Educational Journal of Learning Technology
Vol. 3, No. 1, pp. 85-95, September 2025
https://doi.org/10.58230/edutech.v3i1.69
Received August 27, 2025; Revised September 08, 2025; Accepted September 10, 2025

Empowering Students Through Technology: Evaluating A Project-Based Learning Approach to Address Clean Water Scarcity

Rendi Indiwara[1]
SMKN 1 Kasongan
Tambang Street, Hampalit, Katingan Hilir District, Katingan Regency, Central Kalimantan Province, Indonesia
rendi.indiwara@gmail.go.id

Abstract. This study applies a goal-free evaluation model to examine the implementation of Project-Based Learning (PBL) in addressing clean water scarcity through the use of NodeMCU ESP8266 and Internet of Things (IoT) technology. Conducted with vocational students at SMKN 1 Kasongan, the project involved designing a water quality monitoring system in response to local river pollution caused by illegal mining. Data were collected through observations, interviews, reflections, and product evaluations, and then analyzed thematically. The findings show that students developed technical skills in sensor integration, programming, and real-time data visualization, alongside non-technical skills such as collaboration, communication, and problem-solving. Unexpected outcomes also emerged, including greater environmental awareness, community engagement, and intrinsic motivation to expand the project. This study highlights the value of PBL in vocational education, recommending its wider adoption to link technology with real-world issues, and contributes theoretically by demonstrating the effectiveness of goal-free evaluation in capturing emergent learning outcomes.

Keywords: Internet of Things (IoT); NodeMCU ESP8266; Project-Based Learning.

1. Introduction

21st-century education faces a significant challenge in preparing the younger generation to adapt to increasingly complex global and local problems. Environmental problems such as climate change, water pollution, and exploitation of natural resources have been proven to not only damage ecosystems, but also threaten public health, food security, and sustainable development (Aprisanti et al., 2025). It is within this framework that education is required to go beyond traditional cognitive learning by fostering critical awareness, problem-solving skills, and stronger collaboration (Falaah et al., 2025). As emphasized in the study (Yu, 2024) The need for innovative learning models is increasingly urgent, mainly because the times have demanded that students be able to think systematically, creatively, and adaptively.

Project-Based Learning (PBL) is one of the approaches that has been developed to answer these needs. In its implementation, students engage in long-term projects related to real problems around them, so that learning is no longer just in the form of delivering theory, but also includes hands-on experience in designing, developing, and evaluating solutions (Ramadan & Hindun, 2023). This model has been proven to increase critical thinking skills, creativity, and motivation to learn, as seen in the results of the research presented (Zhang & Ma, 2023). Furthermore, PBL also strengthens students' readiness to face the demands of the modern world of work because it trains collaborative

©Authors
This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0).

skills, communication, and sustainable adaptation, which is emphasized through analysis (Maros et al., 2023).

The Indonesian context presents its own urgency for the implementation of PBL. In Central Kalimantan, especially Katingan Regency, the clean water crisis is a real problem that has a direct impact on people's lives (Mustapa et al., 2019). Rivers that have been the primary source of daily necessities have been seriously polluted due to illegal gold mining. As a result, the content of sediments and heavy metals in the waters increases, so that the availability of water suitable for consumption decreases drastically. This condition has a broad impact on public health, agricultural productivity, and biodiversity conservation. This phenomenon was recorded in the study (Pebryanto et al., 2025) This illustrates the level of vulnerability of communities to water pollution, as well as strengthened findings (Prihatiningtyas et al., 2023; Rifqi & Syaikhon, 2025) Highlighting the long-term ecological impact. This situation highlights the need for continuous innovation, particularly through the active involvement of schools in integrating education with environmental issues.

Vocational High Schools have great potential to make environmental issues an integral part of contextual learning. By focusing on practical skills, vocational schools can teach students not only technical skills, but also social awareness relevant to the needs of society. The implementation of PBL in vocational schools allows students to connect vocational competencies with the real challenges they face. One example can be seen in the initiative of SMKN 1 Kasongan, where students majoring in Electronics and Informatics developed a NodeMCU ESP8266 and Internet of Things (IoT) based water quality monitoring project. This project serves as both a technical learning tool and a medium for students to gain a deeper understanding of environmental problems in their area.

The integration of PBL with modern technology further strengthens the effectiveness of learning. Findings (Mesutoglu et al., 2024) Shows that the application of PBL in science learning can encourage students' active participation and prepare them for multidisciplinary challenges. Students' creativity also increases when theory is combined with practice, as noted in the study (Chang et al., 2022). This shows that the project approach is not only pedagogically relevant but also capable of forming an innovative mindset that is important for vocational education.

The use of IoT technology adds a new dimension to the learning process. According to the results of the study (Aloufi et al., 2024)The use of IoT has been proven to improve students' technical skills while strengthening teamwork. (Magalhães et al., 2024) Additionally, it demonstrates that applying IoT in PBL can enhance student engagement by allowing them to interact directly with real-world data relevant to daily life. Thus, IoT serves not only as a technical instrument but also as a means to bridge the gap between theory and practice while deepening students' understanding of the surrounding environmental phenomena.

In the context of environmental education, the use of sensor devices for monitoring has proven to be effective. (Dias & Brantley-Dias, 2017) Found that students' involvement in environmental monitoring activities encouraged them to develop a sense of ecological responsibility. (Zulkifli et al., 2022) Reports indicate that IoT-based monitoring systems can provide accurate real-time data, supporting community decision-making. In other words, the application of technology-based projects in education not only provides technical experience but also fosters higher ecological awareness.

Although there is a considerable amount of research related to PBL and IoT, several gaps remain unfilled. Existing studies still primarily emphasize the achievement of learning objectives that were determined from the beginning. According to the analysis (Youker & Ballard, 2024), unexpected results that arise during the learning process are often underappreciated, even though

emergent aspects such as intrinsic motivation, social awareness, and student adaptability actually contribute significantly to educational success. In addition, research on the application of IoT-based PBL in vocational schools is still limited. Most research focuses more on public schools or universities, so the potential of vocational schools to become a vehicle for practical technology-based learning has not been explored optimally.

Furthermore, the goal-free evaluation model is still rarely used in research on the effectiveness of PBL. This model allows for a more open evaluation of learning outcomes by assessing all the results that appear, both anticipated and not. (Stevens et al., 2023) This approach is emphasized as important because it can capture learning dynamics more comprehensively. Therefore, this study seeks to fill the gap by evaluating students' experiences in IoT-based water quality monitoring projects using a goal-free evaluation model.

The research questions focus on three main aspects. First, what technical and non-technical skills can be developed by students through the IoT-based PBL project at SMKN 1 Kasongan? Second, what unexpected results appear during the implementation of the project, especially those related to learning dynamics? Third, the extent to which students' involvement in this project increases environmental awareness and fosters their social responsibility in the community.

The purpose of this research aligns with the formulation of the question. This research aims to evaluate students' technical skills in designing IoT-based water quality monitoring systems, identify the collaboration, creativity, and problem-solving skills that develop during PBL implementation, and uncover unexpected benefits, including increased environmental awareness and community engagement. The theoretical contribution of this research lies in the application of a goal-free evaluation model that can capture the dynamics of learning outcomes as a whole. The practical contribution is in the form of recommendations for vocational schools to be more daring in integrating modern technology with local environmental issues, so that students have a meaningful, contextual, and sustainable learning experience.

2. Method

This study uses a goal-free evaluation model to assess the implementation of Project-Based Learning (PBL) in overcoming the problem of clean water scarcity in Katingan Regency, Central Kalimantan. This evaluation model, as stated by (Scriven, 1991), focusing on the results that emerge during the process without being tied to the initial goal that has been set. This approach was chosen because it can capture a broader range of impacts, both expected and unexpected, so that it can provide a comprehensive understanding of the value of an educational program. Through this model, the research not only assesses the achievement of learning targets, but also pays attention to the processes, challenges, skills that develop, and the contribution of students in designing an IoT-based water quality monitoring system.

The research was carried out at SMKN 1 Kasongan, a vocational school that focuses on the fields of electronics, informatics, and applied sciences. The study focuses on class X students in the Electronics and Informatics expertise program, aged 15–17. The students were involved in designing and developing a NodeMCU-based water quality monitoring system using ESP8266, with the support of Internet of Things (IoT) technology. The project is integrated into the curriculum so that students gain hands-on experience in designing solutions to water pollution problems caused by illegal gold mining activities. The diverse characteristics of the subjects, both in terms of initial knowledge of technology and understanding of environmental issues, allow this study to explore complex learning dynamics.

Data collection was carried out through a combination of qualitative and quantitative methods to obtain a comprehensive picture. Participant observations were carried out at each stage of the project, from design, device assembly, testing, to presentation of results, with a focus on student interaction, teamwork dynamics, and the role of teachers as facilitators. In addition, semi-structured interviews were conducted with students, teachers, and schools to explore their perceptions of the learning process, skills acquired, challenges faced, and impact felt. (Shaukat et al., 2023). Students were asked to reflect on their experiences in operating technology, understanding water quality, and working in teams. At the same time, teachers provided views on the effectiveness of the PBL approach in vocational contexts. Additional data was obtained through student journals, reflection notes, product assessments, and project presentation documentation.

All collected data were analyzed using thematic analysis. The analysis process includes the coding stage, categorization, and discovery of the main themes that reflect the student's learning experience. This analysis enables researchers to identify general patterns related to the development of both technical and soft skills, as well as uncover unexpected results that emerge during the project. With this approach, the research was able to present a complete picture of the effectiveness of IoT-based PBL while highlighting its contribution to vocational learning and environmental awareness at the local level.

3. Results

The results of the research on the implementation of Project-Based Learning (PBL) based on NodeMCU ESP8266 and Internet of Things (IoT) at SMKN 1 Kasongan show various achievements that include technical skills, non-technical skills (soft skills), increased environmental awareness, community involvement, and unexpected results that enrich students' learning experience. Overall, these findings confirm that PBL not only produces products in the form of water quality monitoring systems but also has a broad impact on student learning and attitudes.

Evaluate students' technical skills in developing IoT-based water quality monitoring systems.

In the early stages, the majority of students do not have experience in using microcontrollers or IoT platforms. However, as the project progressed, their technical capabilities improved significantly. Students successfully integrate a Total Dissolved Solids (TDS) sensor and a temperature sensor with a NodeMCU ESP8266, then connect them to Blynk's IoT platform to display the data in real-time.

This process is inseparable from various technical constraints, especially in terms of sensor calibration and internet connection stability. However, this obstacle is actually an opportunity for students to practice problem-solving skills. They learn to identify errors, debug, and find solutions through experiments and group discussions. As a result, students not only master fundamental programming skills and hardware integration, but also gain a deeper understanding of the working principles of sensors and IoT systems.

Table 1. Students' Key Technical Skills Achievement

Technical Aspects	Achievement Indicators	Result
Hardware integration	Ability to connect TDS and temperature sensors with NodeMCU	Students can assemble a basic monitoring system that functions stably
Microcontroller programming	Writing the base code to read sensor data and send it to the IoT platform	The whole group managed to write a simple program using an Arduino IDE
Sensor calibration	Adjust sensor readings to water quality standards	Students perform manual calibration with reference to the clean water standard data

Data visualization	View real-time data in the Blynk dashboard	TDS and temperature data are successfully displayed in the form of a graph
Technical troubleshooting	Resolve errors, sensor malfunctions, and connection issues	Students develop troubleshooting skills through discussion and experimentation

Identify collaboration, creativity, and problem-solving skills that develop during the PBL process.

In addition to technical skills, the study also found that students experience development in non-technical aspects, especially in terms of collaboration, communication, and creativity. At the project's outset, the division of tasks among team members was not well structured. However, over time, students began to form role specializations naturally: some focused on hardware assembly, some managed programming, and some were responsible for testing and documentation.

This change shows an improvement in team management and coordination skills. Students learn to complement each other in teams, resolve minor conflicts independently, and keep all members engaged. Students' creativity is evident in the variations in prototype designs among groups. Some groups are adding auto-logging features, while other groups are trying to connect the system with additional applications to expand the monitoring function.

Table 2. Student's Non-technical Skills Achievement

Soft Skills Indicator	Key Findings
Team collaboration	Students form a division of roles (hardware, software, testing).
Communication	Intensive discussions focused on resolving technical issues and delivering project presentations.
Leadership	Some students naturally appear as group coordinators.
Creativeness	Variations of prototype designs and additional innovations (pH features, additional applications).
Troubleshooting	Technical barriers are overcome through cooperation and brainstorming.

Uncover the unexpected benefits that arise, including increased environmental awareness and community engagement.

The research also found several unexpected benefits that emerged during the project process. One of the most notable findings is the increase in students' environmental awareness. Many students initially did not understand the impact of river pollution, but after conducting hands-on prototype testing in the field, they realized the importance of maintaining water quality. This awareness prompted some groups to expand the measurement parameters and more seriously discuss the factors that cause water pollution in their area.

In addition, this project resulted in a form of community involvement. When students presented the measurement results to residents, the community showed great interest in IoT-based monitoring systems. These presentations not only boost students' confidence but also strengthen the relationship between the school and the local community.

Another unplanned finding is the emergence of intrinsic motivation in students. They feel that the project is not only a school assignment, but also has real benefits for the environment and society. Some students even proposed the idea of developing similar technologies for air quality monitoring and energy savings in the future.

Table 3. Unexpected Benefits That Arise

Aspects	Key Findings
Environmental awareness	Students gain a better understanding of the impact of river pollution after the field test.

Community involvement	The presentation of the monitoring results received a positive response from residents.
Intrinsic motivation	Students are encouraged to develop advanced ideas (air quality, energy monitoring).
Social responsibility	Students feel that the results of the project are directly beneficial to the community.

Overall, the results of this study show that the implementation of IoT-based PBL at SMKN 1 Kasongan has a dual impact: (1) the achievement of technical skills relevant to the student's field of expertise, (2) the strengthening of soft skills such as collaboration, communication, and creativity, and (3) unexpected benefits in the form of environmental awareness, community involvement, and the emergence of intrinsic motivation. All of these findings align with the research objectives, which aim to evaluate students' technical and non-technical skills and uncover unexpected results from project implementation.

4. Discussion

Evaluate students' technical skills in developing IoT-based water quality monitoring systems.

The results of the study showed that the students successfully developed important technical skills in designing and building a NodeMCU-based water quality monitoring system, ESP8266. The students' success in integrating TDS and temperature sensors, programming microcontrollers, calibrating sensors, and displaying data in real-time on the Blynk platform is an indicator that PBL can improve their technical capacity. This process is not just an exercise in assembling a device, but also a means of learning that demands a conceptual understanding of the working principles of sensors, basic programming, and data processing. In other words, the technical skills students gain reflect the success of the PBL approach in connecting theory with practice directly.

Interpretation of these findings shows that although students depart with limited technical abilities, they can achieve fairly complex competencies through project-based learning experiences. Obstacles that arise, such as difficulties in calibrating sensors and interruptions of internet connections, are actually a means of meaningful learning. This situation is in line with the view (Rees Lewis et al., 2019) This emphasizes that PBL provides space for students to learn through challenges, so that technical skills develop through an authentic trial-and-error process.

When compared to previous research, the students' achievements in this project are consistent with the findings (Tariq et al., 2024) This states that the integration of IoT in education can improve students' technical skills while training them in the face of the complexities of modern technology. Similarly, research (Pogoh et al., 2024) Demonstrate how the application of sensors and IoT systems in the classroom fosters a deeper understanding of hardware and software integration. This comparison confirms that the results of this study are not only relevant in the local context but also in line with global trends in technology education.

The practical implication of these findings is that the implementation of PBL with the support of technologies such as IoT can be an effective strategy in vocational education. Teachers can leverage similar models to teach other technical skills relevant to the world of work, such as industrial automation, environmental monitoring, or data-driven systems development. For students, hands-on experience in assembling and programming IoT-based devices provides real-world experience that can increase their competitiveness in the industrial era 4.0.

Meanwhile, the theoretical implications are that these findings strengthen the conceptual framework of PBL as a practical approach to building technical skills (Lewis & Williams, 1994). Using a goal-free evaluation model, the study also shows that technical learning outcomes are not

always predictable in advance, but arise from students' interactions with real challenges. This confirms that PBL theory is not only valid in the context of general learning, but also highly relevant for vocational education that demands applicative skills.

Identify collaboration, creativity, and problem-solving skills that develop during the PBL process.

The research findings show that students' non-technical skills, particularly collaboration, creativity, and problem-solving, develop significantly during the process of implementing IoT-based PBL. At the project's outset, coordination among team members was poorly structured, marked by unclear role divisions and challenges in regulating the group work's rhythm. However, as the project progresses, students begin to organize themselves by forming role specializations: some students focus on hardware, others manage programming, while others are responsible for testing or documentation. This dynamic shows that PBL creates a collaborative learning space that requires students to adjust, hone their communication, and resolve internal conflicts independently.

An interpretation of these findings suggests that students' collaboration skills do not develop instantly, but rather through a repetitive process of adaptation. The technical obstacles they face are actually the trigger for the birth of creativity and critical thinking. For example, when the sensors do not provide accurate results, students brainstorm together to find solutions, from manual calibration to programming code adjustments. This process proves that problem-solving is not only a matter of technical skills, but also involves cooperation, communication, and openness to new ideas.

These findings are in line with research (Naseer et al., 2025), which shows that PBL can foster collaborative abilities as students are faced with long-term projects that require intensive cooperation. (Wijnia et al., 2024) Also affirms that PBL increases students' intrinsic motivation, which in turn encourages creativity and innovation in completing tasks. This comparison shows that the results of the research at SMKN 1 Kasongan are consistent with the global literature that emphasizes the importance of PBL in developing soft skills that are relevant to the 21st century.

In terms of practical implications, these findings suggest that vocational education should not only emphasize technical aspects but also provide space for the development of collaborative skills and problem-solving. The IoT-based PBL model has proven to be able to integrate both aspects, so that students are not only skilled in using technology, but also able to work in teams and lead small projects. For teachers, these results confirm the importance of playing a role as a facilitator who encourages discussion, providing minimal guidance, but still giving room for students to find their own solutions.

The theoretical implication of these findings is that PBL reinforces the concept of experiential learning, in which non-technical skills develop as students interact with real challenges (Lewis & Williams, 1994). The goal-free evaluation model used in this study shows that non-technical outcomes, even if not designed from the outset, are an important part of learning success. This broadens the understanding of the effectiveness of PBL, not only as a method of teaching technical skills, but also as a vehicle for the formation of soft skills that are essential in the modern world of work.

Uncover the unexpected benefits that arise, including increased environmental awareness and community engagement.

The findings of the study show that the IoT-based PBL project at SMKN 1 Kasongan produces several unexpected benefits that go beyond technical skills and soft skills. One of the most notable outcomes is the increased awareness of the students' environment. In the early stages, many students lack a deep understanding of the impact of water pollution in their area. However, after testing the prototype in the river around Kasongan, the students witnessed firsthand the murky and polluted

water conditions due to illegal gold mining activities. This real-life experience aroused ecological concern and sparked an internal group discussion about the factors that cause pollution and ways to mitigate it. This awareness is a crucial emergency outcome because it demonstrates that technology can serve as a gateway to promoting environmental responsibility among the younger generation.

In addition to ecological awareness, this project also gives rise to a form of community involvement. The students' presentation regarding the results of water monitoring received a positive response from residents. The community showed interest in the IoT-based system developed by the students, as well as providing input related to river conditions and local needs. These interactions not only strengthen the relationship between the school and the community but also foster a sense of civic responsibility in students. They realize that the results of their projects are not just academic tasks, but have real relevance to people's lives.

Another benefit that emerges is the growth of intrinsic motivation. Students feel more excited because the projects they are working on are considered to be of direct benefit to the environment and the community. Some students even expressed a desire to expand similar projects to other issues, such as air quality monitoring and energy efficiency. This shows the formation of a sustainability mindset, where students see technology not only as a technical skill but also as a means to make a broader social impact.

When compared to previous research, these findings are in line with (Janmaimool & Khajohnmanee, 2020) This emphasizes that students' involvement in environmental monitoring can increase their sense of ecological responsibility. (AlMetwally et al., 2020) The application of IoT systems in water quality monitoring also provides direct benefits to the community by presenting real-time data relevant for decision-making. This comparison shows that the unexpected benefits found at SMKN 1 Kasongan are consistent with the literature, but have added value because they appear in the context of vocational education that involves students directly in solving environmental problems.

In terms of practical implications, these findings suggest that vocational schools can play a further role as agents of social change. By facilitating projects related to local environmental issues, the school produces not only technically skilled graduates but also citizens who care about and are responsible for the sustainability of its ecosystem. For teachers, this experience is proof that contextual learning not only increases student motivation but also strengthens the relevance of education to the needs of society.

Theoretically, these results broaden the understanding of the effectiveness of PBL by affirming that the goal of education does not stop at the mastery of technical or non-technical skills, but also includes the formation of values, attitudes, and social awareness (Sapphire et al., 2025). The goal-free evaluation model has proven to be effective in capturing these emergent benefits, as it does not limit the evaluation to measurable initial goals, but rather opens up space to see the dynamics of learning outcomes more broadly. Thus, this research contributes to the development of a more holistic theory of PBL, that is, as a learning strategy that not only prepares students for the world of work but also shapes them into agents of social and ecological change.

5. Conclusion

This study demonstrates that the implementation of Project-Based Learning (PBL) using NodeMCU ESP8266 and Internet of Things (IoT) at SMKN 1 Kasongan yields several significant achievements. In terms of technical skills, students manage to master sensor integration, microcontroller programming, calibration, and real-time data visualization, although they initially

depart from limited knowledge. In addition, this study also found the development of non-technical skills in the form of collaboration, communication, leadership, creativity, and problem-solving that arise naturally during project work. Another important finding is the unexpected benefits in the form of increased environmental awareness, community involvement, and the birth of students' intrinsic motivation to develop similar projects in the future.

Based on these findings, this study recommends that vocational schools integrate more project-based learning with real issues in the surrounding environment, so that students not only learn technical skills but also build social and ecological awareness. Teachers can take on the role of facilitators who encourage exploration, provide space for creativity, and ensure the connection between theory, practice, and community needs. The study also suggests the need for further development in the technical support aspect, for example, by providing more varied sensor devices to expand the scope of data obtained by students.

The contribution of this research lies in the application of a goal-free evaluation model in the context of PBL-based vocational education, which can capture learning outcomes more comprehensively, including emergent benefits that were not designed from the beginning. Theoretically, this study enriches the literature on the effectiveness of PBL in developing technical skills as well as soft skills. In practical terms, this study provides concrete evidence that vocational education can play an active role in addressing local environmental problems, fostering community collaboration, and empowering students to become agents of social and ecological change.

6. References

AlMetwally, S. A. H., Hassan, M. K., & Mourad, M. H. (2020). Real-Time Internet of Things (IoT) Based Water Quality Management System. *Procedia CIRP*, *91*, 478–485. https://doi.org/10.1016/j.procir.2020.03.107

Aloufi, F., Tashtoush, M. A., Shirawia, N., Tashtoush, R. A., & Az-Zo'Bi, E. A. (2024). Internet of Things in Education: Teachers' Perspectives, Practices and Challenges. *WSEAS Transactions on Computer Research*, *12*, 429–442. https://doi.org/10.37394/232018.2024.12.42

Aprisanti, R., Fajri, N. E., & Budijono, B. (2025). Kontribusi Ekosistem Alam dalam Meningkatkan Ketahanan Ekonomi dan Pangan Nasional di Era Perubahan Iklim yang Dinamis. *JURNAL RISET INOVASI DAERAH*, *3*(1), 1–11.

Chang, T.-S., Wang, H.-C., Haynes, A. M., Song, M.-M., Lai, S.-Y., & Hsieh, S.-H. (2022). Enhancing student creativity through an interdisciplinary, project-oriented problem-based learning undergraduate curriculum. *Thinking Skills and Creativity*, *46*, 101173. https://doi.org/10.1016/j.tsc.2022.101173

Dias, M., & Brantley-Dias, L. (2017). Setting the Standard for Project Based Learning: A Proven Approach to Rigorous Classroom Instruction. *Interdisciplinary Journal of Problem-Based Learning*, *11*(2). https://doi.org/10.7771/1541-5015.1721

Falaah, M. F., Suryadin, A., Makmur, M., Safira, A., & Purnamasari, N. (2025). Integrasi Islamic Critical Thinking dalam Pendidikan Kontemporer: Upaya Meningkatkan Kecerdasan Berpikir Kritis Pelajar. *Jurnal Pendidikan Indonesia : Teori, Penelitian, Dan Inovasi*, *5*(3). https://doi.org/10.59818/jpi.v5i3.1677

Janmaimool, P., & Khajohnmanee, S. (2020). Enhancing university students' global citizenship, public-mindedness, and moral quotient for promoting a sense of environmental responsibility and pro-environmental behaviours. *Environment, Development and Sustainability*, *22*(2), 957–970. https://doi.org/10.1007/s10668-018-0228-6

Lewis, L. H., & Williams, C. J. (1994). Experiential Learning: Past and Present. *New Directions for Adult and Continuing Education*.

Magalhães, A., Alves, J. M., & Andrade, A. (2024). The internet of things in education. Technology, pedagogy and learning. *Revista Portuguesa de Investigação Educacional*, *27*, 1–25. https://doi.org/10.34632/investigacaoeducacional.2024.16057

Maros, M., Korenkova, M., Fila, M., Levicky, M., & Schoberova, M. (2023). Project-based learning and its effectiveness: Evidence from Slovakia. *Interactive Learning Environments*, *31*(7), 4147–4155. https://doi.org/10.1080/10494820.2021.1954036

Mesutoglu, C., Bayram-Jacobs, D., Vennix, J., Limburg, A., & Pepin, B. (2024). Exploring multidisciplinary teamwork of applied physics and engineering students in a challenge-based learning course. *Research in Science & Technological Education*, *42*(3), 639–657. https://doi.org/10.1080/02635143.2022.2154334

Mustapa, L. A., Purnamadewi, Y. L., & Dharmawan, A. H. (2019). Dampak dan Keberlanjutan Program Cetak Sawah di Kabupaten Katingan, Provinsi Kalimantan Tengah. *Analisis Kebijakan Pertanian*, *17*(2), 123–137. https://doi.org/10.21082/akp.v17n2.2019.123-137

Naseer, F., Tariq, R., Alshahrani, H. M., Alruwais, N., & Al-Wesabi, F. N. (2025). Project based learning framework integrating industry collaboration to enhance student future readiness in higher education. *Scientific Reports*, *15*(1), 24985. https://doi.org/10.1038/s41598-025-10385-4

Noho, F. A., Umar, M. K., Uloli, R., Odja, A. H., Supartin, S., & Buhungo, T. J. (2023). Self-evaluation using the model goal-free evaluation in physics subjects in high schools: Abstract. *Jurnal Pijar Mipa*, *18*(2), 224–230. https://doi.org/10.29303/jpm.v18i2.4807

Pebryanto, P., Saptawartono, S., Iashania, Y., Wijaya, D. A. K., & Putrawiyanta, I. P. (2025). Analisis Dampak Pertambangan Emas Tanpa Izin Terhadap Kualitas Air Sungai Katingan Dan Persepsi Masyarakat Di Desa Garagu Kecamatan Pulau Malan Kabupaten Katingan Provinsi Kalimantan Tengah. *Innovative: Journal Of Social Science Research*, *5*(4), 1–10. https://doi.org/10.31004/innovative.v5i4.20103

Pogoh, D. S., Pinangkaan, S. N., Bawimbang, D. E. S., Takaendengan, D. J., Ladi, J. K., & Torar, M. (2024). The Implementation of Internet of Things (IOT) In Education to Improve The Quality of Learning. *Jurnal Syntax Admiration*, *5*(12), 5980–5986. https://doi.org/10.46799/jsa.v6i1.1978

Prihatiningtyas, W., Wijoyo, S., Wahyuni, I., & Fitriana, Z. M. (2023). Perspektif Keadilan Dalam Kebijakan Perdagangan Karbon (Carbon Trading) Di Indonesia Sebagai Upaya Mengatasi Perubahan Iklim. *Refleksi Hukum: Jurnal Ilmu Hukum*, *7*(2), 163–186. https://doi.org/10.24246/jrh.2023.v7.i2.p163-186

Ramadhan, E. H., & Hindun, H. (2023). Penerapan Model Pembelajaran Berbasis Proyek untuk Membantu Siswa Berpikir Kreatif. *Protasis: Jurnal Bahasa, Sastra, Budaya, Dan Pengajarannya*, *2*(2), 43–54. https://doi.org/10.55606/protasis.v2i2.98

Rees Lewis, D. G., Gerber, E. M., Carlson, S. E., & Easterday, M. W. (2019). Opportunities for educational innovations in authentic project-based learning: Understanding instructor perceived challenges to design for adoption. *Educational Technology Research and Development*, *67*(4), 953–982. https://doi.org/10.1007/s11423-019-09673-4

Rifqi, & Syaikhon, A. (2025). Politik Ekologis: Peran Istilah 'Ramah Lingkungan' dalam Melegitimasi Aktivitas Industri dan Pemerintah (Ecological Politics: The Role of the Term 'Environmentally Friendly' in Legitimizing Industrial and Government Activities). *Lentera Demokrasi: Jurnal Ilmu Sosial, Politik, Hukum, Ekonomi Dan Pemerintahan*, *1*(1), 18–30.

Saptadi, N. T. S., Sukamdi, S., Septiani, S., Wardoyo, T. H., Hidayati, W., Thoif, M., Talindong, A., Isminarti, I., Audia, F., Ratnawati, R., Nashiroh, P. K., Hadikusumo, R. A., Agusriati, A., Suroya, L. F., Kuntaua, D., Dewi, N. K., Thomas, F., & Ramdani, M. (2025). *Pendidikan Vokasional: Teori dan Praktik*. Sada Kurnia Pustaka.

Scriven, M. (1991). Prose and Cons about Goal-Free Evaluation. *Evaluation Practice*, *12*(1), 55–62. https://doi.org/10.1177/109821409101200108

Shaukat, N., Ali, D. M., Jaffer, M., Jarrar, Z., Ashraf, N., Hassan, S., Daudpota, A. A., Qadir, M. A., Khowaja, A. H., & Razzak, J. (2023). Lifesaving skills training in schools – A qualitative study to explore students, teachers, and parent's perceived opportunities and challenges. *BMC Public Health*, *23*(1), 400. https://doi.org/10.1186/s12889-023-15284-9

Tariq, R., Casillas-Muñoz, F., Hassan, S., & Ramírez-Montoya, M. (2024). Synergy of Internet of Things and Education: Cyber-physical Systems Contributing towards Remote Laboratories, Improved Learning, and School Management. *Journal of Social Studies Education Research*, *15*(2), 305–352.

Wijnia, L., Noordzij, G., Arends, L. R., Rikers, R. M. J. P., & Loyens, S. M. M. (2024). The Effects of Problem-Based, Project-Based, and Case-Based Learning on Students' Motivation: A Meta-Analysis. *Educational Psychology Review*, *36*(1), 29. https://doi.org/10.1007/s10648-024-09864-3

Youker, B., & Ballard, A. (2024). Goal-Free Evaluation: An Orientation for Foundations' Evaluations – Updated 2024. *The Foundation Review*, *16*(1). https://doi.org/10.9707/1944-5660.1697

Yu, H. (2024). RETRACTED: Enhancing creative cognition through project-based learning: An in-depth scholarly exploration. *Heliyon*, *10*(6). https://doi.org/10.1016/j.heliyon.2024.e27706

Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: A meta-analysis study. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1202728

Zulkifli, C. Z., Garfan, S., Talal, M., Alamoodi, A. H., Alamleh, A., Ahmaro, I. Y. Y., Sulaiman, S., Ibrahim, A. B., Zaidan, B. B., Ismail, A. R., Albahri, O. S., Albahri, A. S., Soon, C. F., Harun, N. H., & Chiang, H. H. (2022). IoT-Based Water Monitoring Systems: A Systematic Review. *Water*, *14*(22), 3621. https://doi.org/10.3390/w14223621