Tadris: Jurnal Keguruan dan Ilmu Tarbiyah 9 (2): 413-425 (2024)
DOI: 10.24042/tadris.v9i2.24627

TADRIS: JURNAL KEGURUAN DAN ILMU TARBIYAH
(Tadris: Journal of Education and Teacher Training)
P-ISSN: 2301-7562 | E-ISSN: 2579-7964
ejournal.radenintan.ac.id/index.php/tadris/index

Enhancing Problem-Solving Skills and Learning Motivation Through Problem-Based Learning Modules in Biology Education

Frida Fadwa, Muhibbuddin, Hafnati Rahmatan, Wiwit Artika, Muhammad Ali Sarong
Department of Biology Education, Universitas Syiah Kuala, Banda Aceh, Indonesia

Article History:
Submitted: October 4th, 2024
Revised: November 7th, 2024
Accepted: December 10th, 2024
Published: December 29th, 2024

Keywords:
Biology education,
Learning motivation,
Problem-based learning,
Problem-solving skills,
Student worksheets

***Correspondence Address:**
fridafadwa@gmail.com

Abstract: Problem-solving skills and learning motivation are essential components of 21st-century education, particularly in biology, where these competencies enable students to connect scientific concepts to real-world challenges. This study investigates the effectiveness of problem-based learning modules integrated with student worksheets in enhancing problem-solving skills and learning motivation on the topic of global warming. Conducted with tenth-grade students at a private high school in Banda Aceh, Indonesia, the research utilized an experimental design with pretest-posttest control groups. A total of 72 students were divided into experimental and control groups. Data collection included problem-solving skills tests based on Polya's framework and learning motivation questionnaires developed using Keller's ARCS model. The results revealed significant improvements in the experimental group, with an average normalized gain score of 77 for problem-solving skills, categorized as high, compared to 22 in the control group, categorized as low. Furthermore, the experimental group demonstrated strong learning motivation across all ARCS indicators. A correlation test indicated a very strong relationship between learning motivation and problem-solving skills, with motivation accounting for 74% of the variance in problem-solving performance. These findings underscore the effectiveness of problem-based learning modules in fostering critical competencies, supporting their integration into biology education to prepare students for future challenges. Further research is recommended to extend this approach to other scientific topics and diverse student populations.

INTRODUCTION

In life, no individual is exempt from encountering problems (AlAli, 2024). In the realm of education, challenges arise across various dimensions, including those faced by students and teachers (Hansen, 2009; Claro et al., 2012; Du et al., 2013; Kadir, 2017). However, every problem inherently holds the potential for a solution, preventing it from becoming an excessive burden on an individual's mental or psychological well-being (Akot, 2020). This underscores the essential nature of problem-solving skills in all aspects of life, including the workplace (Suratno et al., 2020; Özdemir et al., 2010; Yeung et al., 2023; Merriënboer, 2024).

Individuals with strong problem-solving skills can address challenges effectively, leveraging creativity to find solutions. These skills encompass four key indicators: identifying problems, formulating strategies, implementing solutions, and verifying results (Yayuk et al., 2020). Moreover, critical thinking

plays a vital role in analyzing information related to problems, enabling individuals to manage problem-solving processes proficiently (Eren & Öztuğ, 2020). Problem-solving is defined as a structured effort to achieve specific objectives (Yao et al., 2023). For learners, it involves selecting appropriate methods to resolve issues based on theoretical frameworks they have studied (Hermansyah, 2020; Dia et al., 2021; Liu & Tongxi, 2022).

Connecting classroom lessons to the surrounding environment enhances learning's meaningfulness by enabling students to relate academic material to their everyday lives (Tai et al., 2019). In biology education, students are encouraged to adopt scientific approaches when addressing environmental issues such as global warming (Musyaddad & Suyanto, 2019; Karmana et al., 2019; Arsil, 2019). However, interviews with biology teachers revealed that 60% of students failed to achieve mastery in learning about global warming. This finding indicates a deficiency in students' problem-solving skills for this topic. Student interviews further revealed a lack of training in problem-solving during lessons, leading to reliance on rote memorization, difficulty grasping broader concepts, and limited ability to connect material to real-life applications.

To address these challenges, teachers must employ engaging instructional tools and implement dynamic, non-monotonous learning models to motivate students. One effective instructional approach involves using problem-based learning (PBL) modules, which support the independent curriculum and facilitate deeper understanding during the learning process. Motivation plays a pivotal role in learning success, as it provides enthusiasm, energy, and enjoyment, enabling active engagement and improved academic performance (Filgona et al., 2020; Tamu & Atte, 2024; Tekkaya, 2006; Schunk & Di Benedetto, 2021; Susanti et al., 2022).

Teachers' ability to enhance education quality can be strengthened through teaching approaches that cultivate critical thinking and conceptual understanding (Burić & Kim, 2020). Active learning instructional materials, such as PBL modules, are instrumental in fostering communication, collaboration, problem-solving skills, and motivation, particularly in biology education on topics like global warming (Fidan & Tuncel, 2019; Fitriani et al., 2020; Dewi et al., 2022; Herawati & Wilujeng, 2023). Innovative instructional materials, such as PBL modules integrated with student worksheets, represent a promising approach.

Research by Nur Arafah et al. (2023) demonstrated that PBL worksheets integrating religious and practical values enhance learning outcomes on global warming. However, this study focused on general learning outcomes without specifically examining students' problem-solving skills or motivation. Addressing this gap, the present study investigates the use of PBL modules integrated with student worksheets (LKS) to improve students' problem-solving skills and learning motivation. Using a pretest-posttest control group experimental design, this research evaluates the direct impact of the module and explores the correlation between problem-solving skills and motivation. While prior studies have explored the general benefits of PBL-based modules, limited research has specifically addressed their application to enhance problem-solving skills and motivation on global warming. This study contributes novel insights to the development of PBL modules applicable to broader biology topics.

METHOD

This study employed an experimental research design utilizing a pretest-posttest control group approach.

Such a design offers significant advantages, including the ability to determine cause-and-effect relationships and establish connections between the results and the specific variables under investigation. The research was conducted in three distinct stages: (1) administration of the pretest to assess baseline knowledge and skills, (2) implementation of the problem-based learning (PBL) module as the experimental intervention, and (3) administration of the posttest to evaluate the outcomes of the intervention. The experimental research design employed in this study is illustrated in Table 1.

Table 1. Pretest-Posttest Control Group Design.

Class	Pretest	Treatment	Posttest
Experimental	Y_1	X_1	Y_3
Control	Y_2	X_2	Y_4

Notes:
X1 : Group that will receive the treatment
X2 : Group that will not receive the treatment
Y1 : Pretest Experimental Class
Y2 : Pretest Control Class
Y3 : Posttest Experimental Class
Y4 : Posttest Control Class

The instruments were developed based on the problem-solving skills aspects according to Polya (1957), and the motivation instrument was derived from the ARCS model by Keller. The use of problem-based learning modules to enhance students' problem-solving skills and motivation evolved from the design phase to its implementation in teaching. The idea of using this module is presented in Figure 1.

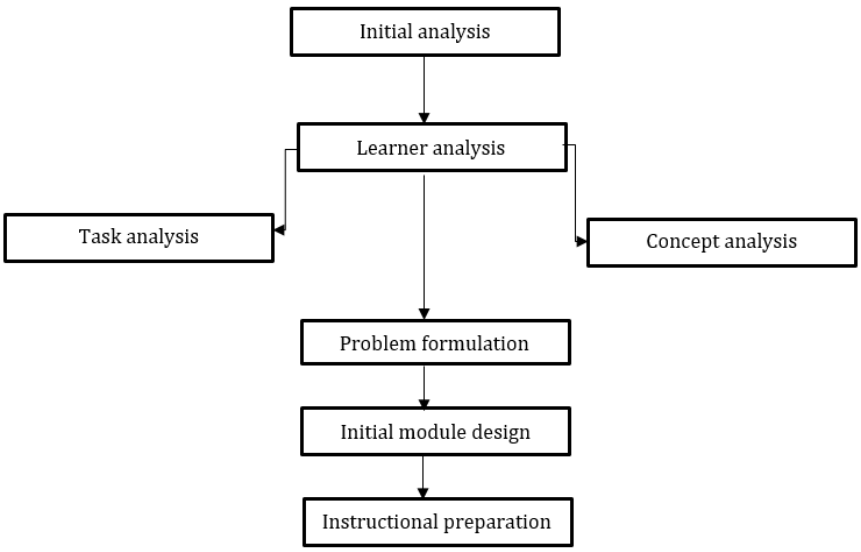

Figure 1. Flowchart of the Use of Problem-based Learning Module.

One of the key advantages of the learning module developed in this study is its comprehensive integration of instructional materials. These materials include a systematically and attractively organized set of content, methods, limitations, and assessment strategies, designed to facilitate the achievement of desired competencies at varying levels of complexity.

This study was conducted at the Laboratory School of SMA USK Banda

Aceh from April to May 2024, during the second semester of the 2024/2025 academic year. The population for this study consisted of 108 students from the X Science class at SMA Laboratory USK Banda Aceh. A purposive sampling technique was employed to ensure the sample aligned with the study's objectives. The selected sample comprised 72 participants, with 36 students from class X-1 and 36 students from class X-2, all of whom were enrolled during the second semester of the 2024/2025 academic year.

Students' learning motivation was assessed using a questionnaire comprising 40 items based on the four motivational indicators outlined by Keller's ARCS model: Attention, Relevance, Confidence, and Satisfaction. To evaluate the differences in motivation between the experimental and control classes, a normalized Gain (N-Gain) score analysis was conducted to measure the improvement from pretest to posttest.

The average N-Gain scores were subjected to normality and homogeneity tests as prerequisites for statistical analysis. Once the data were confirmed to follow a normal distribution and exhibit homogeneity, an Independent Samples t-test was performed to compare the mean scores between the two groups.

RESULT AND DISCUSSION

The findings of this study demonstrate that the use of problem-based learning (PBL) modules integrated with student worksheets significantly enhances students' problem-solving skills and learning motivation. The implementation of PBL was shown to positively influence students' ability to address complex problems and increase their motivation to learn. These results highlight the effectiveness of the PBL approach in fostering critical thinking and active engagement with learning materials. Furthermore, a strong correlation was identified between learning motivation and problem-solving skills, indicating that motivated students are more likely to excel in tackling complex challenges.

Process of Using Student Worksheets to Enhance Problem-Solving Skills

The implementation of the PBL module integrated with student worksheets on the topic of global warming followed three stages: preparation, design, and implementation.

1. **Preparation Stage**: The instructional materials, including student worksheets aligned with PBL, were developed based on the principles of the PBL approach.
2. **Design Stage**: The instructional module was structured to align with the PBL syntax and tailored to address the topic of global warming effectively.
3. **Implementation Stage**: A pretest was administered to both experimental and control classes to assess students' baseline problem-solving abilities.

During the learning sessions in the experimental class, the student worksheets were utilized as part of the instructional process, adhering to the PBL syntax outlined in the module. After the instructional period, a posttest was conducted to evaluate the students' final problem-solving abilities. Additionally, a motivation questionnaire was administered in the experimental class to measure the impact of the module on students' learning motivation. The results were then analyzed to identify differences in problem-solving skills and motivation between the experimental class (which received the PBL intervention) and the control class (which followed conventional teaching methods).

Problem-Solving Skills

The analysis of students' problem-solving skills was conducted using pretest and posttest scores, along with the normalized Gain (N-Gain) scores for both the experimental and control classes. The

comparative results, as well as the improvement trends, are illustrated in Figure 2. These findings underscore the significant impact of the PBL module integrated with student worksheets in enhancing problem-solving skills, particularly in addressing environmental issues like global warming.

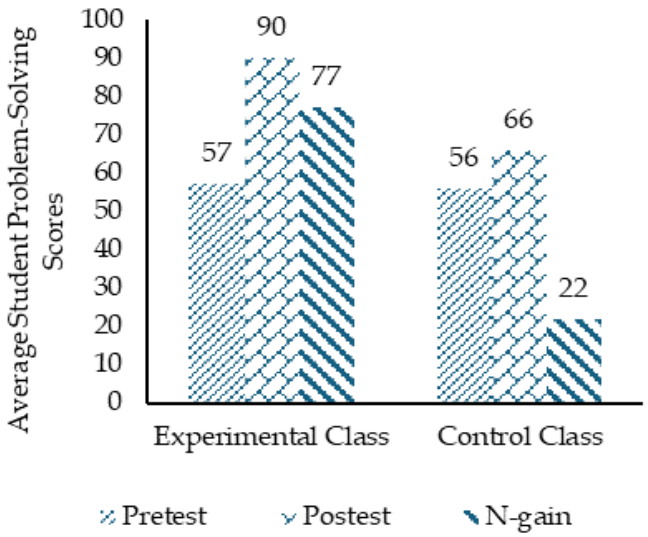

Figure 2. Average Student Problem-Solving Scores.

Figure 2 presents the average pretest and posttest scores for both the experimental and control classes. The average pretest score for the experimental class was 57, while the control class scored 56, both categorized as "satisfactory." These results indicate that students in both groups began with relatively similar initial abilities. Following the intervention, the average posttest score for the experimental class increased significantly to 90, categorized as "excellent," while the control class achieved an average posttest score of 66, categorized as "good."

These findings highlight the positive impact of implementing the problem-based learning (PBL) module in the experimental class. The use of the PBL module demonstrated a clear improvement in students' problem-solving skills, underscoring its effectiveness in enhancing critical thinking and analytical abilities. This aligns with the research by Nurhemy (2019), which found that PBL modules effectively improve students' analytical skills. Additionally, Lestari et al. (2022) demonstrated that problem-based e-modules significantly enhance students' problem-solving capabilities.

The analysis of normalized gain (N-Gain) scores further supports these findings. The experimental class achieved an average N-Gain score of 77, categorized as "high," indicating the intervention's effectiveness. In contrast, the control class scored an average N-Gain of 22, categorized as "low," reflecting the lack of improvement due to the absence of intervention. These results are consistent with previous studies by Astuti et al. (2021), Hakim et al. (2021), and Wardhana et al. (2022), which reported that problem-based learning modules effectively enhance students' problem-solving skills and foster independent learning. Table 4 summarizes the N-Gain score differences between the experimental and control classes, providing further evidence of the effectiveness of the PBL module in improving problem-solving skills.

Table 2. T-test Mean Comparison of N-Gain Between Experimental and Control Classes.

Class	N-Gain	SD	t-test
Experimental	77	12.038	0.000
Control	22	9.842	

The findings reveal a significant difference in the normalized gain (N-Gain) between the experimental and control classes. Results from the Independent Samples t-test indicate a Sig. (2-tailed) value of 0.00, which is less than the significance threshold ($\alpha = 0.05$). This demonstrates a statistically significant difference in N-Gain scores between the two groups, confirming that the intervention had a positive impact on students in the experimental class. Students in the experimental class, who received the problem-based learning (PBL) module intervention, achieved higher average problem-solving skill scores compared to those in the control class. These results are consistent with prior research by Sujanem (2020), Pratiwi (2021), and Biner (2022), which concluded that implementing PBL effectively enhances problem-solving skills, particularly on the topic of global warming. This supports the acceptance of the study's hypothesis.

The average problem-solving skill scores across the four problem-solving aspects are presented in Figure 3. On the topic of global warming, the experimental class scored an average of 96, categorized as "highly capable," compared to the control class's average of 72, categorized as "capable." For the solution planning aspect, the experimental class scored 84 ("highly capable"), while the control class scored 67 ("capable"). In the problem-solving execution aspect, the experimental class scored 86 ("highly capable"), and the control class scored 63 ("capable"). Lastly, for the evaluation aspect, the experimental class achieved an average score of 95 ("highly capable"), compared to 63 ("capable") in the control class.

These findings indicate that the experimental class exhibited a greater improvement in problem-solving skills across all four aspects compared to the control class. This underscores the effectiveness of the PBL module in fostering higher-order thinking skills, particularly in addressing complex topics such as global warming.

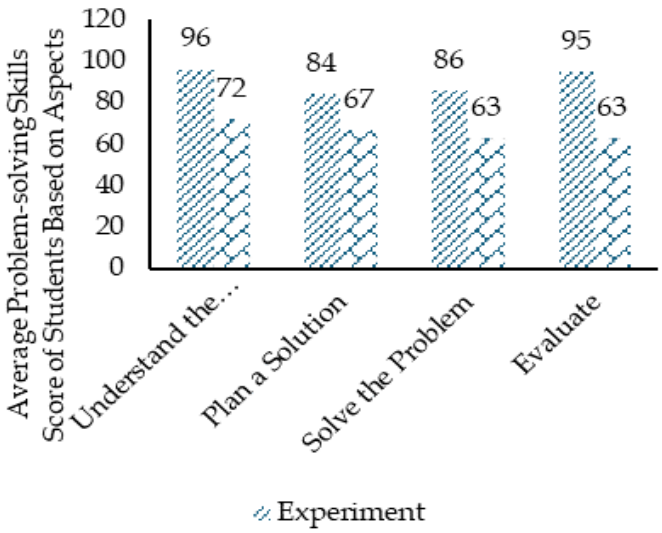

Figure 3. Average Problem-Solving Skills Scores of Students Based on Aspects.

Learning Motivation

Students' learning motivation was assessed using four categories based on Keller's ARCS model: Attention, Relevance, Confidence, and Satisfaction. The composition and distribution of students in the experimental class across these motivational categories are illustrated in Figure 4.

The analysis of students' motivation levels, as measured by the ARCS model, indicates that the implementation of the problem-based learning (PBL) module effectively enhanced learning motivation. The distribution of students across all ARCS categories falls within the "good" criterion according to the assessment guidelines. This suggests that the PBL module met its intended objectives, fostering a positive motivational impact and positioning students in the experimental class as highly motivated learners.

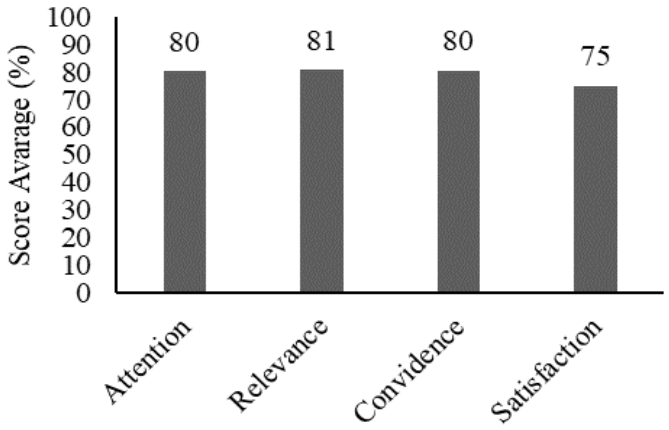

Figure 4. Average Motivation in the Experimental Class.

In line with the findings of Fadillah (2022), it has been stated that teachers who implement engaging teaching models and provide motivation can significantly enhance students' intrinsic motivation. Similarly, research by Pembuat (2020) indicates that the use of instructional modules is highly effective in improving students' learning motivation and achieving better learning outcomes.

Correlation Between Learning Motivation and Problem-Solving Skills

Students' success in the learning process is closely tied to their intrinsic motivation. High motivation serves as a key indicator of quality teaching aimed at fostering problem-solving skills. Students with greater learning motivation are more likely to engage actively in learning activities, leading to optimal outcomes. To explore the relationship between learning motivation and problem-solving skills, a correlation test was conducted, and the results are presented in Table 3.

The correlation test results revealed a coefficient value of r=0.864r = 0.864r=0.864, indicating a very strong positive relationship between learning motivation and problem-solving skills, based on Sugiyono's (2013) correlation criteria. Furthermore, to quantify the extent of the influence of learning motivation on problem-solving skills, a coefficient of determination (R^2) analysis was performed, yielding a value of 0.746. This result suggests that approximately 74.6% of the variance in problem-solving skills can be explained by students' learning motivation.

Table 3. Result of the Correlation Test Between Learning Motivation and Problem-Solving Skills.

Variable	Mean	Correlation	
		Pearson Correlation	**Sig.**
Problem-Solving	77	0.864	0.000
Motivation	88		

The findings indicate that the learning motivation variable contributes 74% to the variance in problem-solving skills, with the remaining 26% influenced by other factors not examined in this study. Effective strategies for teachers to enhance students' motivation in the classroom include providing guidance and support, fostering positive relationships, delivering constructive feedback, and offering appropriate rewards.

Research by Hudha et al. (2023), Safitri and Hadi (2023), and Laura et al. (2024) highlights that learning motivation is closely linked to students' problem-solving abilities. Students with higher motivation are more inclined to engage in exploring and addressing problems, thereby demonstrating stronger problem-solving skills. The regression relationship between learning motivation and problem-solving skills is depicted in Figure 5.

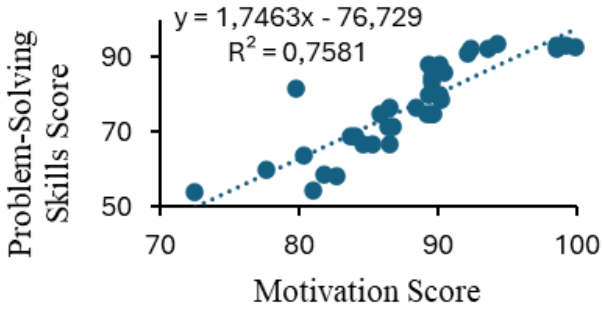

Figure 5. Regression of Learning Motivation and Problem-Solving Skills.

Figure 5 illustrates the regression relationship between learning motivation and problem-solving skills. The scatter plot forms a regression line described by the equation y = 1.7463x − 76.729. Based on this equation, when the learning motivation score (X) is 0, the problem-solving skills score (Y) is predicted to have a constant value of -76.729.

Furthermore, if a student achieves a learning motivation score (X) of 100, their problem-solving skills score (Y) is estimated to be 97.901. This relationship demonstrates that an increase in learning motivation directly contributes to an improvement in problem-solving skills. For every 10 point increase in learning motivation, problem-solving skills improve by 17.463 points.

These findings align with the research conducted by Velly (2021), which highlighted that problem-based learning (PBL) is an effective teaching model for stimulating higher-order thinking skills through the use of real-world problems. The approach has also been shown to enhance both students' motivation and their problem-solving abilities.

Implications for Biology Education

The results of this study have notable implications for biology education, particularly in promoting critical skills such as problem-solving and learning motivation. The successful implementation of PBL modules integrated with student worksheets demonstrates their potential as a model

for enhancing teaching methodologies in high school biology classes. This approach encourages active learning, fosters deeper engagement with instructional materials, and aligns with the competencies required for 21st-century learners.

By addressing real-world problems, PBL modules help students develop both cognitive and affective skills, making them valuable tools for creating interactive, student-centered learning environments.

Study Limitations and Future Directions

While this study provides valuable insights into the impact of PBL modules on problem-solving skills and learning motivation, certain limitations should be acknowledged. First, the research was conducted at a single school with a relatively small sample size, limiting the generalizability of the findings to other educational contexts or populations. Second, the study focused exclusively on the topic of global warming in biology education, leaving the applicability of the findings to other topics or subjects uncertain. Finally, the reliance on self-reported data for learning motivation introduces potential bias, which could affect the accuracy of the results.

Future research should expand the scope by including larger and more diverse samples from different schools and regions to enhance the generalizability of the findings. Additionally, exploring the impact of PBL modules on other science subjects or interdisciplinary topics could provide insights into the broader applicability of this instructional approach. Longitudinal studies are also recommended to investigate the long-term effects of PBL on students' problem-solving skills and motivation. Furthermore, examining additional variables such as scientific literacy, critical thinking, and collaboration skills could offer a more comprehensive understanding of the benefits of PBL modules.

CONCLUSION

This study underscores the significance of problem-solving skills and learning motivation in 21st-century biology education, emphasizing their role in connecting scientific concepts to real-world challenges. The integration of problem-based learning (PBL) modules with student worksheets proved highly effective in enhancing these competencies. The experimental group demonstrated a high average normalized gain (N-Gain) score of 77 for problem-solving skills, compared to 22 in the control group, and exhibited strong learning motivation across all ARCS indicators—attention, relevance, confidence, and satisfaction. A very strong correlation between learning motivation and problem-solving skills was observed, with motivation accounting for 74% of the variance in problem-solving performance. These findings highlight the potential of PBL modules to create interactive, student-centered learning environments, fostering critical skills essential for addressing future challenges. While the study focused on a single topic and educational setting, future research should explore the broader applicability of PBL modules across diverse topics and student populations, as well as their long-term impact on scientific literacy and critical thinking. This approach presents a promising strategy for equipping students with the competencies needed to succeed in a rapidly evolving world.

REFERENCES

Akot, B. (2020). The perspective of psychological freedom and avoiding freedom according to Erich Fromm. *Hamdard Islamicus, 43*(2), 67–88.

AlAli, R. (2024). Enhancing 21st-century skills through integrated STEM education using project-

oriented problem-based learning. *GeoJournal of Tourism and Geosites, 53*(2), 421–430. https://doi.org/10.30892/gtg.53205-1217

Arafah, N., Sulastri, S., & Safrida, S. (2023). Pengembangan lembar kerja peserta didik materi pemanasan global berbasis problem-based learning terintegrasi nilai untuk meningkatkan hasil belajar peserta didik. *Jurnal Pendidikan Sains Indonesia, 11*(1), 50–66. https://doi.org/10.24815/jpsi.v11i1.26838

Arsil, A. (2019). Implementasi model problem-based learning berbantuan multimedia di Sekolah Dasar. *Jurnal Gentala Pendidikan Dasar, 4*(1), 1–9. https://doi.org/10.22437/gentala.v4i1.6905

Astuti, N. H., Rusilowati, A., & Subali, B. (2021). STEM-based learning analysis to improve students' problem-solving abilities in science subjects: A literature review. *Journal of Innovative Science Education, 10*(19), 79–86.

Binar, et al. (2022). Assisted by digital book with 3D animations to improve students' physics problem-solving skills in magnetism. *Journal of Technology and Science Education, 12*(2), 379–396.

Burić, I., & Kim, L. E. (2020). Teacher self-efficacy, instructional quality, and student motivational beliefs: An analysis using multilevel structural equation modeling. *Learning and Instruction, 66*, 101302. https://doi.org/10.1016/j.learninstruc.2019.101302

Claro, M., Preiss, D. D., San, E., Jara, I., Hinostroza, J. E., Valenzuela, S., Cortes, F., & Nussbaum, M. (2012). Assessment of 21st-century ICT skills in Chile: Test design and results from high school level students. *Computers & Education, 59*(3), 1042–1053. https://doi.org/10.1016/j.compedu.2012.04.004

Dewi, W. S., Mairizwan, M., Afrizon, R., Arif, K., & Sundari, P. D. (2022). Improvement of science teachers' competence in developing integrated science worksheets based on scientific literacy to support the implementation of the Merdeka curriculum. *Jurnal Penelitian Pendidikan IPA, 8*(6), 2980–2986. https://doi.org/10.29303/jppipa.v8i6.2558

Du, X., Su, L., & Liu, J. (2013). Developing sustainability curricula using the PBL method in a Chinese context. *Journal of Cleaner Production*, 1–9. https://doi.org/10.1016/j.jclepro.2013.01.012

Eren, H. C., & Öztuğ, E. K. (2020). The implementation of virtual choir recordings during distance learning. *Cypriot Journal of Educational Sciences, 15*(5), 1117–1127. https://doi.org/10.18844/cjes.v15i5.5159

Fadillah, I. (2022). Mathematical problem-solving ability viewed from students' mathematical disposition. *Formatif: Jurnal Ilmiah Pendidikan MIPA, 12*(148), 47–62.

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*, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Filgona, J., Sakiyo, J., Gwany, D. M., & Okoronka, A. U. (2020). Motivation in learning. *Asian Journal of Education and Social Studies, 10*(4), 16–37. https://doi.org/10.9734/ajess/2020/v10i430273

Fitriani, A., Zubaidah, S., Susilo, H., & Al Muhdhar, M. H. I. (2020). The effects of integrated problem-based

learning, predict, observe, explain on problem-solving skills and self-efficacy. *Eurasian Journal of Educational Research, 2020*(85), 45–64. https://doi.org/10.14689/ejer.2020.85.3

Hakim, A. R., Asikin, M., & Cahyono, A. N. (2021). The development of a learning module with mobile augmented reality based on the 9E learning cycle to improve problem-solving skills. *UNNES Journal of Mathematics Education Research, 10*(1), 1–9.

Hansen, A. (2009). Basic conceptual systems (BCSs)—Tools for analytic coding, thinking, and learning: A concept teaching curriculum in Norway. *Thinking Skills and Creativity, 4*(3), 160–169. https://doi.org/10.1016/j.tsc.2009.09.001

Herawati, N. I., & Wilujeng, I. (2023). Improving problem-solving ability through problem-based learning e-modules. *Jurnal Penelitian Pendidikan IPA, 9*(9), 6787–6794. https://doi.org/10.29303/jppipa.v9i9.4622

Hermansyah. (2020). Problem-based learning in Indonesian learning. *Social, Humanities, and Education Studies (SHEs): Conference Series, 3*(3), 2257–2262.

Hudha, M. N., Etikamurni, D. P., Ayunda, I. P., Safitri, N. S., Perwita, C. A., & Ayu, H. D. (2023). Problem-based learning (PBL) and problem-solving skills (PSS): A systematic literature review. *Indonesian Journal of Integrated Science Education, 5*(2), 103–116.

Kadir, M. A. A. (2017). What teacher knowledge matters in effectively developing critical thinkers in the 21st-century curriculum? *Thinking Skills and Creativity, 23*, 79–90. https://doi.org/10.1016/j.tsc.2016.10.011

Karmana, I. W., Ibrahim, M., & Susantini, E. (2019). Development of Karmana-problem-based learning model to train problem-solving skills and concept mastery of biology teacher candidates. *Journal of Physics: Conference Series, 1227*(1), 012002. https://doi.org/10.1088/1742-6596/1227/1/012002

Laura, M., Tampubolon, V., & Sipahutar, H. (2024). Development of project-based modules to improve learning outcomes, critical thinking, and problem-solving skills. *Jurnal Pendidikan Biologi Indonesia, 10*(2), 531–541.

Lestari, T., Asih, B., Prayitno, B. A., Retno, S., & Ariani, D. (2022). Improving the problem-solving skill of students using problem-based learning-based e-modules. *Jurnal Penelitian Pendidikan IPA, 8*(3). https://doi.org/10.29303/jppipa.v8i3.1696

Liu, T. (2022). Uncovering students' problem-solving processes in game-based learning environments. *Computers & Education, 182*(February), 104462. https://doi.org/10.1016/j.compedu.2022.104462

Maker, K. F. (2020). E-module development using Kvisoft Flipbook Maker through the problem-based learning model to increase learning motivation. *Journal of Educational Sciences, 4*(4), 834–848.

Merriënboer, J. J. G. Van. (2024). Perspectives on problem-solving and instruction. *Computers & Education, 64*, 153–160. https://doi.org/10.1016/j.compedu.2012.11.025

Musyaddad, A., & Suyanto, S. (2019). Evoking the four dimensions of student knowledge in ecosystem: Effectiveness of real objects, web, and blended learning. *Biosfer, 12*(2), 194–210.

https://doi.org/10.21009/biosferjpb.v12n2.194-210

Nurhemy, T. N. (2019). Efektivitas modul berbasis problem solving untuk meningkatkan kemampuan analisis siswa. *Inkuiri: Jurnal Pendidikan IPA, 8*(2). https://doi.org/10.20961/inkuiri.v8i2.37751

Özdemir, E., Sabri, A., & Albayrak, M. (2010). The relation between the problem-posing and problem-solving skills of prospective elementary mathematics teachers. *Procedia - Social and Behavioral Sciences, 2*, 1577–1583. https://doi.org/10.1016/j.sbspro.2010.03.239

Pratiwi, et al. (2021). Implementation of phenomenon-based learning e-modules to improve critical thinking skills in thermochemistry material. *Jurnal Pendidikan Sains Indonesia, 9*(4), 579–589. https://doi.org/10.24815/jpsi.v9i4.21114

Safitri, R., & Hadi, S. (2023). The effect of the problem-based learning model on students' motivation and learning outcomes. *Jurnal Penelitian Pendidikan IPA, 9*(9), 7310–7316. https://doi.org/10.29303/jppipa.v9i9.4772

Schunk, D. H., & DiBenedetto, M. K. (2021). Self-efficacy and human motivation. In A. J. Elliot (Ed.), *Advances in Motivation Science* (Vol. 8, pp. 153–198). Elsevier Inc. https://doi.org/10.1016/bs.adms.2020.10.001

Sujanem, et al. (2020). The effectiveness of problem-based interactive physics e-module on high school students' critical thinking. *Journal of Physics: Conference Series, 1503*, 012025. https://doi.org/10.1088/1742-6596/1503/1/012025

Suratno, S., Wahono, B., Chang, C. Y., Retnowati, A., & Yushardi, Y. (2020). Exploring a direct relationship between students' problem-solving abilities and academic achievement: A STEM education at a coffee plantation area. *Journal of Turkish Science Education, 17*(2), 211–224. https://doi.org/10.36681/tused.2020.22

Susanti, D., Sari, L. Y., & Fitriani, V. (2022). Increasing student learning motivation through the use of interactive digital books based on project-based learning (PjBL). *Jurnal Penelitian Pendidikan IPA, 8*(4), 2022–2028. https://doi.org/10.29303/jppipa.v8i4.1669

Tai, K. W. H., Wei, L., & Tai, K. W. H. (2019). Bringing the outside in: Connecting students' out-of-school knowledge and experience through translanguaging in Hong Kong EMI classes. *System, 3*(5), 1–51.

Tamu, F. H. U., & Atte, O. (2024). Transforming emergency education to accredited school: A case study of SMAN 4 Takari. *SAKAGURU: Journal of Pedagogy and Creative Teacher, 1*(1), 42–52. https://doi.org/10.70211/sakaguru.v1i1.46

Tekkaya, S., & Sungur, S. (2006). Effects of problem-based learning and traditional instruction on self-regulated learning. *Active Learning in Higher Education, 7*(2), 37–41. https://doi.org/10.3200/JOER.99.5.307-320

Velly, D. (2021). Increasing the motivation and learning outcomes of students through the application of the problem-based learning model in learning physics. *Journal of Science and Science Education, 2*(1). https://doi.org/10.29303/jossed.v2i1.719

Wardhana, D., Maryanti, B., & Ayu Kartika, S. (2022). Analisis perbandingan laju keausan kampas

rem belakang sepeda motor listrik Inovasi Karya Nusa (IKN). *Rekayasa Mesin Dan Inovasi Teknologi*, *3*(1), 180–184.

Yao, S., Yu, D., Zhao, J., Shafran, I., Griffiths, T. L., Cao, Y., & Narasimhan, K. (2023). Tree of thoughts: Deliberate problem solving with large language models. *Advances in Neural Information Processing Systems*, *36*(1), 1–14.

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yeung, M. M., Yuen, J. W., Chen, J. M., & Lam, K. K. (2023). The efficacy of team-based learning in developing the generic capability of problem-solving ability and critical thinking skills in nursing education: A systematic review. *Nurse Education Today*, *122*(September), 105704. https://doi.org/10.1016/j.nedt.2022.105704