

THE IMPLEMENTATION OF PROJECT-BASED LEARNING TO FOSTER 21ST-CENTURY SKILLS IN PRIMARY EDUCATION

Icha Andriani¹, and Milan Zelenovic²

¹ Universitas Islam Negeri Mahmud Yunus Batusangkar, Indonesia

² University of East Sarajevo, Bosnia and Herzegovina

Corresponding Author:

Icha Andriani,

Department of Madrasah Ibtidaiyah Teacher Education, Faculty of Tarbiyah and Teacher Training, Mahmud Yunus Batusangkar State Islamic University.

Email: ichaandriani488@gmail.com

Article Info

Received: December 25, 2025

Revised: January 25, 2026

Accepted: February 07, 2026

Online Version: March 04, 2026

Abstract

In facing the dynamic challenges of globalization, rapid technological advancement, and evolving 21st-century competencies, Indonesia's primary education system must undergo transformative changes in its instructional practices. This study aims to analyze the implementation of the Project-Based Learning (PjBL) model in fostering 21st-century skills among primary school students. Utilizing a qualitative case study approach conducted at a primary school in Yogyakarta, data were collected through classroom observations, in-depth interviews with teachers and students, and documentation analysis. The findings indicate that PjBL significantly enhances students' critical thinking, creativity, collaboration, and communication skills. Students become more actively engaged, intrinsically motivated, and confident in expressing ideas, solving real-life problems, and working in teams. Teachers reported a shift in their instructional role toward facilitation, which demands better planning and flexibility. The study also emphasizes the importance of institutional support, adequate learning resources, and the integration of digital tools that foster digital literacy and enrich the learning experience. Despite challenges such as time constraints and diverse student capabilities, the results demonstrate that PjBL aligns well with the goals of the Kurikulum Merdeka, offering a holistic and relevant educational approach. Therefore, PjBL is recommended as an effective model to equip primary students with essential 21st-century competencies and should be supported by sustainable policies and professional development programs for teachers.

Keywords: Innovative Learning Model, Primary Education, Project-Based Learning, 21st-Century Skills



© 2026 by the author(s)

This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution-ShareAlike 4.0 International (CC BY SA) license

(<https://creativecommons.org/licenses/by-sa/4.0/>).

Journal Homepage	https://journal.zmsadra.or.id/index.php/fej
How to cite:	Andriani, I., & Zelenovic, M. (2026). The Implementation of Project-Based Learning to Foster 21st-Century Skills in Primary Education. <i>JOB: Journal of Basic Education</i> , 2(1), 133–141. https://doi.org/XX.XXXXX/fej.v2i1.1420
Published by:	Yayasan Zia Mulla Sadra

INTRODUCTION

Primary education serves as the fundamental foundation for shaping students' character, knowledge, and skills. At this stage, students begin to explore the world more broadly and systematically (Aktoprak & Hursen, 2022; Atlam dkk., 2022). They are introduced not only to various subjects but also to life values, social norms, and cultural understanding. Therefore, the quality of primary education plays a crucial role in determining students' development at the next educational levels. In the context of current globalization and digitalization, primary education must be capable of preparing a generation that is adaptive and competent in facing contemporary challenges. The challenges of 21st-century education go beyond mastery of academic content and include essential skills that enable students to survive, grow, and innovate in real life. These are commonly referred to as "21st-century skills," which encompass communication, collaboration, critical thinking, and creativity (Berlinski dkk., 2009; Chou & Chou, 2011). These four skills are fundamental to creating a meaningful and relevant learning experience that aligns with the needs of the modern era. Therefore, appropriate learning strategies are required to optimally develop these competencies.

One approach that is increasingly being adopted in the learning process is the Project-Based Learning (PjBL) model. This model provides students with authentic learning experiences through active involvement in real-life related projects. During implementation, students are encouraged to identify problems, seek solutions, collaborate in groups, and present their findings (Christophe dkk., 2022). This process indirectly fosters critical thinking, creativity, teamwork, and effective communication skills. Although Project-Based Learning is not entirely a new instructional model, its implementation in the context of primary education in Indonesia still requires further exploration. This is particularly important since many primary schools continue to rely on traditional teacher-centered approaches, which often limit students' opportunities to explore and develop their potential. Therefore, PjBL can serve as a relevant alternative to address the demands of 21st-century education.

Previous research has shown that PjBL can improve student learning outcomes and motivation in the learning process. Moreover, this model has proven effective in creating a more enjoyable and engaging learning environment. However, its implementation at the primary education level still faces various challenges, such as time constraints, limited facilities, and teachers' capacity to design and manage effective learning projects (Diab dkk., 2023; Gary, 2015). Hence, empirical studies on the implementation of PjBL in primary schools are essential.

Theoretically, Project-Based Learning is rooted in constructivist theory, which asserts that knowledge is actively constructed by learners through experience and interaction with their environment. In this context, the teacher acts as a facilitator who guides students in the process of discovering and building knowledge (Gresnigt dkk., 2014; Hailey dkk., 2016). This concept aligns with the spirit of 21st-century learning, which emphasizes active, collaborative, and student-centered education. As such, PjBL is believed to foster independent learning and a sense of responsibility in students regarding their own learning process. In primary education, the application of PjBL must be adapted to the cognitive, affective, and psychomotor developmental characteristics of students. Elementary school children tend to prefer concrete, enjoyable, and challenging activities. Therefore, the projects designed within PjBL should cater to students' needs and interests. Additionally, parental involvement and a supportive school

environment play a vital role in the successful implementation of this model. Collaboration among teachers, students, and parents creates a positive synergy in the learning process.

The implementation of PjBL in primary education is also closely related to the strengthening of students' character. Well-designed projects can teach students responsibility, cooperation, discipline, and curiosity—values that are essential in character formation from an early age (Karakose dkk., 2023). Thus, PjBL not only contributes to academic skills but also to the development of strong character traits that prepare students to face future challenges. The Kurikulum Merdeka (Independent Curriculum), which is currently being introduced across various educational levels in Indonesia, provides a great opportunity to develop innovative learning models like PjBL. This curriculum emphasizes contextual, flexible, and student-centered learning. In this context, PjBL is highly relevant to support the goals of the Kurikulum Merdeka. Therefore, a deep understanding of how to design and implement PjBL effectively at the primary school level is necessary.

Nevertheless, implementing PjBL is not without challenges. Teachers, as the key agents of curriculum implementation, must possess adequate pedagogical and professional competence to design meaningful learning projects. Furthermore, support from school principals, supervisors, and other stakeholders is essential to create a conducive learning ecosystem. Without such support, innovative approaches like PjBL may be difficult to implement optimally. The integration of technology in PjBL is also a crucial factor to consider. In this digital era, technology can be an effective tool for designing, executing, and evaluating learning projects. Students can use various applications and digital platforms to gather information, collaborate, and present their project outcomes. However, unequal access and varying levels of digital literacy remain challenges that must be addressed.

The novelty of this study lies in its specific focus on implementing PjBL at the primary education level to foster 21st-century skills within the framework of the Kurikulum Merdeka. Most previous studies have focused on secondary and higher education (Kaufman, 2013; Kirschner, 2005). Therefore, this study is expected to contribute meaningfully to the development of innovative teaching practices in primary schools and serve as a reference for teachers in designing relevant and contextual learning strategies.

This study also emphasizes the importance of students' active involvement throughout all stages of project learning. In this approach, students are not merely passive recipients of information but active participants who design, carry out, and reflect on their learning. This is expected to increase their learning autonomy and sense of responsibility toward their own educational progress. By understanding and properly implementing PjBL, teachers can create a learning environment that is enjoyable, challenging, and meaningful for students. Such an environment encourages students to develop their full potential cognitively, affectively, and psychomotorically. Ultimately, primary education will produce graduates who are not only academically capable but also possess strong character and essential life skills required in the 21st century.

This study aims to provide an in-depth description of how the Project-Based Learning model can foster 21st-century skills at the primary education level. The research is conducted using a qualitative approach with a case study method. It is hoped that the findings will offer new insights and practical recommendations for educators in developing adaptive and innovative learning models suited to contemporary challenges.

RESEARCH METHOD

This study employs a qualitative approach using a case study method. This approach was chosen to gain an in-depth understanding of the implementation of the Project-Based Learning (PjBL) model in fostering 21st-century skills among primary school students (Kokotsaki dkk., 2016). The research was conducted at a primary school that has consistently applied the PjBL model within its curriculum. The main focus of this study is to explore how the model is implemented and its impact on students' skill development. The research site was selected purposively, namely a primary school in Yogyakarta that has shown a strong commitment to developing innovative learning models. The research subjects consisted of classroom teachers, students, and the school principal. Data collection techniques included direct observation of the learning process, in-depth interviews with teachers and students, and documentation of project outcomes and learning activities. These techniques allowed the researcher to collect data from various sources, thereby increasing the validity of the findings.

Observations were carried out over six consecutive weeks with a frequency of twice per week. Each observation session lasted approximately 90 minutes and covered all stages of the project implementation, from planning to final presentation. Field notes were taken systematically to record interactions between teachers and students, group dynamics, and the use of learning resources. The purpose of the observations was to capture the learning process naturally without disrupting classroom activities. Interviews were conducted in a semi-structured format to allow flexibility in data exploration. Teachers were interviewed regarding their strategies in planning and implementing PjBL, the challenges they encountered, and the impact on students' development (Lu dkk., 2022). Students were interviewed individually and in groups to share their experiences participating in the projects, the learning they experienced, and the skills they gained. The school principal was also interviewed regarding institutional policies and support for the implementation of this model.

Documentation was collected in the form of activity photos, teacher journals, student worksheets, project reports, and evaluation results. These documents were used to reinforce the findings from observations and interviews and to provide a visual representation of the PjBL implementation. All documents were analyzed qualitatively to identify patterns that support the development of 21st-century skills. Data analysis was carried out thematically, following the stages of data reduction, data display, and conclusion drawing (Munawaroh dkk., 2018; Muruganandam dkk., 2023). Data from various sources were coded and categorized based on key themes such as collaboration, communication, critical thinking, and creativity. The analysis also considered the interconnection between themes and the contextual implementation of PjBL in the primary school environment.

To ensure data validity, the researcher used source and method triangulation techniques. Triangulation was done by comparing the results of observations, interviews, and documentation to identify data consistency and reliability. Additionally, member checking was conducted by asking for confirmation from teachers and students regarding the interpretation of the collected data. Research ethics were maintained by informing the school about the objectives and procedures of the study. Written consent was obtained from the principal and teachers. The identity of respondents was kept confidential by using specific codes. All data collected were used solely for research purposes and stored securely.

The limitations of this study include the relatively short observation period and the limited number of schools included in the case study. Therefore, the findings of this research cannot be broadly generalized but can offer valuable contextual insights for the development of learning practices at the primary education level (Papageorgiou, 2003). With a holistic approach and systematic methodology, this study is expected to provide a comprehensive depiction of the implementation of Project-Based Learning and its contribution to fostering 21st-century skills among primary school students. The following section will present the findings obtained from the field.

RESULTS AND DISCUSSION

Result

The findings of this study indicate that the implementation of Project-Based Learning (PjBL) has a significant impact on the development of 21st-century skills among primary school students. Observations revealed a noticeable improvement in students' critical thinking skills through the processes of problem identification, solution-seeking, and decision-making in various assigned projects (Rostami dkk., 2022). Project activities encouraged students to think deeply, question existing information, and formulate new ideas. In addition to critical thinking, students' creativity also developed through designing and creating project products. Each student group was given the freedom to determine the format and media for their project presentation. In this process, they integrated various learning resources and unique ideas to produce innovative solutions. Teachers reported that students became more enthusiastic and motivated when given the opportunity to freely express their ideas.

Students' collaboration skills were honed through group work, which is central to the PjBL model. Students learned to share responsibilities, listen to one another, and respect differing opinions. Conflicts that arose within groups were resolved through discussion and negotiation, indirectly fostering their social skills and empathy. Peer interaction improved not only in academic contexts but also in more positive interpersonal relationships. Communication skills also showed significant improvement. At each stage of the project, students were required to express their ideas both orally and in writing. Project presentations in front of the class became effective means for students to practice confidence, articulation, and public speaking skills. Teachers observed that students who were previously passive began to speak up and participate actively in discussions.

Students' learning motivation increased significantly during the implementation of PjBL. They showed high interest in learning materials as they felt they had an important role in the learning process (Putri dkk., 2023). This active engagement was reflected in their enthusiasm during project work, improved attendance, and increased independence in learning. Teachers noted that this approach created a learning environment that was both enjoyable and challenging. The implementation of PjBL also had a positive impact on students' time management and sense of responsibility. In every project, students had to plan work stages, set deadlines, and distribute tasks fairly. This fostered a sense of individual and group responsibility and taught the importance of discipline and planning in achieving goals.

The project planning process by teachers showed a high level of readiness and structure. Teachers designed projects based on learning themes relevant to students' daily lives. The alignment between projects and the curriculum was a key factor in successful implementation. Teachers also provided work guidelines, assessment rubrics, and clear schedules to ensure the project ran effectively and efficiently. In terms of assessment, teachers employed an authentic approach that evaluated both processes and products (Sharmin dkk., 2023). Assessment was conducted both formatively and summatively through observations, portfolios, self-assessment, and peer feedback (L. Zhang dkk., 2022; Zhao dkk., 2024). As a result, assessment focused not only on final outcomes but also on student engagement, thought processes, and social skill development. This made the assessment more holistic and meaningful.

Interviews with students revealed that they felt more confident and capable of completing tasks independently. They felt appreciated as their opinions and ideas were taken seriously. Several students stated that working on projects provided them with new insights and made them more eager to attend school. This indicates that PjBL contributes to creating a positive and memorable learning experience. Teachers involved in the study expressed that the PjBL model requires more effort and preparation compared to conventional models. However, they felt that the outcomes justified the effort. Teachers also reported greater satisfaction as they could observe tangible and in-depth development in students' skills.

The school principal provided full support for the implementation of PjBL by offering teacher training, sufficient learning resources, and classrooms conducive to collaborative learning. This support was a crucial factor in the successful implementation of PjBL. The principal also integrated this model into the school's development program as a strategy to improve the quality of education. Challenges in implementing PjBL included differences in student abilities within the same class, limited time for project execution, and the need for sufficient resources (Tondeur dkk., 2007). To address these issues, teachers adjusted project designs for greater flexibility, formed heterogeneous groups, and utilized digital learning resources.

Observations showed that the use of technology in PjBL provided significant added value. Students used digital devices to search for information, create presentations, and document project results. Technology use also enhanced students' digital literacy, which is a crucial part of 21st-century skills. Documentation in the form of activity photos, student work, and project reports demonstrated that students were capable of producing creative products relevant to real life. Some projects were even showcased at school events and received appreciation from parents and the local community. This highlights the positive social impact of learning through PjBL. Overall, the findings of this study reinforce the argument that Project-Based Learning is an effective instructional model for fostering 21st-century skills among primary school students. Its implementation requires commitment from various stakeholders, but the long-term benefits are substantial in shaping adaptive, collaborative, and innovative learners.

Discussion

The discussion of this study's findings reveals how Project-Based Learning (PjBL) effectively facilitates the integrated development of 21st-century skills. First, in terms of critical thinking, students are trained to identify real-world problems relevant to their own lives. This process not only stimulates higher-order thinking skills but also fosters reflective and analytical mindsets, which are crucial in the information age (Tonkes dkk., 2005; Tsaramiris dkk., 2022). Second, creativity emerges as a result of the space provided for students to express their ideas and solutions through project work. The freedom to design project products and the novelty of the ideas produced demonstrate that creativity can flourish in an open and supportive learning environment. PjBL serves as an effective medium for fostering courage in innovation.

Third, collaboration within project groups becomes a tangible form of social learning. Student interaction, cooperation in task completion, and negotiation during decision-making teach essential teamwork values necessary for social and professional life. This collaboration also nurtures leadership and a sense of responsibility. Fourth, students' communication skills improve as they are required to articulate their ideas, deliver presentations, and engage in project discussions. This contributes to the enhancement of both oral and written literacy—foundational for effective communication. Presenting also boosts the confidence of students who were previously passive in the learning process.

The increased learning motivation among students indicates that meaningful learning has taken place. When students are actively involved and their work is valued, they demonstrate greater learning commitment. This supports the theory that intrinsic motivation can be cultivated through responsibility and real-life experiences. From the teacher's perspective, implementing PjBL shifts their role from information deliverer to facilitator. Teachers are required to design relevant projects, guide group work, and comprehensively evaluate both processes and products (Tsarava dkk., 2022). While this transformation demands a high level of professionalism, it opens opportunities for more dynamic and personalized learning.

Assessment in PjBL offers a more authentic and equitable approach than conventional methods. The emphasis on process enables both teachers and students to observe holistic skill development. Student involvement in self- and peer-assessment also strengthens metacognitive skills and learning responsibility. The integration of technology in PjBL enriches the learning process and provides access to various digital resources (Vankdothu dkk., 2022; W. Yang dkk., 2022). This promotes digital literacy, which is a fundamental 21st-century skill. Students are also trained to use digital tools productively and ethically.

The social contributions of student projects show that PjBL is not solely focused on academic outcomes but also supports character development and meaningful contributions to the surrounding community (T. Yang dkk., 2019; C. Zhang dkk., 2023). This aligns with the mission of education not only to produce intelligent individuals but also to empower them to be useful members of society. However, the implementation of PjBL is not without challenges. Time constraints, resource limitations, and student ability differences are obstacles that must be managed wisely. Teachers require training and support to manage dynamic classrooms with varied activities effectively.

Institutional support from school principals and parents is key to the success of PjBL. When all stakeholders share a common vision of the importance of 21st-century skills, the implementation of PjBL becomes smoother and has a broader impact. In the context of primary education, PjBL has proven to be adaptable to the characteristics of young learners, who are typically active, curious, and eager to explore. This approach aligns with their cognitive and social development and provides a more natural and enjoyable learning environment.

This study contributes to the pedagogical literature by demonstrating the effectiveness of PjBL in the context of Indonesian primary education. Previous studies have largely focused on secondary and higher education levels. Thus, this study offers novelty in the implementation of an innovative model for younger learners. Ultimately, the application of PjBL should be viewed as part of the broader transformation toward contextual, collaborative, and meaningful learning. This model aligns with the goals of the Kurikulum Merdeka (Independent Curriculum), which emphasizes student autonomy, reflection, and character development.

CONCLUSION

This study concludes that Project-Based Learning (PjBL) is effective in fostering 21st-century skills among primary school students, including critical thinking, creativity, collaboration, and communication. PjBL also enhances students' motivation to learn, independence, and self-confidence. Teachers play a vital role as facilitators, and successful implementation requires support from both schools and parents. Although challenges exist in its application, the long-term benefits of PjBL make it a highly relevant learning model for widespread use in Indonesian primary education. Therefore, it is essential to strengthen teacher capacity and establish supportive policies for the systematic and sustainable implementation of PjBL.

REFERENCES

- Aktoprak, A., & Hursen, C. (2022). A BIBLIOMETRIC AND CONTENT ANALYSIS OF CRITICAL THINKING IN PRIMARY EDUCATION. *Thinking Skills and Creativity*, 44, 101029. <https://doi.org/10.1016/j.tsc.2022.101029>
- Atlam, E.-S., Ewis, A., El-Raouf, M. M. A., Ghoneim, O., & Gad, I. (2022). A new approach in identifying the psychological impact of COVID-19 on university student's academic performance. *Alexandria Engineering Journal*, 61(7), 5223–5233. <https://doi.org/10.1016/j.aej.2021.10.046>

- Berlinski, S., Galiani, S., & Gertler, P. (2009). The effect of pre-primary education on primary school performance. *Journal of Public Economics*, 93(1–2), 219–234. <https://doi.org/10.1016/j.jpubeco.2008.09.002>
- Chou, A. Y., & Chou, D. C. (2011). Course Management Systems and Blended Learning: An Innovative Learning Approach. *Decision Sciences Journal of Innovative Education*, 9(3), 463–484. <https://doi.org/10.1111/j.1540-4609.2011.00325.x>
- Christophe, N. K., Stein, G. L., Kiang, L., Johnson, N. C., Jones, S. C. T., Stevenson, H. C., Anyiwo, N., & Anderson, R. E. (2022). A 21st Century Take on Racial-Ethnic Socialization: Patterns of Competency and Content among Diverse Parents of Color. *Social Sciences*, 11(2), 88. <https://doi.org/10.3390/socsci11020088>
- Diab, A., Dastmalchi, L. N., Gulati, M., & Michos, E. D. (2023). A Heart-Healthy Diet for Cardiovascular Disease Prevention: Where Are We Now? *Vascular Health and Risk Management*, Volume 19, 237–253. <https://doi.org/10.2147/vhrm.s379874>
- Gary, K. (2015). Project-Based Learning. *Computer*, 48(9), 98–100. <https://doi.org/10.1109/MC.2015.268>
- Gresnigt, R., Taconis, R., Van Keulen, H., Gravemeijer, K., & Baartman, L. (2014). Promoting science and technology in primary education: A review of integrated curricula. *Studies in Science Education*, 50(1), 47–84. <https://doi.org/10.1080/03057267.2013.877694>
- Hailey, T., Connolly, T. M., Boyle, E. A., Wilson, A., & Razak, A. (2016). A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education*, 102, 202–223. <https://doi.org/10.1016/j.compedu.2016.09.001>
- Karakose, T., Demirkol, M., Yirci, R., Polat, H., Ozdemir, T. Y., & Tülübaşı, T. (2023). A Conversation with ChatGPT about Digital Leadership and Technology Integration: Comparative Analysis Based on Human–AI Collaboration. *Administrative Sciences*, 13(7), 157. <https://doi.org/10.3390/admsci13070157>
- Kaufman, K. J. (2013). 21 Ways to 21st Century Skills: Why Students Need Them and Ideas for Practical Implementation. *Kappa Delta Pi Record*, 49(2), 78–83. <https://doi.org/10.1080/00228958.2013.786594>
- Kirschner, P. A. (2005). Learning in innovative learning environments. *Computers in Human Behavior*, 21(4), 547–554. <https://doi.org/10.1016/j.chb.2004.10.022>
- Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19(3), 267–277. <https://doi.org/10.1177/1365480216659733>
- Lu, H., Uddin, S., Hajati, F., Moni, M. A., & Khushi, M. (2022). A patient network-based machine learning model for disease prediction: The case of type 2 diabetes mellitus. *Applied Intelligence*, 52(3), 2411–2422. <https://doi.org/10.1007/s10489-021-02533-w>
- Munawaroh, H., Sudiyanto, S., & Riyadi, R. (2018). Teachers’ Perceptions of Innovative Learning Model toward Critical Thinking Ability. *International Journal of Educational Methodology*, 4(3), 153–160. <https://doi.org/10.12973/ijem.4.3.153>
- Muruganandam, S., Joshi, R., Suresh, P., Balakrishna, N., Kishore, K. H., & Manikanthan, S. V. (2023). A deep learning based feed forward artificial neural network to predict the K-barriers for intrusion detection using a wireless sensor network. *Measurement: Sensors*, 25, 100613. <https://doi.org/10.1016/j.measen.2022.100613>
- Papageorgiou, C. (2003). Distinguishing Between the Effects of Primary and Post-primary Education on Economic Growth. *Review of Development Economics*, 7(4), 622–635. <https://doi.org/10.1111/1467-9361.00213>
- Putri, N. A., Cale, W., & Nitin, M. (2023). The Importance of National Integration to Strengthen Religious Diversity in Community Life. *International Journal of Educational Narratives*, 1(2), 100–107. <https://doi.org/10.55849/ijen.v1i2.263>

- Rostami, A., Shah-Hosseini, R., Asgari, S., Zarei, A., Aghdami-Nia, M., & Homayouni, S. (2022). Active Fire Detection from Landsat-8 Imagery Using Deep Multiple Kernel Learning. *Remote Sensing*, 14(4), 992. <https://doi.org/10.3390/rs14040992>
- Sharmin, S., Ahammad, T., Talukder, Md. A., & Ghose, P. (2023). A Hybrid Dependable Deep Feature Extraction and Ensemble-Based Machine Learning Approach for Breast Cancer Detection. *IEEE Access*, 11, 87694–87708. <https://doi.org/10.1109/access.2023.3304628>
- Tondeur, J., Van Braak, J., & Valeke, M. (2007). Towards a typology of computer use in primary education. *Journal of Computer Assisted Learning*, 23(3), 197–206. <https://doi.org/10.1111/j.1365-2729.2006.00205.x>
- Tonkes, E. J., Loch, B. I., & Stace, A. W. (2005). An innovative learning model for computation in first year mathematics. *International Journal of Mathematical Education in Science and Technology*, 36(7), 751–759. <https://doi.org/10.1080/00207390500271677>
- Tsaramirsis, G., Kantaros, A., Al-Darraj, I., Piromalis, D., Apostolopoulos, C., Pavlopoulou, A., Alrammal, M., Ismail, Z., Buhari, S. M., Stojmenovic, M., Tamimi, H., Randhawa, P., Patel, A., & Khan, F. Q. (2022). A Modern Approach towards an Industry 4.0 Model: From Driving Technologies to Management. *Journal of Sensors*, 2022, 1–18. <https://doi.org/10.1155/2022/5023011>
- Tsarava, K., Moeller, K., Román-González, M., Golle, J., Leifheit, L., Butz, M. V., & Ninaus, M. (2022). A cognitive definition of computational thinking in primary education. *Computers & Education*, 179, 104425. <https://doi.org/10.1016/j.compedu.2021.104425>
- Vankdothu, R., Hameed, M. A., & Fatima, H. (2022). A Brain Tumor Identification and Classification Using Deep Learning based on CNN-LSTM Method. *Computers and Electrical Engineering*, 101, 107960. <https://doi.org/10.1016/j.compeleceng.2022.107960>
- Yang, T., Yi, X., Wu, J., Yuan, Y., Wu, D., Meng, Z., Hong, Y., Wang, H., Lin, Z., & Johansson, K. H. (2019). A survey of distributed optimization. *Annual Reviews in Control*, 47, 278–305. <https://doi.org/10.1016/j.arcontrol.2019.05.006>
- Yang, W., Shi, J., Li, S., Song, Z., Zhang, Z., & Chen, Z. (2022). A combined deep learning load forecasting model of single household resident user considering multi-time scale electricity consumption behavior. *Applied Energy*, 307, 118197. <https://doi.org/10.1016/j.apenergy.2021.118197>
- Zhang, C., Schiebl, J., Plöbl, L., Hofmann, F., & Gläser-Zikuda, M. (2023). Acceptance of artificial intelligence among pre-service teachers: A multigroup analysis. *International Journal of Educational Technology in Higher Education*, 20(1). <https://doi.org/10.1186/s41239-023-00420-7>
- Zhang, L., Carter, R. A., Qian, X., Yang, S., Rujimora, J., & Wen, S. (2022). Academia's responses to crisis: A bibliometric analysis of literature on online learning in higher education during COVID-19. *British Journal of Educational Technology*, 53(3), 620–646. <https://doi.org/10.1111/bjet.13191>
- Zhao, Z., Alzubaidi, L., Zhang, J., Duan, Y., & Gu, Y. (2024). A comparison review of transfer learning and self-supervised learning: Definitions, applications, advantages and limitations. *Expert Systems with Applications*, 242, 122807. <https://doi.org/10.1016/j.eswa.2023.122807>

Copyright Holder :

© Icha Andriani t.al (2026).

First Publication Right :

© JOBE: Journal of Basic Education

This article is under:

