Analysis of Student Perceptions of Project-Based Learning: A Case Study in Experimental Physics Course

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Abstract - *The urgency of this research lies in the critical need to understand the effectiveness of Project-Based Learning (PjBL) within the context of the Experimental Physics course, particularly in responding to modern curricular demands that emphasize problem-solving and creativity. This study aims to analyze student perceptions of PjBL implementation, covering learning style profiles, learning experiences, challenges, support systems, and the impact on problem-solving abilities. Utilizing a quantitative approach with a descriptive design, data were collected through surveys administered to students enrolled in the Experimental Physics course. The results indicate that the majority of students (65.7%) possess a Kinesthetic learning style, which aligns strongly with PjBL characteristics that emphasize hands-on practical activities. Student perceptions were classified as highly positive, with the highest ratings observed in the aspects of enhanced creativity and the relevance of projects to real-world applications. An interesting finding highlights the presence of "productive struggle," where, although task difficulty was rated as challenging, students perceived this difficulty as highly instrumental in developing new skills. Regarding problem-solving abilities, students felt competent in procedural design and analysis; however, accurate data collection and hypothesis formulation were identified as areas with the lowest scores. It is concluded that while PjBL is effective in enhancing student competence, its implementation requires optimization through more intensive scaffolding regarding the technical aspects of data measurement and hypothesis formulation, alongside improved laboratory facility support.*

Keywords: *Experimental Physics; Project-Based Learning; Student Perception; Problem Solving; Learning Styles.*

INTRODUCTION

Higher education, particularly in the fields of science and technology, plays an essential role in shaping human resources that are adaptive, innovative, and globally competitive. In the midst of the digital era and the Industrial Revolution 4.0, problem-solving skills have become a fundamental competency required not only in professional and industrial contexts but also for navigating the complexities of daily life (OECD, 2018). Consequently, higher education institutions bear the responsibility of continuously improving the quality of learning, particularly in the sciences, to produce graduates capable of effective problem-solving.

Physics, as a fundamental discipline, plays a crucial role in developing analytical mindsets and problem-solving capabilities. Specifically, the Experimental Physics course is designed to provide students with the opportunity to practice these skills through laboratory practicums, ranging from formulating problems and designing procedures to conducting observations, analyzing data, and drawing conclusions (Ramírez-Montoya et al., 2021). However, observations and various studies indicate that experimental physics learning is often perceived as difficult and unengaging by students. Instruction frequently adheres rigidly to predetermined procedures, providing minimal space for students to think critically, create, or develop deep conceptual understanding. Consequently, students' problem-solving abilities in experimental physics tend to be low and are often limited to the application of formulas without strong conceptual understanding. This is corroborated by Santyasa et al. (2020), who found that students still struggle with formulating problems, designing experiments, analyzing data, and drawing scientifically valid conclusions. Similarly, Suradika et al. (2023) identified that less innovative learning models contribute to students' low problem-solving abilities in physics.

To address these issues, various instructional innovations have been implemented, one of which is the Student-Centered Learning (SCL) approach, which emphasizes the active role and autonomy of students in the learning process. Project-Based Learning (PjBL) is a highly promising implementation of SCL for enhancing problem-solving abilities (Almulla, 2020; Zhou, 2012). In PjBL, students are not merely passive recipients of information but are actively involved in a systematic research cycle, gaining contextual learning experiences relevant to real-world challenges (Zhou, 2012). PjBL provides students with the opportunity to independently formulate problems, design experiments, conduct observations, analyze data, and draw conclusions under lecturer guidance, thereby significantly improving conceptual understanding and problem-solving skills (Almulla, 2020; Kiong et al., 2022). Furthermore, PjBL has the potential to stimulate student creativity (Gunawan et al., 2019; Wijayati et al., 2019) and increase self-efficacy (Gunawan et al., 2025a; Samsudin et al., 2020; Krsmanovic, 2021), transforming students into active and confident learners. Research by Gunawan et al. (2025b) and Baran et al. (2018) even demonstrates that incorporating game elements into PjBL can boost student enthusiasm and focus in learning physics.

However, the effectiveness of an instructional strategy, including PjBL, can be moderated by various factors, one of which is student learning style (Kolb, 1984). Students possess varied learning preferences—visual, auditory, kinesthetic, active, reflective, theoretical, or pragmatic. These learning styles influence how students process information, understand concepts, and apply knowledge. Therefore, it is important for educators to understand student learning styles and design instruction that aligns with these preferences (Lin & Wu, 2016; Lee & Chung, 2024). Integrating an understanding of learning styles can significantly improve learning outcomes and creativity, especially in the context of PjBL (Lin & Wu, 2016). Based on the initial survey of this research, the majority of Experimental Physics students (65.7%) showed a tendency toward a kinesthetic learning style, which is highly relevant to the hands-on activities in PjBL. This indicates a significant potential for PjBL to accommodate the dominant learning style of students.

The urgency of this research is grounded in several factors: first, the need to enhance problem-solving capabilities as a critical competency in the global era and Industrial Revolution 4.0; second, the gap between expected problem-solving abilities and the actual capabilities of students in experimental physics; third, the need for innovation and the development of more effective, student-centered learning models in experimental physics, particularly PjBL; and fourth, the importance of considering the influence of student learning styles in PjBL implementation to maximize effectiveness, ensuring learning is inclusive and relevant for every individual.

Based on the background and urgency outlined, the underlying problem of this research is the need for a comprehensive understanding of how students perceive the implementation of Project-Based Learning (PjBL) in the Experimental Physics course, and how their learning style characteristics interact with this method. Given the importance of active engagement in PjBL, evaluation from the student's perspective is crucial for authentically mapping learning effectiveness. Specifically, this study answers the following questions: (1) What is the profile of learning styles among students taking the Experimental Physics course? (2) What are student perceptions regarding the learning experience using PjBL, including aspects of creativity, relevance, challenges, and support received? (3) How do students perceive their mastery of problem-solving skills while participating in PjBL? In line with these questions, this study aims to: (1) identify the dominant learning style preferences of students; (2) analyze student perceptions of the dynamics of PjBL implementation; and (3) evaluate the perceived impact on students' experimental physics problem-solving abilities.

RESEARCH METHODS

This study applies a quantitative approach with a descriptive design to examine student perceptions of Project-Based Learning (PjBL) implementation in the Experimental Physics course. This approach was selected to obtain measurable and objective data and to provide a systematic overview of students' experiences, challenges, and assessments without manipulating variables (Creswell, 2014; Sugiyono, 2018; Bell, 2010; Larmer & Mergendoller, 2010). Participants were selected using a purposive sampling technique from the population of students enrolled in the course. This sample selection was based on the relevance of participants who directly experienced the PjBL process, ensuring that the perceptions provided were accurate and aligned with the research objectives (Patton, 2015; Emzir, 2016).

Data collection was conducted after one semester of PjBL implementation using two main instruments: a learning style questionnaire to identify visual, auditory, or kinesthetic preferences (Fleming & Mills, 1992), and a perception survey to measure learning effectiveness (Fowler Jr., 2013; Cohen, Manion, & Morrison, 2018). All instruments underwent validity and reliability testing, including expert validation, to ensure measurable responses (Hair Jr. et al., 2014). The collected data were analyzed using descriptive statistics assisted by SPSS software to calculate means, frequencies, and percentages (Field, 2018; Pallant, 2020). This analysis aimed to identify trends in the distribution of learning preferences and the aspects of PjBL deemed most beneficial by students.

RESULTS AND DISCUSSION

Result

Student Learning Style Profile

To understand the initial characteristics of the learners involved in this study, a survey regarding their learning style preferences was conducted. The results are visualized in Figure 1, which shows the percentage distribution of students based on their primary learning style.

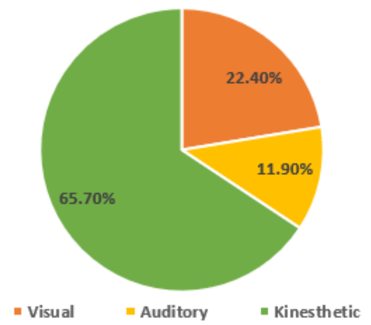

Figure 1. Percentage of Students' Learning Style Preferences

Based on Figure 1, the majority of students possess a Kinesthetic learning style (65.7%), which is highly relevant to the Experimental Physics course due to its emphasis on hands-on activities and practicums. This is followed by Visual learning preferences (22.4%), which rely on visual materials, while the smallest proportion is Auditory (11.9%), which is more effective through oral explanations. This distribution provides crucial information for designing inclusive instructional strategies that not only leverage the dominant kinesthetic style but also accommodate students with visual and auditory preferences.

Experience with PjBL in Experimental Physics

Table 1 presents the survey results of student experiences with PjBL implementation, which generally indicate a highly positive response with majority mean scores above 4.4. The highest ratings were obtained in the aspect of encouraging creative thinking in problem-solving (4.63) and the relevance of tasks to real-world applications (4.60), indicating the method's effectiveness in stimulating creativity and contextualizing physics theory with the professional world.

Table 1. Student Perceptions of Learning Experiences with PjBL

Questionnaire Items	Number of Respondents					Mean
	SA	A	CS	SA	A	
PjBL helps me understand Experimental Physics concepts better.	38	27	2	0	0	4.54
I feel more motivated to learn Experimental Physics using PjBL.	38	27	3	0	0	4.52
PjBL enhances my problem-solving abilities in Experimental Physics.	39	27	3	0	0	4.53
I enjoy the learning process with PjBL.	39	26	3	0	0	4.46
I would recommend PjBL to other students for the Experimental Physics course.	34	31	3	0	0	4.53
The project tasks in this Experimental Physics course are relevant to real-world physics applications.	39	26	3	0	0	4.60
PjBL encourages me to think more creatively in solving Experimental Physics problems.	44	21	3	0	0	4.63
I felt that I received constructive feedback during the PjBL process that helped improve my project.	45	21	2	0	0	4.56
PjBL enables me to work independently on Physics experiments while still receiving support.	40	26	2	0	0	4.43
The difficulties I encountered during this project helped me learn more about Experimental Physics.	31	34	2	0	0	4.54
PjBL provides me with the opportunity to apply learned physics theories into practice.	37	29	1	0	0	4.55
I feel more confident in conducting Physics experiments after participating in PjBL.	39	26	2	0	0	4.37

Note: Strongly Agree (SA); Agree (A); Moderately Agree (MA); Disagree (D); Strongly Disagree (SD)

Challenges and Student Role During Experimental Physics Course with PjBL

Table 2 highlights the challenges and roles of students during the PjBL course. Generally, responses were positive, though there was a specific note on the aspect of "appropriateness of task difficulty level," which received the lowest score (4.31). This indicates that some students felt the workload was quite heavy. However, this is balanced by the finding of the highest score in the aspect of "benefit of difficulty in developing new skills" (4.55), confirming that the challenges faced were viewed constructively and contributed significantly to the enhancement of student competence.

Table 2. Student Perceptions of Challenges and Roles in PjBL

Questionnaire Items	Number of Respondents					Mean
	SA	A	MA	D	SD	
The project tasks in this Experimental Physics course had an appropriate level of difficulty.	26	37	5	0	26	4.31
I felt I had a significant role within this project group.	37	33	0	0	37	4.53
I had sufficient opportunity to take the initiative in completing the project.	40	28	2	0	40	4.54
The difficulties I encountered during the project helped me develop new skills.	43	24	4	0	43	4.55
Note: Strongly Agree (SA); Agree (A); Moderately Agree (MA); Disagree (D); Strongly Disagree (SD)						

Support and Collaboration During Experimental Physics Course with PjBL

Table 3 evaluates student perceptions regarding support and collaboration. Group cooperation effectiveness emerged as the strongest point with the highest score (4.59). Conversely, the availability of resources and the intensity of lecturer guidance received the lowest average scores (4.39 and 4.41, respectively). This indicates that while support is generally rated positively, there is a need to optimize facility provision and facilitator mentoring to support project smooth operation.

Table 3. Student Perceptions of Support and Collaboration in PjBL

Questionnaire Items	Number of Respondents					Mean
	SA	A	CS	SA	A	
Collaboration within my group during the project was highly effective.	44	22	3	0	0	4.59
I felt I received adequate support from my group members.	41	23	4	0	0	4.54
The available resources (tools, materials, information) sufficiently supported the project's completion.	31	35	2	1	0	4.39
I felt I received sufficient guidance from the lecturer/facilitator during the project.	36	30	4	0	1	4.41
Note: Strongly Agree (SA); Agree (A); Moderately Agree (MA); Disagree (D); Strongly Disagree (SD)						

Problem-Solving Ability: Problem Identification

Table 4 analyzes student ability in identifying problems, with overall average scores ranging between 4.10 and 4.17, reflecting a good level of confidence. The ability to design logical and systematic experimental procedures was the most prominent aspect (4.17), showing high competence in planning, while formulating clear hypotheses before the experiment (4.10) was an area that students found slightly more challenging.

Table 4. Problem-Solving Abilities: Problem Identification

Questionnaire Items	Number of Respondents					Mean
	SA	A	CS	SA	A	
I feel capable of identifying the main problem in an experimental physics phenomenon.	17	45	7	1	0	4.11

Questionnaire Items	Number of Respondents					Mean
	SA	A	CS	SA	A	
I am confident in formulating a clear hypothesis before conducting an experiment.	17	44	8	1	0	4.10
I am able to design a logical and systematic experimental procedure to test a hypothesis.	22	41	8	1	0	4.17
I consider confounding factors (control variables) when designing an experiment.	20	42	7	1	0	4.16
Note: Strongly Agree (SA); Agree (A); Moderately Agree (MA); Disagree (D); Strongly Disagree (SD)						

Problem-Solving Ability: Data and Analysis

Table 5 evaluates student competence in experimental data management, where all indicators showed solid ability with mean scores above 4.0. Students felt most competent in data processing and presentation (4.19), while the aspect of accurate and precise data collection was recorded as the lowest point (4.06). This indicates that the physical data collection process in the laboratory is perceived as more challenging than the analysis and visualization stages.

Table 5. Problem-Solving Abilities: Data Collection and Analysis

Questionnaire Items	Number of Respondents					Mean
	SA	A	CS	SA	A	
I am capable of collecting experimental data accurately and precisely.	18	40	10	2	0	4.06
I understand how to select the appropriate data collection method for each experiment.	20	40	7	1	0	4.16
I am able to process and present experimental data (e.g., in tables or graphs) effectively.	23	37	8	1	0	4.19
I feel capable of analyzing data to discover patterns or relationships between variables.	20	40	8	1	0	4.14
Note: Strongly Agree (SA); Agree (A); Moderately Agree (MA); Disagree (D); Strongly Disagree (SD)						

Problem-Solving Ability: Drawing Conclusions

Table 6 details student ability in drawing conclusions, generally showing a high level of confidence with consistent scores above 4.19. The aspect of drawing valid conclusions based on data received the highest rating (4.26), confirming strong logical ability in result analysis. On the other hand, confidence in presenting results was recorded as the lowest score (4.19), indicating that although content mastery is excellent, oral communication and public presentation remain areas with potential for improvement.

Table 6. Problem-Solving Abilities: Drawing Conclusions and Communication

Questionnaire Items	Number of Respondents					Mean
	SA	A	CS	SA	A	
I am capable of drawing valid conclusions based on the data and analysis performed.	23	42	5	0	0	4.26
I can connect the experimental conclusions with relevant physics concepts.	21	41	6	0	0	4.22
I am capable of communicating experimental results (orally or in writing) clearly and concisely.	21	41	5	1	0	4.21
I feel confident presenting my experimental results in front of the class.	20	41	7	0	0	4.19
Note: Strongly Agree (SA); Agree (A); Moderately Agree (MA); Disagree (D); Strongly Disagree (SD)						

Discussion

This study aimed to analyze student perceptions of PjBL implementation in the Experimental Physics course, focusing on learning style profiles, PjBL experiences, challenges, support, and the impact on problem-solving abilities. The results show an overall positive perception of PjBL, consistent with literature supporting the effectiveness of this method in science education.

Student Learning Style Profiles and Implications for PjBL Design

The findings regarding student learning style profiles (Figure 1) show a dominance of the Kinesthetic style (65.7%), followed by Visual (22.4%) and Auditory (11.9%). This high preference for kinesthetic learning is highly relevant in the context of Experimental Physics, which emphasizes practical activities and "learning by doing." When students are actively involved in designing and executing experiments, they can construct a deeper understanding of physics concepts (Handayani et al., 2017).

Although dominated by kinesthetic learners, the presence of visual and auditory styles demands the application of varied strategies. This aligns with a systematic literature review by Gunawan et al. (2025c), which emphasizes the importance of multimodal approaches in project-based and inquiry learning models to accommodate diverse student characteristics in science education. Integrating learning modalities—such as using visual simulations or interactive discussions alongside practical activities—becomes crucial so that PjBL can be inclusive and effective for all students (Aljohani, 2016; Prastowo et al., 2019).

Student Experience: Creativity and Relevance of PjBL

In general, student perceptions of PjBL in Experimental Physics were highly positive (Table 1). The statements with the highest average scores were "PjBL encourages me to think more creatively in solving Experimental Physics problems" (4.63) and "Project tasks in this Experimental Physics learning are relevant to real-world physics applications" (4.60). These high scores in creativity confirm findings by Ulfa et al. (2024), stating that PjBL has a significant impact on enhancing student creativity in physics learning. The project environment, which challenges students to find original solutions, encourages them to go beyond mere procedural understanding.

Furthermore, this positive perception aligns with research by Gunawan et al. (2017), which found that PjBL—especially when assisted by appropriate media—is effective in developing student creativity. Through authentic projects, students are trained to apply physics concepts in real situations, which enhances not only conceptual understanding but also learning motivation (Hafsa et al., 2021).

Dynamics of Challenges, Support, and Collaboration

This study identified interesting dynamics between task challenges and self-development (Table 2). The statement regarding the suitability of task difficulty received the lowest score (4.31), indicating that some students felt the workload was substantial. However, a positive paradox emerged where the statement "The difficulties I faced during the project helped me develop new skills" received a very high score (4.55). This indicates the occurrence of "productive struggle," where the difficulties faced by students did not dampen their spirits but were viewed as opportunities for growth (Warshauer, 2015).

Regarding support (Table 3), group collaboration was rated as most effective (4.59), indicating strong peer-learning interactions. Conversely, aspects of "Available resources" (4.39) and "Guidance from lecturers" (4.41) received relatively lower scores compared to collaboration. These findings signal the need to optimize the facilitator's role and facility provision. As suggested by Gunawan et al. (2017), integrating virtual media or supporting technology could be a solution to overcome physical resource limitations and provide better scaffolding for students. Appropriate support is crucial to ensure student learning autonomy remains effective (Hmelo-Silver, 2004).

Impact of PjBL on Problem-Solving Abilities

The analysis of problem-solving abilities (Tables 4, 5, and 6) shows that students possess solid competence, yet there are variations at each stage:

- **Problem Identification:** Students felt highly competent in designing logical experimental procedures (4.17) but slightly more challenged in formulating clear hypotheses (4.10). This suggests that the transition from observing phenomena to formulating scientific conjectures requires further reinforcement.
- **Data Processing:** Regarding data, students felt most capable in presenting and processing data (4.19). However, "collecting experimental data accurately and precisely" had the lowest score in this category (4.06). The low score on physical data collection accuracy in the laboratory compared to post-experiment data processing highlights the importance of strengthening technical measurement skills in the field.
- **Drawing Conclusions:** Students had high confidence in drawing valid conclusions (4.26). Nevertheless, confidence in presenting results in front of the class (4.19) was slightly below their logical analysis capabilities.

Overall, these results are consistent with literature positioning PjBL as an effective approach for developing complex problem-solving skills (Capraro et al., 2013; Han & Bhattacharya, 2022). Although students excelled in analytical aspects (procedure design and drawing conclusions), practical aspects (accurate data collection) and communicative aspects (presentation and hypothesis) still have room for improvement through more intensive mentoring and more adaptive multimodal strategies (Gunawan et al., 2025c).

CONCLUSION

Based on the research results, it can be concluded that the implementation of Project-Based Learning (PjBL) in the Experimental Physics course is rated as highly effective and received positive responses from students. The prevalence of students with a Kinesthetic learning style (65.7%) is a key success factor, given that PjBL characteristics emphasizing physical activity and practicum align closely with their learning preferences. Specifically, PjBL was rated highest in stimulating creativity (score 4.63) and contextualizing physics theory with real-world applications (score 4.60).

In terms of problem-solving abilities, students demonstrated strong competence in designing logical experimental procedures and drawing valid conclusions based on data. Regarding challenges, although there were notes on the suitability of task difficulty (score 4.31) and resource limitations (score

4.39), students held a constructive perception that these difficulties helped them develop new skills (score 4.55).

To optimize PjBL implementation in the future, the following suggestions are made based on areas with the lowest evaluation scores in this study:

1. **Strengthening Technical and Hypothesis Aspects:** Given that the lowest scores in problem-solving were in "collecting data accurately" (4.06) and "formulating hypotheses" (4.10), lecturers are advised to provide more intensive scaffolding or preliminary training regarding precision measurement techniques and the logic of hypothesis formulation before projects begin.
2. **Enhancing Resource Support:** The lowest average score in the support aspect (4.39) indicates a need for institutions or laboratory management to ensure the availability and quality of experimental tools and materials so that technical obstacles do not reduce learning effectiveness.
3. **Optimizing Guidance and Communication Skills:** Although group collaboration proceeded very effectively, perceptions of lecturer guidance (4.41) and confidence in presentation (4.19) still have room for improvement. Lecturers are advised to be more proactive in monitoring group progress and providing presentation practice forums or peer-reviews so that students are more confident in communicating their experimental results orally.

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REFERENCES

Aljohani, M. (2016). A review of the use of social learning theories in educational studies. *International Journal of Education and Literacy Studies*, 4(1), 1-8.

Almulla, M. A. (2020). *The effectiveness of the project-based learning (PjBL) approach as a way to engage students in learning*. Sage Open, 10(3), 2158244020938702.

Baran, M., Maskan, A., & Yasar, S. (2018). *Learning Physics through Project-Based Learning Game Techniques*. International Journal of Instruction, 11(2), 221-234.

Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83(2), 39-43.

Capraro, R. M., Capraro, M. M., & Morgan, J. R. (2013). Project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach. Journal of STEM Education: Innovations and Research, 14(5), 29-36.

Cohen, L., Manion, L., & Morrison, K. (2018). Research Methods in Education (8th ed.). Routledge.

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (4th ed.). SAGE Publications.

Emzir. (2016). Metodologi Penelitian Pendidikan: Kuantitatif dan Kualitatif. Raja Grafindo Persada.

Field, A. (2018). Discovering Statistics Using IBM SPSS Statistics (5th ed.). SAGE Publications.

Fleming, N. D., & Mills, C. (1992). Not Another Inventory, Rather a Catalyst for Reflection. To Improve the Academy, 11, 137-155.

Fowler Jr., F. J. (2013). Survey Research Methods (5th ed.). SAGE Publications.

Gunawan, G., Herayanti, L., & Tamami, F. (2025a). Analysis of Science Education Students' Self-Efficacy in Developing Learning Products Through the Project-Based Learning Model. Jurnal Pendidikan Fisika dan Teknologi, 11(1), 301-308.

Gunawan, G., Kosim, K., Nisrina, N., Busyairi, A., Harjono, A., & Herayanti, L. (2025b). Fostering Creative Thinking in Pre-Service Physics Teachers: A Project-Based Learning Model with E-Modules. *Educational Process: International Journal*, 19(1). e2025532.

Gunawan, G., Harjono, A., Kosim, K., Zainuri, B. N. S., & Qothrunnada, Q. (2025c). Multimodal approaches in problem-based, project-based, and inquiry-based learning models in science education: A systematic literature review. *Indonesian Journal of STEM Education*, *7*(1), 1-17.

Gunawan, G., Harjono, A., Sahidu, H., Taufik, M., & Herayanti, L. (2019). Project-based learning on media development course to improve creativity of prospective physics teachers. In *AIP Conference Proceedings*. 2194 (1) p. 020032. AIP Publishing LLC.

Gunawan, G., Sahidu, H., Harjono, A., & Suranti, N. M. Y. (2017). The Effect of Project Based Learning With Virtual Media Assistance on Student's Creativity in Physics. *Jurnal Cakrawala Pendidikan*, *36*(2), 167–179. https://doi.org/10.21831/cp.v36i2.13514

Hafsa, S., Nurhayati, S., & Rosana, D. (2021). The effectiveness of project-based learning model to improve students' creative thinking skills in physics. Journal of Physics: Conference Series, 1873(1), 012028.

Hair Jr., J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). Multivariate Data Analysis (7th ed.). Pearson Education.

Han, S., & Bhattacharya, S. (2022). Investigating the Impact of Project-Based Learning on Students' Problem-Solving Skills and Scientific Understanding. Journal of Research in Science Teaching, 59(4), 543-568.

Handayani, R. D., Dwikoranto, & Susilo, A. (2017). Project-based learning as a learning model to improve physics students' creative thinking skills. Jurnal Inovasi Pendidikan Fisika, 6(3), 11-15.

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn?. Educational Psychology Review, 16(3), 235-266.

Kiong, T. T., Rusly, N. S. M., Abd Hamid, R. I., Swaran, S. C. K., & Hanapi, Z. (2022). *Inventive problem-solving in project-based learning on design and technology: a needs analysis for module development*. Asian Journal of University Education, 18(1), 271-278.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.

Krsmanovic, M. (2021). *Course Redesign: Implementing Project-Based Learning to Improve Students' Self-Efficacy*. Journal of the Scholarship of Teaching and Learning, 21(2), 93-106.

Larmer, J., & Mergendoller, J. R. (2010). 7 Essentials for Project-Based Learning. Educational Leadership, 68(1), 34-37.

Lee, B. C., & Chung, J. (2024). *An empirical investigation of the impact of ChatGPT on creativity*. Nature Human Behaviour, 8(10), 1906-1914. https://doi.org/10.1038/s41562-024-01953-1.

Lin, C. S., & Wu, R. Y. W. (2016). *Effects of web-based creative thinking teaching on students' creativity and learning outcome*. Eurasia Journal of Mathematics, Science and Technology Education, 12(6), 1675-1684.

OECD (2018). Organisation for Economic Co-operation and Development (OECD). (2018). *The Future of Education and Skills 2030*. OECD Publishing.

Pallant, J. (2020). SPSS Survival Manual: A Step by Step Guide to Data Analysis using IBM SPSS (7th ed.). Allen & Unwin.

Patton, M. Q. (2015). Qualitative Research & Evaluation Methods (4th ed.). SAGE Publications.

Prastowo, S. B., Suyatna, A., & Ryanti, D. (2019). The influence of learning style to students' physics learning outcomes. Journal of Physics: Conference Series, 1155(1), 012025.

Ramírez-Montoya, M. S., Andrade-Vargas, L., Rivera-Rogel, D., & Durán-Medina, N. E. (2021). *Pedagogical Models for Physics Education in a Digital Context*. Sustainability, 13(11), 6009.

Samsudin, M. A., Jamali, S. M., Md Zain, A. N., & Ale Ebrahim, N. (2020). *The effect of STEM project based learning on self-efficacy among high-school physics students*. Journal of Turkish Science Education, 16(1), 94-108.

Santyasa, I. W., Rapi, N. K., & Sara, I. (2020). *Project based learning and academic procrastination of students in learning physics*. International Journal of instruction, 13(1), 489-508.

Sugiyono. (2018). Metode Penelitian Kuantitatif, Kualitatif, dan R&D. Bandung: Alfabeta.

Suradika, A., Dewi, H. I., & Nasution, M. I. (2023). *Project-based learning and problem-based learning models in critical and creative students*. Jurnal Pendidikan IPA Indonesia, 12(1), 153-167.

Ulfa, M., Wahyudi, W., Gunawan, G., & Gunada, I. W. (2024). The Effect of Project-Based Learning on Student Creativity in Physics Learning. *Indonesian Journal of STEM Education*, *6*(2), 75-85.

Warshauer, M. L. (2015). Productive struggle in middle school mathematics classrooms. Journal of Mathematical Behavior, 37, 1-13.

Wijayati, N., Sumarni, W., & Supanti, S. (2019). *Improving student creative thinking skills through project based learning*. KnE Social Sciences, 408-421.

Zhou, C. (2012). *Integrating creativity training into problem and project-based learning curriculum in engineering education*. European Journal of Engineering Education, 37(5), 488-499.