Jayapangus Press
Cetta: Jurnal Ilmu Pendidikan
Volume 8 Nomor 1 (2025)
ISSN : 2615-0891 (Media Online)

Problem Based Learning A Pathway to Critical Thinking and Digital Literacy in Geography

Ayla Yuli Rokhman*, Rusijono, Lamijan Hadi Susarno
Universitas Negeri Surabaya, Surabaya, Indonesia
*ayla.23021@mhs.unesa.ac.id

Abstract

21st-century skills, such as critical thinking and digital literacy, have become essential in modern learning. This study aims to examine the impact of the Problem Based Learning (PBL) model on students' critical thinking and digital literacy skills in the topic of atmospheric dynamics at Sekolah Indonesia Kota Kinabalu, Sabah-Malaysia. The research design used a quasi-experimental approach with a nonequivalent control group design. The sample consisted of 34 students in the experimental group and 31 students in the control group. The experimental class implemented the Problem Based Learning (PBL) model, while the control class used conventional methods. The results showed a significant improvement in both variables in the experimental group, with N-Gain Scores categorized as effective. Problem Based Learning (PBL) helps students understand scientific concepts in-depth, identify real-world problems, and develop creative, technology-based solutions. These findings prove that Problem Based Learning (PBL) is an innovative teaching method that is effective in enhancing students' competencies, especially in preparing them to face global challenges and the digital era.

Keywords: Problem Based Learning (PBL); Geography; Critical Thinking; Digital Literacy

Introduction

The 21st-century skills, such as collaboration, problem-solving, critical thinking, and digital literacy, have become essential competencies needed to meet the increasingly complex global demands. As technological advancements and globalization accelerate, education plays a crucial role in preparing the younger generation to confront significant challenges, including societal, technological, and environmental issues (Habibah et al., 2023; Haleem et al., 2022). In this context, technology-based learning is pivotal in creating interactive and engaging learning environments. Innovative digital learning enhances student engagement while fostering motivation to learn, as students can directly interact with learning materials and media in a more immersive manner (Kowitlawakul et al., 2022; Ullah and Anwar, 2020).

Among various academic disciplines, Geography education holds a strategic position in developing critical thinking and digital literacy, particularly in addressing complex global issues such as climate change and environmental (Varenina et al., 2022; Yli-Panula et al., 2020; Zamista and Charona, 2023). Geography education not only provides scientific understanding of natural phenomena but also cultivates analytical skills for solving environmental problems in a practical context. In this regard, integrating digital literacy and critical thinking into Geography education can enhance students' learning experiences, allowing them to understand and apply learned concepts to real-world situations (Leaning, 2019).

Thus, an instructional approach capable of developing both skills is crucial in preparing students for the global challenges of a rapidly evolving world. Furthermore, Geography plays a critical role in environmental education. For instance, the subtopic of atmospheric dynamics, which encompasses weather and climate, is highly relevant in the context of the global climate change crisis (Mesarović, 2019). Fu (2020) asserts that Geography integrates both physical and social aspects, fostering environmental awareness and social responsibility. A deep understanding of atmospheric phenomena allows students to connect scientific concepts with everyday realities, such as understanding the impact of climate change on local communities and environments (Virranmäki et al., 2019).

In this context, the development of critical thinking and digital literacy is essential, enabling students to explore and find concrete solutions to real-world problems, both scientifically and socially (Vodă et al., 2022). To achieve these goals, effective teaching methods that integrate digital literacy and critical thinking are essential, particularly in the context of Geography education. In this regard, PBL has emerged as an innovative and effective instructional model that aligns with the demands of modern pedagogy (Smith et al., 2022). PBL is recognized for its ability to encourage students to engage in scientific inquiry and seek solutions to real world geographical problems (Sonrum and Worapun, 2023).

According to Kleemola et al., (2023), PBL significantly enhances active student participation by shifting the focus from passive to active learning, which is particularly beneficial for understanding spatial phenomena and addressing complex geographical issues. The importance of PBL in Geography education is further reinforced by its ability to bridge theory and practice, equipping students with problem-solving skills and real-world applications (Ardiansyah et al., 2024). A study by Singha and Singha, (2024) reported that approximately 78% of students exposed to PBL demonstrated improved critical thinking and digital literacy skills, which are essential competencies for analyzing spatial data and interpreting geospatial technologies.

As a problem centered approach, PBL not only fosters theoretical understanding but also empowers students to apply geographical concepts in real-life contexts. In the context of Geography education, PBL is an effective approach for equipping students with critical thinking and problem-solving skills to address real-world geographical challenges (Ardiansyah et al., 2024). PBL fosters active learning through multidisciplinary analysis and collaboration in solving complex problems (Rajabzadeh et al., 2022). Through this approach, students can explore spatial relationships, environmental challenges, and sustainable development goals (SDGs) in a practical and analytical manner (González and Sebastián-López, 2022).

Research Sari et al., (2021), indicates that students engaged in PBL based Geography instruction show significant improvements in problem-solving skills and learning engagement compared to traditional lecture-based methods. Similarly Singha and Singha (2024), found that PBL cultivates critical thinking skills by encouraging students to propose solutions for environmental issues, climate change adaptation, and resource management. According to Smith et al., (2022), PBL involves a series of activities focused on problem-solving, where students are encouraged to explore, investigate, and systematically resolve issues.

The presentation of relevant and contextual problems serves as the foundation for exploration and discovery, directly supporting the development of digital literacy, as students engage in research and use technology in critical and creative ways (Putra et al., 2021; Weng et al., 2022). Therefore, this study is highly relevant for evaluating the extent to which PBL can enhance critical thinking and digital literacy in Geography education, particularly in the context of atmospheric dynamics. This study employs the PBL model, focusing on the topic of atmospheric dynamics, to assess its impact on critical thinking and digital literacy among students.

PBL is an effective pedagogical approach that integrates both critical thinking and digital literacy, enriching students' learning experiences by enabling them to engage deeply with the subject matter (Fajrin et al., 2024; Yondler and Blau, 2023). The PBL model helps students understand information more comprehensively and apply it to real-world contexts Yang et al., (2023), fostering skills that are crucial in tackling global environmental challenges (Thomassen and Stentoft, 2020). By contextualizing atmospheric dynamics within local issues, this approach encourages students to conduct investigations based on relevant real-life problems (Nagarajan and Overton, 2019).

The novelty of this research lies in its application of PBL to a contextual learning approach aimed at solving weather and climate issues in the local environment (Schwartz, 2019). This approach is designed to raise students' awareness of weather-related and climate-related issues that affect their immediate surroundings. The specific goal of this study is to analyze the impact of PBL on improving students' critical thinking and digital literacy, particularly in the context of geographical education concerning atmospheric dynamics.

Methods

The type of research employed was a quantitative method approach using a quasi-experimental design. This study applied a non-equivalent control group to evaluate the effects of the PBL model on students' critical thinking and digital literacy skills in Geography education. In this design, the experimental group, consisting of 34 students, received PBL-based intervention, while the control group, comprising 31 students, was taught using conventional methods. The independent variable in this study was the PBL model, while the dependent variables were critical thinking skills and digital literacy. The participants of this study were Grade X students at Sekolah Indonesia Kota Kinabalu (SIKK), located in Sabah, Malaysia, during the 2024/2025 academic year. These students were studying atmospheric dynamics as part of the Geography curriculum. The research sample was selected using purposive sampling, based on the assumption that the chosen sample represents characteristics relevant to the study population. This study utilized pre-test and post-test essay questions as instruments to collect data, specifically designed to assess critical thinking and digital literacy skills. The Mann-Whitney U test was applied following the ANOVA analysis. Additionally, the N-Gain score was calculated from the pre-test and post-test results to evaluate the effectiveness of the PBL model.

Results And Discussion

1. Implementation of Problem Based Learning (PBL) in Geography Education

Problem Based Learning (PBL) is a student-centered learning approach in which learners are presented with real world problems as a stimulus to acquire new concepts and skills. The PBL model in Geography education encourages students to actively participate in collaboratively solving problems, engaging in critical thinking, and exploring various information sources (Silviariza et al., 2021). In Geography learning, PBL emphasizes the development of critical thinking skills and digital literacy through a systematic investigative process based on problems relevant to real-life contexts (Anggraeni et al., 2023). The implementation of PBL in Geography education involves a series of systematic steps that require active student participation and teacher facilitation, as outlined in Table 1.

Table 1. Experiment Class Activities based on PBL Model Syntax

Sintax	Learning Activity	Time
Problem Oriented	Teacher: • Provide basic concepts and local issues related to atmospheric dynamics Learners: • Understand issues about atmospheric dynamics.	Week 1 (2 Meeting)
Organized Oriented	Students categorize the details of the discussed problems and explore ways to solve issues related to atmospheric dynamics, including climate problems, by utilizing geospatial technology.	
Investigations Guide as Individual or Group	Students identify complex, relevant, and authentic problems or cases related to atmospheric dynamics by utilizing geospatial technology.	
Attainments Development and Presentations	Learners explain the results of the problem solving that has been found.	Week 2 (2 Meeting)
Problem Solving Analysation and Evaluation	Learners: • Learners summarize the correct and appropriate problem solving. Teacher: • The teacher evaluates and concludes the problem solving.	

The implementation of the PBL model in learning transforms the traditional learning paradigm. Teachers are no longer the center of learning but act as facilitators who support students in independently finding solutions to problems (Sukackė et al., 2022). Teachers play a role in guiding critical thinking processes, providing feedback, and ensuring that learning runs effectively (Burgess et al., 2018). On the other hand, students become the focal point of the learning process. They actively identify problems, gather information, engage in discussions, and evaluate solutions (Smith et al., 2022). Through PBL, students are trained to think critically, solve problems, and utilize technology to enhance digital literacy.

In the context of Geography education, particularly in the study of atmospheric dynamics, PBL can be implemented through specific activities requiring students to analyze real-time weather data using satellite imagery, digital weather maps, and simulation tools (Rienow et al., 2020). For example, students can collaboratively identify the causes of extreme weather phenomena, such as hurricanes or monsoons, and propose appropriate mitigation strategies based on the collected data (Hazrat et al., 2023; Skorenkyy et al., 2021). This approach not only strengthens students' critical thinking skills but also enhances their ability to process and interpret geographic information (Ardiansyah et al., 2024). Furthermore, integrating digital platforms, such as GIS software, enables students to connect theoretical knowledge with practical problem-solving, fostering digital literacy and analytical skills essential for addressing real-world atmospheric challenges (Shook et al., 2019). The assessment of critical thinking skills in this study was measured based on indicators established by (Ennis, 2018).

2. Comparative Analysis of Critical Thinking

Students' critical thinking skills can be significantly enhanced through active participation in the learning process, particularly when the PBL model is implemented. PBL is a student centered learning approach in which the learning process focuses on solving real, relevant, and complex problems (Soubra et al., 2022). In implementing PBL, the teacher's role shifts to that of a facilitator who guides students during the processes of exploration, investigation, and reflection. Meanwhile, students take an active role as learning agents who are responsible for seeking information, engaging in discussions, and solving problems collaboratively (Belland et al., 2020). These steps not only encourage improvements in critical thinking and problem-solving skills but also build students' independence and presentation abilities.

Research by Nutt et al., (2024) has proven the effectiveness of this model in enhancing students' problem-solving skills. Post-test results show that the experimental group using PBL experienced significant improvement compared to the control group that employed conventional teaching methods.

Table 2. Average Scores of the Experimental and Control Groups on Critical Thinking Indicators

Critical Thinking Indicator	Experimental Group		Control Group	
	Average	Category	Average	Category
Problem Formulation	85.88	Very High	30.96	Very Low
Providing Arguments	82.35	Very High	31.61	Very Low
Drawing Conclusions	78.82	High	29.67	Very Low
Alternative Solutions	92.35	Very High	43.22	Low
Evaluating Results	85.29	Very High	34.83	Very Low
Average Score	84.94	Very High	34.06	Very Low

In the pre-test phase, the average score for critical thinking skills in the experimental group was 33.52, while the control group had a lower average score of 31.09. After the intervention, both groups showed an improvement in their average scores. However, the experimental group achieved a significantly higher average score of 84.94, while the control group only reached 34.06. These results confirm that the application of the PBL model is substantially more effective in enhancing students' critical thinking abilities Acharya et al., (2021) particularly in the context of studying atmospheric dynamics.

A more detailed analysis of the average scores based on the indicators of critical thinking, as presented in Table 2 reveals that the experimental group consistently outperformed the control group across all indicators, with a difference of 50.88. This suggests that students in the experimental group demonstrated significantly higher levels of critical thinking compared to those in the control group. The application of the PBL model effectively guided students in constructing knowledge to solve real-world problems (Mohd et al., 2017). Through this process, students were able to formulate complex solutions to various challenges they encountered. Based on the data analysis, the implementation of PBL in the experimental group had a significant impact on improving students' critical thinking abilities.

One of the most notable indicators of this improvement was in the area of Proposing Alternative Solutions, where the experimental group scored an average of 92.35, significantly outperforming the control group, which only scored 43.22. This indicator reflects students' ability to deeply understand problems and develop creative alternative solutions, which aligns with the primary goal of the PBL approach. The marked differences observed across all indicators between the experimental and control groups further reinforce the effectiveness of the PBL model in fostering critical thinking skills. The lower scores in the control group highlight the challenges students face with traditional, conventional learning methods, particularly when tasked with answering complex questions that require deep analysis.

In contrast, the PBL approach facilitated students' ability to tackle these challenges by providing a framework that encourages exploration, analysis, and synthesis of solutions in a more structured manner. This model creates an environment where students can be more exploratory, reflective, and independent in processing information and addressing real-world problems (Wang, 2021). These results suggest that PBL not only contributes to enhancing critical thinking skills but also encourages students to think systematically and innovatively when faced with a variety of learning challenges (Ulger, 2018).

Table 3. N-Gain Scores for Critical Thinking Indicators in the Experimental and Control Groups

Indicator	Experimental Group		Control Group	
	N-Gain Value	Category	N-Gain Value	Category
Problem Formulation	0.78	High/Very Effective	0.00	Low/Less Effective
Providing Arguments	0.73	High/Very Effective	0.00	Low/Less Effective
Drawing Conclusions	0.69	Moderate/ Effective	0.018	Low/Less Effective
Alternative Solutions	0.87	High/Very Effective	0.102	Low/Less Effective
Evaluating Results	0.78	High/Very Effective	0.098	Low/Less Effective

The findings presented in Table 3 indicate that the experimental group, which implemented the PBL model, achieved high N-Gain scores across all critical thinking indicators. Specifically, the Proposing Alternative Solutions indicator saw the highest N-Gain score of 0.87 in the experimental group, whereas the control group only reached a score of 0.10 in the same indicator. This stark difference underscores the superior effectiveness of the PBL model in enhancing students' critical thinking abilities, especially in developing creative and viable solutions to complex problems. The success of PBL in improving this indicator can be attributed to its core pedagogical approach.

The PBL learning process emphasizes problem exploration and solution formulation, which encourages active student engagement and deeper understanding (Ghani et al., 2021; Khamchiyev et al., 2020). In the PBL setting, students are guided to identify problems, seek relevant information, and propose authentic solutions (Koh et al., 2019). These stages foster an environment that promotes critical thinking, allowing students to engage in reflective and independent problem-solving. As such, the findings affirm that PBL is a highly effective method for enhancing students' critical thinking skills compared to traditional learning methods (Y. Liu et al., 2020).

Tabel 4. Mann-Whitney Test Significance for Critical Thinking Indicators

Variable Data	Indicator	Mann-Whitney U	Asymp.Sig. (2-tailed)	Significance
Critical Thinking	Critical Thinking	0.00	0.00	0.05
	Providing Arguments	2.50	0.00	

Drawing Conclusions	4.50	0.00
Proposing Alternative Solutions	36.0	0.00
Evaluating Results	11.5	0.00

The results presented in Table 4 were analyzed using the Mann-Whitney U test, which yielded a significance value of 0.000 across all indicators. This value is well below the threshold of 0.05, indicating that there are statistically significant differences between the experimental and control groups. The low Mann-Whitney U values further strengthen the conclusion that the implementation of the PBL model has a significantly greater impact on students’ critical thinking compared to conventional learning methods (Zhang, 2023). The experimental group, which used PBL, showed a marked improvement in critical thinking skills, aligning with the positive outcomes observed in the N-Gain scores. Thus, the Mann-Whitney U test provides robust statistical evidence that the PBL model is significantly more effective in improving students' critical thinking skills than traditional methods.

The results of this study confirm that PBL is more effective than conventional learning methods in fostering students' critical thinking skills. This finding is consistent with previous research by M. Liu and Mu (2022), which concluded that PBL not only enhances critical thinking but also strengthens digital literacy skills. Additional studies support this conclusion, indicating that PBL helps students become active thinkers (Mohd et al., 2017). In the PBL model, students are encouraged to explore problems in depth, identify solutions based on evidence, and make rational decisions. The statistical analysis conducted in this study further reinforces the superiority of the PBL model, which not only promotes student engagement in the learning process but also significantly improves their critical thinking skills (Li et al., 2024). This finding emphasizes that PBL is an effective approach to prepare students for the 21st-century learning challenges.

3. Comparative Analysis of Digital Literacy

This study evaluates the differences in digital literacy skills between students in the experimental and control groups. The data presented in the tables indicate that the implementation of the PBL model had a significant impact on enhancing the digital literacy of students in the experimental group compared to those in the control group. In the pre-test phase, the experimental group had an average score of 27.05, while the control group scored slightly lower at 25.80. Following the intervention, the experimental group achieved a post-test average score of 85.29, which is substantially higher than the control group's post-test average of 39.09. Research Hazrat et al., (2023) shows in a PBL based Geography lesson on atmospheric dynamics, students analyzed extreme weather patterns using satellite imagery, digital weather maps and climate simulations.

The results show significant improvements in students' digital literacy and critical thinking skills as they identify causes of extreme weather and propose mitigation strategies. Bush et al., (2019) similarly reported enhanced student abilities in analyzing atmospheric circulation systems and predicting weather changes using GIS tools and atmospheric modeling software. In the context of atmospheric dynamics, PBL enhances digital literacy and fosters critical thinking, enabling students to interpret meteorological data and address relevant environmental challenges (Singha and Singha, 2024). These findings indicate that the PBL model is highly effective in improving digital literacy among students. The significant improvement in the experimental group further supports the claim that PBL fosters students' understanding of digital literacy through an active and contextual learning process (Patnawar, 2023). Therefore, this study strengthens the evidence that PBL is an effective method for developing students' digital literacy skills (Jasti & Pavani, 2021). Students' digital literacy skills were assessed using digital literacy indicators as defined by Ng, (2012).

Table 5. Average Scores of The Experimental And Control Groups On Digital Literacy Indicators

Digital Literacy Indicator	Experimental Group		Control Group	
	Average Score	Category	Average Score	Category
Accessing Information	88.82	Very High	36.12	Very Low
Understanding Information	80.58	Very High	45.16	Low
Analyzing Information	94.11	Very High	44.51	Low
Managing Information	85.29	Very High	34.83	Very Low
Logical Reasoning and Evaluation	77.64	Very High	34.83	Very Low
Average Score	85.29	Very High	39.09	Very Low

The significant differences in the average scores between the experimental and control groups are noteworthy. The higher average scores in the experimental group can be attributed to the implementation of the PBL model, which focuses on atmospheric dynamics problems (Acharya et al., 2021). This approach engages students in active thinking to solve problems related to atmospheric dynamics, thereby enhancing their ability to find and formulate solutions (Nutt et al., 2024). The PBL learning process encourages active student participation in searching for authentic information relevant to the problem at hand (Khamchiyev et al., 2020). This process not only strengthens students' understanding of atmospheric dynamics but also boosts their digital literacy by facilitating data exploration and the use of technology for problem-solving (Sundari et al., 2014).

In the experimental group, the average N-Gain scores for each digital literacy indicator were classified as High/Very Effective. Notably, the Analyzing Information indicator recorded the highest N-Gain score of 0.92. This result demonstrates that the PBL model significantly enhances students' ability to think critically and process digital information effectively. This finding aligns with the research by Belland et al., (2020); Srikan et al., (2021), which states that PBL strengthens digital literacy through the active exploration of relevant and valid digital information sources. In contrast, the control group only showed moderate improvement, with the highest N-Gain score of 0.32 recorded in the Understanding Information indicator.

The remaining indicators in the control group showed lower N-Gain scores, falling into the Low/Less Effective category. This suggests that traditional teaching methods are less effective in improving students' digital literacy skills. These findings further support the conclusion that PBL is a highly effective instructional strategy for fostering students' digital literacy skills (Chang et al., 2020).

Table 6. N-Gain Scores for Digital Literacy Indicators in the Experimental and Control Groups

Digital Literacy Indicator	Experimental Group		Control Group	
	N-Gain Value	Category	N-Gain Value	Category
Accessing Information	0.81	High/Very Effective	0.12	Low/Less Effective
Understanding Information	0.74	High/Very Effective	0.27	Low/Less Effective
Analyzing Information	0.92	High/Very Effective	0.32	Moderate/ Effective
Managing Information	0.81	High/Very Effective	0.04	Low/Less Effective
Logical Reasoning and Evaluation	0.68	Moderate/ Effective	0.09	Low/Less Effective

The PBL model has a significant impact because it engages students in active, collaborative learning focused on solving real-world problems. This approach encourages students to independently search for, process, and evaluate information, thereby enhancing their digital literacy. As noted by Das et al., (2023) problem-based approaches not only improve learning motivation but also enhance collaborative skills and the ability to solve complex problems. The findings from this study further confirm that PBL is highly effective in digital learning environments. This is evident in the Understanding Information indicator, where the experimental group achieved a N-Gain score of 0.74 (categorized as high), while the control group only reached 0.27 (categorized as moderate).

These results reinforce the value of PBL as an effective strategy for improving students' digital literacy, particularly in an era that demands strong digital skills. Studies such as Angraini et al., (2023) highlight the critical role of digital literacy in preparing students for the challenges of the information age.

Table 7. Mann-Whitney Test Significance for Digital Literacy Indicators

Indicator		Mann-Whitney U	Asymp. Sig. (2-tailed)	Significance
Digital Literacy	Accessing Information	0.00	0.00	0.05
	Understanding Information	0.00	0.00	
	Analyzing Information	0.00	0.00	
	Managing Information	27.50	0.00	
	Logical Reasoning and Evaluation	27.50	0.00	

The Mann-Whitney U test data analysis shows a significant difference between the experimental group and the control group across all digital literacy indicators. As shown in Table 7, the Asymp. Sig. (2-tailed) values for all indicators are 0.000, which is well below the significance level of 0.05. This result indicates that the differences observed are a genuine impact of the PBL model. The findings highlight that each step in the PBL model was effective in improving students' abilities across all digital literacy indicators (Acharya et al., 2021). The implementation of the PBL model has proven effective in enhancing students' digital literacy across all indicators. This success is supported by the characteristics of PBL, which encourage students to actively seek, analyze, and process information, thereby fostering meaningful learning (Dolmans et al., 2016; Patnawar, 2023). Active learning models like PBL also play a crucial role in preparing students to face the challenges of the digital era (Al-Thomali, 2021; Sukackė et al., 2022). An example of PBL implementation is demonstrated by R. Liu et al., (2019) in a senior high school Geography class, where students solved local flood case studies using GIS tools and digital data. The results showed significant improvements in critical thinking skills and digital literacy, such as data analysis and information presentation. Similar findings were reported by Mufidah et al., (2023) who applied PBL to analyze the impacts of climate change. Through the collection and evaluation of climate data from digital sources, students simultaneously developed critical thinking and digital literacy skills. The analysis of these two case studies confirms that PBL not only enhances higher-order thinking skills but also strengthens digital literacy through the utilization of digital tools and resources (Ali, 2024). Thus, PBL is an ideal method to meet the demands of education in the modern era.

Conclusion

This study demonstrates that the implementation of the PBL model has a significant and effective impact on improving students' critical thinking and digital literacy in the context of atmospheric dynamics. The results of the Mann-Whitney U test revealed a significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between the experimental and control groups. Specifically, the experimental group showed a substantial improvement in both critical thinking and digital literacy compared to the traditional, conventional teaching methods. The experimental group exhibited a consistently higher average increase across all indicators, with N-Gain scores categorized as effective to very effective. These findings underscore the ability of PBL to engage students in actively understanding problems, processing information, and developing creative, real-world solutions. Furthermore, the results confirm that PBL not only enhances students' cognitive and digital skills but also promotes problem-solving and innovative thinking in a collaborative, contextual learning environment. However, this study does have certain limitations that should be addressed in future research. The limited geographic scope, with the study conducted at a single school, restricts the generalizability of the findings. Future studies should involve a broader range of schools, incorporating different geographic, cultural, and educational contexts, to test the replicability of these results across diverse settings.

Reference

Acharya, S., Bhatt, A. N., Chakrabarti, A., Delhi, V. S. K., Diehl, J. C., van Andel, E., Jurelionis, A., Stasiuliene, L., De Jussilainen Costa, L., & Subra, R. (2021). Problem-Based Learning (PBL) in Undergraduate Education: Design Thinking to Redesign Courses. *Smart Innovation, Systems and Technologies*, *222*, 349-360.

Al-Thomali, Y. (2021). The Effect of Active Learning With Block and Problem Based Learning on Motivation, and Academic Performance of Dental Students-a Prospective Study. *International Journal of Current Research and Review*, *13*(5), 110-118.

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.

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic Review of Problem Based Learning Research in Fostering Critical Thinking Skills. *Thinking Skills and Creativity*, *49*.

Angraini, E., Zubaidah, S., & Susanto, H. (2023). TPACK-based Active Learning to Promote Digital and Scientific Literacy in Genetics. *Pegem Journal of Education and Instruction*, *13*(2), 50-61

Ardiansyah, A. I., Putra, A. K., & Nikitina, N. (2024). Investigating Problem-Based Learning Model's Impact on High School Student's Critical Thinking Skills in Environmental Conservation Context. *Jambura Geo Education Journal*, *5*(2), 87-103.

Belland, B. R., Weiss, D. M., & Kim, N. J. (2020). High School Dtudents' Agentic Responses to Modeling During Problem-Based Learning. *Journal of Educational Research*, *113*(5), 374-383.

Burgess, A., Roberts, C., Ayton, T., & Mellis, C. (2018). Implementation of Modified Team-Based Learning Within a Problem Based Learning Medical Curriculum: A Focus Group Study. *BMC Medical Education*, *18*(1), 1-7.

Bush, D., Sieber, R., Seiler, G., Chandler, M., & Chmura, G. L. (2019). Bringing Climate Scientist's Tools into Classrooms to Improve Conceptual Understandings. *Journal of Environmental Studies and Sciences*, *9*(1), 25-34.

Chang, N., Wang, Z., & Hsu, S. H. (2020). A Comparison of the Learning Outcomes for a PBL-Based Information Literacy Course in three Different Innovative Teaching Environments. *Libri*, *70*(3), 213-225.

Das, S., Nandgaonkar, V., Eklarker, R., Balkhande, B. W., & Pande, S. D. (2023). Exploring The Dynamics Of Pbl-Based Learning: A Study On Collaboration, Reflection, Engagement, Critical Thinking, And Student Success. In *Design and Implementation of Higher Education Learners' Learning Outcomes (HELLO)*, 146-158.

Dolmans, D. H. J. M., Loyens, S. M. M., Marcq, H., & Gijbels, D. (2016). Deep and Surface Learning in Problem-Based Learning: a Review of the Literature. In *Advances in Health Sciences Education*, *21*(5), 1087-1112.

Ennis, R. H. (2018). Critical Thinking Across the Curriculum: A Vision. *Topoi*, *37*(1), 165-184.

Fajrin, V. P., Wibowo, F. C., & Nasbey, H. (2024). Analisis Kebutuhan Modul Ajar Pemanasan Global Berbasis PBL untuk Meningkatkan Keterampilan Pemecahan Masalah dan Self-Efficacy Siswa. *Cetta: Jurnal Ilmu Pendidikan*, *7*(1), 33-42.

Fu, B. (2020). Promoting Geography For Sustainability. *Geography and Sustainability*, *1*(1), 1-7.

Ghani, A. S. A., Rahim, A. F. A., Yusoff, M. S. B., & Hadie, S. N. H. (2021). Effective Learning Behavior In Problem-Based Learning: A Scoping Review. *Medical Science Educator*, *31*(3), 1199-1211.

González, R. de M., & Sebastián-López, M. (2022). Education on Sustainable Development Goals: Geographical Perspectives for Gender Equality in Sustainable Cities and Communities. *Sustainability (Switzerland)*, *14*(7), 40-42.

Habibah, K., Putra, A. K., Nilsson, S., & Vielhaber, C. (2023). Digital Estuaries: Exploring the Pedagogical Benefits of Virtual Reality Media in Geography and Spatial Analysis. *Jambura Geo Education Journal*, *4*(2), 187-198.

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the Role of Digital Technologies in Education: A Review. *Sustainable Operations and Computers*, *3*, 275-285.

Hazrat, M. A., Hassan, N. M. S., Chowdhury, A. A., Rasul, M. G., & Taylor, B. A. (2023). Developing a Skilled Workforce for Future Industry Demand: The Potential of Digital Twin-Based Teaching and Learning Practices in Engineering Education. *Sustainability (Switzerland)*, *15*(23).

Jasti, S. D., Pavani, A., & Guntur, A. P. (2021). Employing Problem Based Learning System In Advancing Communication Skills Proficiency In Professional Communication For Engineering Undergraduates. *Journal of Engineering Education Transformations*, *34*, 128-134.

Khamchiyev, K. M., Batyayeva, Y. K., Shandaulov, A. K., Zhashkeyeva, A. M., Suleimenova, F. M., & Sagimova, G. K. (2020). The Role of the Tutor and Students in the Process of Problem-Based Learning (Pbl). *Systematic Reviews in Pharmacy*, *11*(12), 388-393.

Kleemola, K., Hyytinen, H., & Toom, A. (2023). Critical Thinking And Writing In Transition To Higher Education In Finland: Do Prior Academic Performance And Socioeconomic Background Matter?. *European Journal of Higher Education*, *13*(4), 488-508.

Koh, K., Delanoy, N., Thomas, C., Bene, R., Chapman, O., Turner, J., Danysk, G., & Hone, G. (2019). The Role of Authentic Assessment Tasks in Problem-Based Learning. *Papers on Postsecondary Learning and Teaching*, *3*, 17-24.

Kowitlawakul, Y., Tan, J. J. M., Suebnukarn, S., Nguyen, H. D., Poo, D. C. C., Chai, J., Wang, W., & Devi, K. (2022). Utilizing Educational Technology in Enhancing Undergraduate Nursing Students' Engagement and Motivation: A Scoping Review. *Journal of Professional Nursing*, 42, 262-275.

Leaning, M. (2019). An Approach to Digital Literacy Through the Integration of Media and Information Literacy. *Media and Communication*, *7*(2), 4-13.

Li, L., Ismail, S. M., Patra, I., & Lami, D. (2024). Not a Passive Learner but an Active one: a Focus on the Efficacy of Philosophy-Based Language Instruction and its Consequences on EFL Learners' Critical Thinking, Engagement, and Academic Achievement. *BMC Psychology*, *12*(1), 148.

Liu, M., & Mu, X. (2022). Analysis of Computer Network Technology on New Media Problem-Based Learning (PBL) Teaching Method. *Wireless Communications and Mobile Computing*, *2022*(1).

Liu, R., Greene, R., Li, X., Wang, T., Lu, M., & Xu, Y. (2019). Comparing Geoinformation and Geography Students' Spatial Thinking Skills With a Human-Geography Pedagogical Approach in a Chinese Context. *Sustainability (Switzerland)*, *11*(20), 5573.

Liu, Y., Xu, Y., Li, Y., & Wu, Q. (2020). Application of Problem-Based Learning and Case-Based Learning Integrated Method in the Teaching of Maxillary Sinus Floor Augmentation in Implant Dentistry. *PeerJ*, 8(1).

Mesarović, M. M. (2019). Global Warming And Other Climate Change Phenomena On The Geological Time Scale. *Thermal Science*, *23*(5), 1435-1455.

Mohd, H., Darus, N. M., Saip, M. A., Baharom, F., Puteh, N., Husin, M. Z., Marzukiand, Z., & Yasin, A. (2017). Success Factors of Problem Based Learning for IT Courses: Measurements on PBL characteristics, PBL Assessments and PBL Practices. *Journal of Engineering and Applied Sciences*, *12*(21), 5514–5517.

Mufidah, A., Indana, S., & Arifin, I. S. Z. (2023). E-Module Based on Blended Learning Type Flipped Classroom on Climate Change Materials to Train Students' Digital Literacy Ability. *International Journal of Current Educational Research*, *2*(1), 1-16.

Nagarajan, S., & Overton, T. (2019). Promoting Systems Thinking Using Project- and Problem-Based Learning. *Journal of Chemical Education*, *96*(12), 2901-2909.

Ng, W. (2012). Can we Teach Digital Natives Digital Literacy?. *Computers and Education*, *59*(3), 1065-1078.

Nutt, N., Karu, K., & Raamets, J. (2023). Preparing Master's Degree Students for Doctoral Studies-A Lecturer's Perspective: Results of a Case Study of Problem-Based Learning (PBL). *International Conference on Interactive Collaborative Learning*, 355-365.

Patnawar, S. T. (2023). A Comprehensive Review on PBL and Digital PBL in Engineering Education-Status, Challenges and Future Prospects. *Journal of Engineering Education Transformations*, *37*(2), 142-157.

Putra, A. K., Islam, M. N., & Prasetyo, E. B. (2021). Pengembangan Bahan Ajar Digital Mobilitas Penduduk dan Ketenagakerjaan Berbasis STEM. *ASANKA: Journal of Social Science And Education*, *2*(2), 149-159.

Rajabzadeh, A. R., Mehrtash, M., & Srinivasan, S. (2022). Multidisciplinary Problem-Based Learning (MPBL) Approach in Undergraduate Programs. *Lecture Notes in Networks and Systems*, *411*, 454-463.

Rienow, A., Lindner, C., Dedring, T., Hodam, H., Ortwein, A., Schultz, J., Selg, F., Staar, K., & Jürgens, C. (2020). Augmented Reality and Virtual Reality Applications Based on Satellite-Borne and ISS-Borne Remote Sensing Data for School Lessons. *PFG: Journal of Photogrammetry, Remote Sensing and Geoinformation Science*, *88*(2), 187–198.

Sari, Y. I., Sumarmi, Utomo, D. H., & Astina, I. K. (2021). The Effect of Problem Based Learning on Problem Solving and Scientific Writing Skills. *International Journal of Instruction*, *14*(2), 11-26.

Schwartz, J. (2019). What Ifs and Multi-Directional Symptoms Problem-Based Learning Cases: Two Simple and Functional Adjuncts to Problem-Based Learning Materials. *International Journal of Innovation in Science and Mathematics Education*, *27*(8), 49-68.

Shook, E., Bowlick, F. J., Kemp, K. K., Ahlqvist, O., Dale, P. C., DiBiase, D., Kim, E. K., Lathrop, S., Ricker, B., Rickles, P., Rush, J., Swift, J. N., & Wang, S. (2019). Cyber Literacy for GIScience: Toward Formalizing Geospatial Computing Education. *Professional Geographer*, *71*(2), 221-238.

Silviariza, W. Y., & Handoyo, B. (2021). Improving Critical Thinking Skills of Geography Students with Spatial-Problem Based Learning (SPBL). *International Journal of Instruction*, *14*(3), 133-152.

Singha, R., & Singha, S. (2024). Application of Experiential, Inquiry-Based, Problem-Based, and Project-Based Learning in Sustainable Education. *Teaching and Learning for a Sustainable Future: Innovative Strategies and Best Practices*, 109.

Skorenkyy, Y., Kozak, R., Zagorodna, N., Kramar, O., & Baran, I. (2021). Use of Augmented Reality-Enabled Prototyping of Cyber-Physical Systems for Improving Cyber-Security Education. *Journal of Physics: Conference Series*, *1840*(1).

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of Problem-Based Learning (PBL) in STEM Education: Using Expert Wisdom and Research to Frame Educational Practice. *Education Sciences*, *12*(10), 728.

Sonrum, P., & Worapun, W. (2023). Enhancing Grade 5 Student Geography Skills and Learning Achievement: A Problem-Based Learning Approach. *Journal of Education and Learning*, *12*(5), 188-196.

Soubra, L., Al-Ghouti, M. A., Abu-Dieyeh, M., Crovella, S., & Abou-Saleh, H. (2022). Impacts on Student Learning and Skills and Implementation Challenges of Two Student-Centered Learning Methods Applied in Online Education. *Sustainability (Switzerland)*, *14*(15).

Srikan, P., Pimdee, P., Leekitchwatana, P., & Narabin, A. (2021). A Problem-Based Learning (PBL) and Teaching Model using a Cloud-Based Constructivist Learning Environment to Enhance Thai Undergraduate Creative Thinking and Digital Media Skills. *International Journal of Interactive Mobile Technologies*, *15*(22), 68-83.

Sukackė, V., Guerra, A. O. P. D. C., Ellinger, D., Carlos, V., Petronienė, S., Gaižiūnienė, L., Blanch, S., Tallada, A. M., & Brose, A. (2022). Towards Active Evidence-Based Learning in Engineering Education: A Systematic Literature Review of PBL, PjBL, and CBL. In *Sustainability (Switzerland)*, *14*(21).

Sundari, S., Harsono, S. P. T., & Emilia, O. (2014). Applied cal on Problem Based Learning Using Gagne's Instructional Design. *International Journal of Emerging Technologies in Learning*, *9*(9), 11-16.

Thomassen, A. O., & Stentoft, D. (2020). Educating Students for a Complex Future: Why Integrating a Problem Analysis in Problem-Based Learning has Something to Offer. *Interdisciplinary Journal of Problem-Based Learning*, *14*(2), 1-10.

Ulger, K. (2018). The Effect of Problem-Based Learning on the Creative Thinking and Critical Thinking Disposition of Students in Visual Arts Education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1).

Ullah, A., & Anwar, S. (2020). The Effective Use of Information Technology and Interactive Activities to Improve Learner Engagement. *Education Sciences*, *10*(12), 1-20.

Varenina, L., Vecherinina, E., Shchedrina, E., Valiev, I., & Islamov, A. (2022). RETRACTED: Developing Critical Thinking Skills in a Digital Educational Environment. *Thinking Skills and Creativity*, *46*.

Virranmäki, E., Hulkkonen, K. V., & Rusanen, J. (2019). Powerful Knowledge and the Significance of Teaching Geography for in-Service Upper Secondary Teachers–a Case Study from Northern Finland. *International Research in Geographical and Environmental Education*, *28*(2), 103-117.

Vodă, A. I., Cautisanu, C., Grădinaru, C., Tănăsescu, C., & de Moraes, G. H. S. M. (2022). Exploring Digital Literacy Skills in Economics and Social Sciences and Humanities Students. *Sustainability (Switzerland)*, *14*(5), 2483.

Wang, C. C. (2021). The Process of Implementing Problem-Based Learning in a Teacher Education Programme: An Exploratory Case Study. *Cogent Education*, *8*(1).

Weng, X., Cui, Z., Ng, O. L., Jong, M. S. Y., & Chiu, T. K. F. (2022). Characterizing Students' 4C Skills Development During Problem-based Digital Making. *Journal of Science Education and Technology*, *31*(3), 372-385.

Yang, W., Li, H., Su, A., & Ding, L. (2023). Application of Problem Based Learning (PBL) and Case Based Learning (CBL) in the Teaching of International Classification of Diseases Encoding. *Scientific Reports*, *13*(1), 15220.

Yli-Panula, E., Jeronen, E., & Lemmetty, P. (2020). Teaching And Learning Methods in Geography Promoting Sustainability. *Education Sciences*, *10*(1), 5.

Yondler, Y., & Blau, I. (2023). What is the Degree of Teacher Centrality in Optimal Teaching of Digital Literacy in a Technology-Enhanced Environment? Typology of Teacher Prototypes. *Journal of Research on Technology in Education*, *55*(2).

Zamista, A. A., & Charona, M. S. (2023). Tingkat Literasi Digital dan Pengaruhnya terhadap Keterampilan Abad-21 Mahasiswa ditinjau dari Perspektif Gender. *Cetta: Jurnal Ilmu Pendidikan*, *6*(4), 745-756.

Zhang, C. (2023). Influences of Problem-Based Online Learning on the Learning Outcomes of Learners. *International Journal of Emerging Technologies in Learning*, *18*(1), 152-163.