pendidikan Fisika*, 8(1), 102-111.

INTRODUCTION

Learning is something that is needed that must be fulfilled in the technique of life. According to Adri et al. (2020) and Mann et al. (2021), whether a nation is advanced or not is influenced by the level of learning because the level of learning is a way to create worthy offspring. Learning is a method or effort carried out by a person or, in this case, students

obtain new objects from their environment. Teaching is a method of guiding practice that connects two themes: teachers and students. The obligation and responsibility of a teacher are to work so that the reception becomes more competent, interesting, balanced, and of course, creates good things; the teacher must be more active in showing the teaching staff (Adri et al., 2020; Bao



& Koenig, 2019; Ince, 2018; Suliyanah et al., 2021; Williams, 2018). A teaching member is developing their abilities so that their psychology, body, and mind are more focused. An explanation that will be successful fulfills the valuable elements of approaching a goal; these valuable and important elements are people, materials, equipment, and steps, which will be mutually related so that the dreamed goal will also be successful. This goal will change the learning acceptor towards someone more capable than before. Teaching members will approach the goal, namely from the aspects of behavior, insight, and intelligence (Cole et al., 2018; Darmaji et al., 2019; Fidan & Tuncel, 2019; Muktiarni et al., 2019; Rusanganwa, 2015).

What is useful for students to learn is increasing competence in problem-solving. Some of the study results provide solutions to this problem, one of which is that the use of study strategies with problem-based learning can improve students' science process skills (Marisda & Ma'Ruf, 2021; Ma'ruf et al., 2019a, 2019b, 2019c; Ruf Ma'ruf & Dhiqfaini Sultan, 2023a). Problem-based learning is an investigative procedure that forces students to create a desire to find a solution to an authentic case. During the problem-solving method, students construct an understanding and develop mastery of problem-solving and mastery to train themselves independently when looking for solutions to the problem. A case can be interpreted as a situation where a person carries out a job that is not known beforehand (Ma'Ruf et al., 2019a, 2019b; Ma'ruf et al., 2020a; Ma'Ruf et al., 2020a; Ma'ruf et al., 2020b; Ruf Ma'ruf & Dhiqfaini Sultan, 2023b). The constructivist philosophy of learning, which emphasizes the need for students to investigate their environment and create insights that are useful as

individuals, provides the theoretical foundation for problem-based learning.

The problem-based learning model aims to help students improve or improve their thinking abilities, develop students' brilliant ideas in their operations, motivate students deeply in learning, and, of course, improve problem-solving abilities.

Educators conducting research will make physics learning more positive. So, to improve students' explanations and science process skills, educators are encouraged to carry out recitations related to the modules they want to teach students. (Rezki Rahman, 2023; Sapna et al., 2023; Sulistyaningsih & Eko Sujarwanto, 2023).

Students' science process skills must be allowed to participate directly in rational activities or experiences, not at odds with what academics feel. The act of practicing guiding by training students' science process skills can be carried out with tasks if science is a level that has great potential to help improve students' character. The growing character of students is a prerequisite for entering any popular career path. Advancing student productivity means activating students in acceptance activities (Rezki Rahman, 2023; Savin-Baden, 2000; Temel, 2014; Tsalapatas et al., 2019).

Science process skills are all the skills needed to acquire, develop, and implement schemes, principles, laws, and rational schemes in the form of psychological, physical, and social skills. Science process skills are the methods academics use to obtain data (Ayyildiz & Tarhan, 2018; Malmia et al., 2019; Pratiwi et al., 2019; Raiyn & Tilchin, 2015; Sulaiman, 2010). This is the mastery and method used by academics in laboratories to create new data. On the other hand, science process skills are methods children use to obtain data from their initial experience of carrying out activities to train themselves. One of the studies that can provide a self-training

experience is a practicum activity (Husein et al., 2019; Ismail et al., 2018; Mann et al., 2021; Wiranata et al., 2021).

The results of other research show that a problem-based learning model really allows students to develop a scientific attitude, namely, science process skills during learning. Good science process skills will produce good learning outcomes, too (Janah et al., 2018).

Based on the results of questions and answers with the Makassar National High School physics teacher, it is known that students do not detect and dismantle a scheme in a specific module, so students' science process skills cannot grow to the maximum.

Students are less than optimal, especially slow in receiving data from the teacher; students do not understand the design and students only remember the modules given by the teacher, which results in students being less able to solve problems and resulting in reduced science process skills (Saputra et al., 2019; Suhirman et al., 2021).

This statement means that if problem-based learning models have not been used in physics research, especially in the intermediate mixture module, the analytical thinking and scientific system capabilities are not yet ideal. The problem formulation for this research is to analyze the effectiveness of problem-based learning in physics learning in improving students' science process skills.

METHOD

The research model in this study is an imaginary experiment. The research design in this study is a nonequivalent control group design. This research model has a set of controls, but not all of them play a role in regulating external flexibility that influences the implementation of the experiment (Creswell, 2008; Gall & Borg et al., 2003).

The research concepts used are research categories and monitoring categories, either using pretests or posttests, as in Table 1.

Table 1 Nonequivalent control group design research design

Class	Pre test	Treat-ment	Post test
Experiment	O ₁	X ₁	O ₂
Control	O ₁	X ₂	O ₂

The data analysis techniques used in this study were descriptive insights and inferential insights. Descriptive insight methods were used to describe the study's plastic character and the learning unit's validity.

Each learning unit's expert verification data was assessed by considering input, reviews, and validator recommendations. The results of the insights were used as norms for revising study tools and instruments. Meanwhile, inferential insight was used to check research assumptions by using t-experiments. Before carrying out the assumption experiment, a normality and homogeneity experiment was carried out as a term of analysis.

RESULT AND DISCUSSION

Descriptive Analysis Results

Descriptive figures for students' knowledge system skills during the period before the implementation of the model of problem-based learning (pre) and after the implementation of the problem-based learning (post) can be seen in Table 2 and 3.

Table 2 Percentage of science process skills average pretest score per indicator

Indicators of Science Process Skills	Percentage (%)	
	Experiment	Control
Asking question	58.12	52.50
Proposing a Hypothesis	26.88	20.62
Classifying	34.38	34.38

Indicators of Science Process Skills	Percentage (%)	
	Experiment	Control
Analyzing Data	40.00	38.75
Concluding	31.88	29.38

The level of student pretest data science proficiency according to the markers used on the instrument. This tabulation was created to see more clearly the contrast between the percentages of the five markers of scientific knowledge. In the first marker, namely asking, it appears that the percentage in the assessment category and control category is higher in the assessment category. The second marker submitted a thesis; the assessment category had a higher percentage than the control category. The third marker is to classify the percentage of the assessment category and the control category, which is suitable. Then, the fourth marker looks at the data; the assessment category is higher than the control category, even though it only differs by approximately 2%. Meanwhile, the fifth marker is formulating; the assessment category is more noble than the control category. Thus, it is concluded that the percentage of the five markers is the highest price, which is dominated by the assessment category.

Table 3 Percentage of science process skills average posttest score per indicator

Indicators of Science Process Skills	Percentage (%)	
	Experiment	Control
Asking question	66.25	53.75
Proposing a Hypothesis	62.50	39.38
Classifying	63.12	36.25
Analyzing Data	85.62	36.25
Concluding	85.00	43.12

Based on Table 3, The percentage achieved by students is interpreted based on the science process skills markers on the posttest. This sketch was created to see more clearly the percentage differences between the five markers of science process skills. In the initial marker, namely asking, it appears that the percentage in the experimental category and the supervision category is higher in the experimental category. The second pointer expressed that the experimental category had a higher percentage than the supervision category.

The third marker, namely classifying the percentage in the experimental category, is higher than the supervision category. After that, the fourth marker examined the data; the experimental category was at the top, and the supervision category. The fifth marker, formulating the experimental category, is at the top and is very different from the supervision category. So, it can be concluded that the percentage of the five markers is the highest, which is dominated by the experimental category.

The indicators of science process skills are asking questions, proposing a hypothesis, classifying, analyzing data, and concluding. It is very obvious that proposing a hypothesis, classification, and analyzing data is very low in the control class and vice versa in the experimental class, which is very high. This is closely related to problem-based learning, which facilitates students in developing their science process skills, and there are three that provide very good changes, namely proposing a hypothesis, classification, and analyzing data.

The N-gain test results can be seen in the following Table 4.

Table 4 Average N-Gain test results for the experiment class and the control class

Class	N-Gain	Criteria
Experiment	0.59	Currently
Control	0.05	Low

The average results of the N-Gain test are also very consistent with the results of the science process skills obtained. Comparison of data between experimental classes that implement problem-based learning. Overall, students have greatly developed their science process skills. In other words,

there is a fundamental contribution from the problem-based learning treatment studied, especially in physics learning.

Inferential Analysis Results

Results of the normality test are listed in Table 5.

Table 5 Results of the normality test

Treatment		Kolmogorov-Smirnov ^a		
		Statistic	df	Sig
Science process skills	experimental pretest	.140	32	.113
	control pretest	.154	32	.053
	experimental posttest	.149	32	.068
	control posttest	.140	32	.111

Based on the data in Table 5, the Sig. Observed when Sig. for data from the pretest assessment (0.113), posttest assessment (0.053), pretest supervision (0.068), and posttest supervision (0.111) indicates that the data is greater than Sig. 0.05, so it can be concluded that the data is fairly distributed.

Table 6 Result of homogeneity pretest

Levene statistic	df 1	df 2	Sig.
.392	1	62	.534

Based on Table 6, the value of Sig. The pretest data is 0.534, which indicates that the value is greater than Sig. 0.05 so that it can be concluded that the pretest data on the science process skills of students in class X IPA at Makassar National High School came from a homogeneous class. Meanwhile, the posttest data for students' science process skills in the experimental and control classes were also carried out using the one-way ANOVA test in the SPSS application, which can be seen in Table 7.

Table 7 Result of homogeneity posttest

Levene statistic	df 1	df 2	Sig.
3.845	1	62	.054

The posttest Sig. Data figure is 0.054, which shows that if the figure is less than 0.05, it can be concluded that the posttest data on science process skills of students in category X Science at Makassar

National High School comes from a single category.

The results of testing assumptions using SPSS using the Independent Samples T-test showed a Sig number. (2-tailed) in equal variances, it is assumed that because the data is homogeneous, it is 0.000, which means the number is smaller than the Sig value. (2-tailed) This shows the students' science process skills after treatment using problem-based learning examples in the research category and conventional study examples in the supervision category, which means that H_0 is rejected and H_a is obtained. obtained, in essence, there are meaningful results regarding the technical and technical skills of the guard committee participants.

The level of science process skills of students in category Meanwhile, the level of science process skills of students in category. Based on inferential analysis using the SPSS application, pre-checking and post-test study data on science process skills methods were tested using normality, homogeneity, and hypothesis tests.

The results of this study show an antagonism between science process skills that are taught using problem-based learning models and those taught using conventional study. The study results show a sig point < 0.05 , namely $0.000 <$

0.05, so it can be seen that the impact of implementing problem-based learning complications, analytical thinking skills, and science process skills in the buffer fluid module. This appears to be based on the average score of a science process skills test (Ali et al., 2016; Rahman, 2023; Williams, 2018).

Providing practicums using worksheets that have been prepared according to the instructions on the checking instrument and, of course, the worksheets always contain syntax that imitates problem-based learning, namely by providing cases in advance or samples of related modules. with everyday life (Hu et al., 2021; Matthee & Turpin, 2019; Sulistyarningsih & Sujarwanto, 2023). maka pemberian praktikum lebih gampang dimengerti serta didapat oleh anak didik (Ma'ruf et al., 2020c; Ma'Ruf et al., 2020b, 2020c). This can be seen from the average score obtained by students when carrying out the pretest for the examination category and control category, which is less than the average income points obtained by students when carrying out the posttest for the examination category. as well as the control category (Ahriana et al., 2016; Ariansyah et al., 2017; Nuraisyah et al., 2015).

After that, in the posttest, the average score for the monitoring caste was less than the average score for the inspection caste. This is because students in the examination caste understand the direct shock module better. After all, they carry out practicums and can investigate directly, while students in the examination caste do not carry out practicums.

CONCLUSION

The results of this research show a discrepancy in the science process skills of students who are taught using a problem-based learning form and those who are taught using conventional study.

REFERENCES

- Adri, M., Rusdinal, Zainul, R., Darni, Sriadhi, Wahyuningtyas, N., Khaerudin, Nasrun, Rahmulyani, Nuranjani, Nurmaniah, Wedi, A., Surahman, E., Aisyah, E. N., Oktaviani, H. I., Sri Martini Meilanie, R., Purnamawati, S. N., Hapidin, Listyasari, W. D., ... Adnan, E. (2020). Development of content learning system in professional education subjects for educational institutions in indonesia. *Journal of Physics: Conference Series*, 1594(1). <https://doi.org/10.1088/1742-6596/1594/1/012022>
- Ahriana, Yani, A., & Maruf, U. M. M. (2016). Studi analisis hubungan antara self efficacy dengan hasil. *Jurnal Pendidikan Fisika*, 4(2), 223–238. <http://journal.unismuh.ac.id/index.php/jpf/article/viewFile/312/293>
- Ali, M., Talib, C.-A., Hasniza Ibrahim, N., Surif, J., & Halim Abdullah, A. (2016). The importance of monitoring skills in physics problem solving. *European Journal of Education Studies*, 1(3), 1–10.
- Ariansyah, Khaeruddin, & Maruf, U. M. M. (2017). Upaya meningkatkan hasil belajar fisika melalui pembelajaran kontekstual pada siswa kelas vii smp aisyiyah. *Jurnal Pendidikan Fisika*, 3, 91–104.
- Ayyildiz, Y., & Tarhan, L. (2018). Problem-based learning in teaching chemistry: enthalpy changes in systems. *Research in Science and Technological Education*, 36(1), 35–54. <https://doi.org/10.1080/02635143.2017.1366898>
- Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. *Disciplinary and Interdisciplinary Science Education Research*, 1(1), 1–12. <https://doi.org/10.1186/s43031-019-0007-8>

- Cole, M., Cohen, C., Wilhelm, J., & Lindell, R. (2018). Spatial thinking in astronomy education research. *Physical Review Physics Education Research*, 14(1), 10139. <https://doi.org/10.1103/PhysRevPhysEducRes.14.010139>
- Creswell, J. W. (2008). Educational research. *Animal Genetics*, 39(5).
- Darmaji, Kurniawan, D. A., Astalini, Lumbantoruan, A., & Samosir, S. C. (2019). Mobile learning in higher education for the industrial revolution 4.0: Perception and response of physics practicum. *International Journal of Interactive Mobile Technologies*, 13(9), 4–20. <https://doi.org/10.3991/ijim.v13i09.10948>
- Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers and Education*, 142(July), 103635. <https://doi.org/10.1016/j.compedu.2019.103635>
- Gall & Borg, Meredith D. Gall, Walter R. Borg, & Joyce P. Gall. (2003). *Educational research_ an introduction (7th edition)*.
- Hu, L., Chen, G., Li, P., & Huang, J. (2021). Multimedia effect in problem solving: a meta-analysis. In *Educational Psychology Review* (Vol. 33, Issue 4). Educational Psychology Review. <https://doi.org/10.1007/s10648-021-09610-z>
- Husein, S., Gunawan, Harjono, A., & Wahyuni, S. (2019). Problem-based learning with interactive multimedia to improve students' understanding of thermodynamic concepts. *Journal of Physics: Conference Series*, 1233(1). <https://doi.org/10.1088/1742-6596/1233/1/012028>
- Ince, E. (2018). An overview of problem solving studies in physics education. *Journal of Education and Learning*, 7(4), 191–200. <https://doi.org/10.5539/jel.v7n4p191>
- Ismail, N. S., Harun, J., Zakaria, M. A. Z. M., & Salleh, S. M. (2018). The effect of Mobile problem-based learning application DicScience PBL on students' critical thinking. *Thinking Skills and Creativity*, 28, 177–195. <https://doi.org/10.1016/j.tsc.2018.04.002>
- Janah, M. C., Antonius, T. W., & Kasmui, D. (2018). Pengaruh model problem based learning terhadap hasil belajar dan keterampilan proses sains. *Jurnal Inovasi Pendidikan Kimia*, 12(1), 2097–2107.
- Malmia, W., Makatita, S. H., Lisaholit, S., Azwan, A., Magfirah, I., Tinggapi, H., & Umanailo, M. C. B. (2019). Problem-based learning as an effort to improve student learning outcomes. *International Journal of Scientific and Technology Research*, 8(9), 1140–1143.
- Mann, L., Chang, R., Chandrasekaran, S., Coddington, A., Daniel, S., Cook, E., Crossin, E., Cosson, B., Turner, J., Mazzurco, A., Dohaney, J., O'Hanlon, T., Pickering, J., Walker, S., Maclean, F., & Smith, T. D. (2021). From problem-based learning to practice-based education: a framework for shaping future engineers. *European Journal of Engineering Education*, 46(1), 27–47. <https://doi.org/10.1080/03043797.2019.1708867>
- Marisda, D. H., & Ma'Ruf, M. (2021). Situation analysis of mathematical physics learning with online learning during the COVID-19 pandemic. *Journal of Physics: Conference Series*, 1806(1), 2–7. <https://doi.org/10.1088/1742-6596/1806/1/012034>
- Ma'Ruf, M., Handayani, Y., Marisda, D. H., & Riskawati, R. (2020a). The needs analysis of basic physics learning devices based on hybrid learning. *Journal of Physics:*

- Conference Series*, 1422(1).
<https://doi.org/10.1088/1742-6596/1422/1/012029>
- Ma'Ruf, M., Handayani, Y., Marisda, D. H., & Riskawati, R. (2020b). The needs analysis of basic physics learning devices based on hybrid learning. *Journal of Physics: Conference Series*, 1422(1).
<https://doi.org/10.1088/1742-6596/1422/1/012029>
- Ma'Ruf, M., Handayani, Y., Marisda, D. H., & Riskawati, R. (2020c). The needs analysis of basic physics learning devices based on hybrid learning. *Journal of Physics: Conference Series*, 1422(1).
<https://doi.org/10.1088/1742-6596/1422/1/012029>
- Ma'Ruf, M., Marisda, D. H., & Handayani, Y. (2019a). The basic physical program based on education model online assisted by alfa media to increase creative thinking skills. *Journal of Physics: Conference Series*, 1157(3).
<https://doi.org/10.1088/1742-6596/1157/3/032068>
- Ma'Ruf, M., Marisda, D. H., & Handayani, Y. (2019b). The basic physical program based on education model online assisted by alfa media to increase creative thinking skills. *Journal of Physics: Conference Series*, 1157(3).
<https://doi.org/10.1088/1742-6596/1157/3/032068>
- Ma'ruf, M., Setiawan, A., & Suhandi, A. (2019a). Identification of Android-based interactive multimedia needs for basic physics content. *AIP Conference Proceedings*, 2194(December).
<https://doi.org/10.1063/1.5139792>
- Ma'ruf, M., Setiawan, A., & Suhandi, A. (2019b). Identification of Android-based interactive multimedia needs for basic physics content. *AIP Conference Proceedings*, 2194(December).
<https://doi.org/10.1063/1.5139792>
- Ma'ruf, M., Setiawan, A., Suhandi, A., & Siahaan, P. (2020a). Identification of the ability to solve the problem of contextual physics possessed by prospective physics teachers related to basic physics content. *Journal of Physics: Conference Series*, 1521(2).
<https://doi.org/10.1088/1742-6596/1521/2/022011>
- Ma'ruf, M., Setiawan, A., Suhandi, A., & Siahaan, P. (2020b). Identification of the ability to solve the problem of contextual physics possessed by prospective physics teachers related to basic physics content. *Journal of Physics: Conference Series*, 1521(2).
<https://doi.org/10.1088/1742-6596/1521/2/022011>
- Ma'ruf, M., Setiawan, A., Suhandi, A., & Siahaan, P. (2020c). Identification of the ability to solve the problem of contextual physics possessed by prospective physics teachers related to basic physics content. *Journal of Physics: Conference Series*, 1521(2).
<https://doi.org/10.1088/1742-6596/1521/2/022011>
- Mathee, M., & Turpin, M. (2019). Teaching critical thinking, problem solving, and design thinking: Preparing IS students for the future. *Journal of Information Systems Education*, 30(4), 242–252.
- Muktiarni, M., Widiaty, I., Abdullah, A. G., Ana, A., & Yulia, C. (2019). Digitalisation trend in education during industry 4.0. *Journal of Physics: Conference Series*, 1402(7), 0–6. <https://doi.org/10.1088/1742-6596/1402/7/077070>
- Nuraisyah, Samad, A., & Maruf, U. M. M. (2015). Upaya meningkatkan hasil

- belajar fisika melalui model pemecahan masalah (problem solving). *Jurnal Pendidikan Fisika*, 3(3), 270–278. <http://journal.unismuh.ac.id/index.php/jpf/article/view/279/264>
- Pratiwi, S. N., Cari, C., Aminah, N. S., & Affandy, H. (2019). Problem-based learning with argumentation skills to improve students' concept understanding. *Journal of Physics: Conference Series*, 1155(1). <https://doi.org/10.1088/1742-6596/1155/1/012065>
- Raiyn, J., & Tilchin, O. (2015). Higher-order thinking development through adaptive problem-based learning. *Journal of Education and Training Studies*, 3(4), 93–100. <https://doi.org/10.11114/jets.v3i4.769>
- Rezki Rahman, M. (2023). Development of physics teaching material with problem-based learning to train students' problem-solving skills. *Jurnal Ilmiah Pendidikan Fisika*, 7(3), 459–470. <https://doi.org/10.20527/jipf.v7i3.9395>
- Ruf Ma'ruf, M. ', & Dhiqfaini Sultan, A. (2023a). Analysis of the use of interactive multimedia android thermodynamics to reduce student misconceptions. *European Online Journal of Natural and Social Sciences*, 12(1), 213–219. www.european-science.com
- Ruf Ma'ruf, M. ', & Dhiqfaini Sultan, A. (2023b). Analysis of the use of interactive multimedia android thermodynamics to reduce student misconceptions. *European Online Journal of Natural and Social Sciences*, 12(1), 213–219. www.european-science.com
- Rusanganwa, J. A. (2015). Developing a multimedia instrument for technical vocabulary learning: a case of EFL undergraduate physics education. *Computer Assisted Language Learning*, 28(2), 97–111. <https://doi.org/10.1080/09588221.2013.784708>
- Sapna, H., Miriam, S., Hafiz Ridho, M., & Saukani, M. (2023). Improving students' problem-solving skills using direct instruction-oriented worksheets on the subject of temperature and heat. *Jurnal Ilmiah Pendidikan Fisika*, 7(3), 391–399. <https://doi.org/10.20527/jipf.v7i3.8988>
- Saputra, M. D., Joyoatmojo, S., Wardani, D. K., & Sangka, K. B. (2019). Developing critical-thinking skills through the collaboration of Jigsaw model with problem-based learning model. *International Journal of Instruction*, 12(1), 1077–1094. <https://doi.org/10.29333/iji.2019.12169a>
- Savin-Baden, M. (2000). Problem-based learning in higher education: untold stories. *Biochem. Mol. Biol. Educ. Biochemistry and Molecular Biology Education*, 31(5), 454–. <http://www.worldcat.org/oclc/425421421%5Cnhttp://www.worldcat.org/oclc/423538701%5Cnhttp://www.worldcat.org/oclc/4656440090%5Cnhttp://www.worldcat.org/oclc/748996635>
- Suhirman, S., Prayogi, S., & Asy'ari, M. (2021). Problem-based learning with character-emphasis and naturalist intelligence: examining students critical thinking and curiosity. *International Journal of Instruction*, 14(2), 217–232. <https://doi.org/10.29333/iji.2021.14213a>
- Sulaiman, F. (2010). Students' perceptions of implementing problem-based learning in a physics course. *Procedia - Social and Behavioral Sciences*, 7(2), 355–362. <https://doi.org/10.1016/j.sbspro.2010.10.048>
- Sulistyaningsih, D., & Eko Sujarwanto, dan. (2023). The effect of the 5e learning cycle model assisted by

- problem-solving-based student worksheets on student learning outcomes in the material of thermodynamics. *Jurnal Ilmiah Pendidikan Fisika*, 7(3), 522–531. <https://doi.org/10.20527/jipf.v7i3.8386>
- Suliyannah, Deta, U. A., Kurniawan, F. K., Lestari, N. A., Yantidewi, M., Jauhariyah, M. N. R., & Prahani, B. K. (2021). Literature review on the use of educational physics games in improving learning outcomes. *Journal of Physics: Conference Series*, 1805(1). <https://doi.org/10.1088/1742-6596/1805/1/012038>
- Temel, S. (2014). The effects of problem-based learning on pre-service teachers' critical thinking dispositions and perceptions of problem-solving ability. *South African Journal of Education*, 34(1), 1–20. <https://doi.org/10.15700/201412120936>
- Tsalapatas, H., De Carvalho, C. V., Heidmann, O., & Houstis, E. (2019). Active problem-based learning for engineering higher education. *CSEDU 2019 - Proceedings of the 11th International Conference on Computer Supported Education*, 2(Csedu), 347–351. <https://doi.org/10.5220/0007720403470351>
- Williams, M. (2018). The missing curriculum in physics problem-solving education. *Science and Education*, 27(3–4), 299–319. <https://doi.org/10.1007/s11191-018-9970-2>
- Wiranata, D., Widiana, I. W., & Bayu, G. W. (2021). The effectiveness of learning activities based on revised bloom taxonomy on problem-solving ability. *Indonesian Journal Of Educational Research and Review*, 4(2), 289. <https://doi.org/10.23887/ijerr.v4i2.37370>