Enhancing Student Engagement through Project-Based Learning and Technology Integration

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DOI: 10.21580/wa.v12i2.26198

Abstract

Although initial research suggests that Project-Based Learning (PJBL) and technology integration enhance student engagement and critical thinking, there is a lack of comprehensive long-term evidence on their effective adaptation in resource-constrained elementary schools. This study directly examines how PJBL combined with technology can foster deeper learning and knowledge retention in such settings. Using qualitative methods, including semi-structured interviews and classroom observations at An-Nawawiyyah Islamic School, this research provides clear evidence that PJBL, when linked to real-life problems and supported by technology, significantly boosts student engagement and understanding. However, persistent challenges—limited resources, insufficient staff training, and difficulty maintaining innovative teaching—hinder broader impact. This study contributes by clarifying how PJBL with technology can drive more meaningful learning in challenging contexts and provides an empirical basis for shaping relevant teacher development and curriculum policies. Further

research should explore the long-term and comparative effectiveness of these strategies in diverse Indonesian schools.

Keywords: Meaningful Learning, Project-Based Learning, Student Engagement, Technology Integration.

Abstrak

Meskipun penelitian awal menunjukkan bahwa Pembelajaran Berbasis Proyek (PJBL) dan integrasi teknologi meningkatkan keterlibatan dan pemikiran kritis siswa, belum ada bukti jangka panjang yang komprehensif tentang adaptasi efektifnya di sekolah dasar dengan keterbatasan sumber daya. Studi ini secara langsung mengkaji bagaimana PJBL yang dikombinasikan dengan teknologi dapat mendorong pembelajaran yang lebih mendalam dan retensi pengetahuan dalam lingkungan tersebut. Dengan menggunakan metode kualitatif, termasuk wawancara semi-terstruktur dan observasi kelas di Sekolah Islam An-Nawawiyyah, penelitian ini memberikan bukti yang jelas bahwa PJBL, ketika dikaitkan dengan masalah kehidupan nyata dan didukung oleh teknologi, secara signifikan meningkatkan keterlibatan dan pemahaman siswa. Namun, tantangan yang terus-menerus—sumber daya yang terbatas, pelatihan staf yang tidak memadai, dan kesulitan mempertahankan pengajaran yang inovatif—menghambat dampak yang lebih luas. Studi ini berkontribusi dengan mengklarifikasi bagaimana PJBL dengan teknologi dapat mendorong pembelajaran yang lebih bermakna dalam konteks yang menantang dan memberikan dasar empiris untuk membentuk pengembangan kompetensi guru dan kebijakan kurikulum yang relevan. Penelitian lebih lanjut diharapkan dapat mengeksplorasi efektivitas jangka panjang dan komparatif dari strategi ini di berbagai sekolah di Indonesia.

Kata Kunci: Integrasi Teknologi, Keterlibatan Siswa, Pembelajaran Bermakna, Pembelajaran Berbasis Proyek.

A. Introduction

Meaningful learning, a theory derived from the work of David Ausubel, is essential to modern education systems, especially in primary schools. Ausubel's theory emphasizes the importance of relating new information to students' existing knowledge, leading to a better understanding and retention of ideas. By encouraging active participation and problem-solving abilities that extend beyond the classroom, meaningful learning distinguishes itself from rote memorization. This approach has, however, shifted tremendously over the years in education research, adopting various active learning approaches such as project-based learning (PJBL), experiential learning, and technology integration, which have independently

been shown to enhance students' engagement and academic performance.[1] These strategies are now central to elementary education since they are effective in boosting motivation among students as well as building foundational skills for the 21st century.[2]

Project-based learning (PJBL), nonetheless, encourages learners to take responsibility for their learning by using classroom knowledge to address real-world problems. By incorporating real-world applications into learning, PJBL fosters greater comprehension and critical thinking, as learners not only study the theoretical foundations of a subject but also learn how to apply their knowledge practically.[3] Similarly, experiential learning allows learners to learn by practicing activities, reflecting, and resolving problems, thereby making the learning process enjoyable and effective.[4] Furthermore, the integration of technology, such as augmented reality and gamification, has been proven to be particularly beneficial in creating engaging and interactive learning environments. These materials offer students the chance to engage with sophisticated ideas in a motivating visual presentation, enhancing both comprehension and memory.[5] All of these approaches not only assist in maximizing academic performance but also promote critical thinking and collaboration skills, laying the groundwork for future success.

Despite the obvious merits of effective learning strategies, their use in primary school grades is hindered by several important constraints, especially when resources are limited. These schools lack ready access to appropriate tools and technology for implementing the new teaching methods. Moreover, instructors frequently fail to receive the professional training they need to employ these strategies productively in class. The integration of deep learning strategies involves not only a shift in pedagogies but also alignment with typical curricula, which are typically designed to prioritize rote memorization over more inquiry-based and collaborative types of learning.[6] The pressure of timelines and institutional resistance to unorthodox pedagogies also prevent the effective implementation of PJBL and technology integration.[7] Breaking down these barriers is crucial to developing an educational

[1] S D Anjos Freitas and A S de Andrade Neto, "Use of Different External Mediating Mechanisms of the Bohr Atom Model: Evidence of Meaningful Learning through Verbal-Gestural Analysis in Elementary School Students," *Acta Scientiae* 21, no. 4 (2019): 133–48, doi:10.17648/acta.scientiae.v21iss4id5253.

[2] B Sisman, S Kucuk, and N Ozcan, "Collaborative Behavioural Patterns of Elementary School Students Working on a Robotics Project," *Journal of Computer Assisted Learning* 38, no. 4 (2022): 1018–32, doi:10.1111/jcal.12659.

[3] M Gresalfi et al., "Virtual Worlds, Conceptual Understanding, and Me: Designing for Consequential Engagement," *On the Horizon* 17, no. 1 (2009): 21–34, doi:10.1108/10748120910936126.

[4] H Friman et al., "Higher Education Learning How to Protect the Environment," *Energies* 13, no. 20 (2020), doi:10.3390/en13205450.

[5] B Rayan and A Watted, "Enhancing Education in Elementary Schools through Gamified Learning: Exploring the Impact of Kahoot! On the Learning Process," *Education Sciences* 14, no. 3 (2024), doi:10.3390/educsci14030277; W Tarng et al., "A Sun Path Observation System Based on Augment Reality and Mobile Learning," *Mobile Information Systems* 2018 (2018), doi:10.1155/2018/5950732.

[6] L A Ávila-Meléndez, "Meaningful ICT Integration into Deprived Rural Communities' Multigrade Classrooms," *Research and Practice in Technology Enhanced Learning* 19 (2024), doi:10.58459/rptel.2024.19005.

[7] Tarng et al., "A Sun Path Observation System Based on Augment Reality and Mobile Learning."

climate that promotes meaningful learning and the acquisition of critical skills in elementary students.

To address these problems, several solutions have been proposed in the literature. Technology integration and project-based learning have been cited as key strategies in building critical thinking capacity and promoting a more participatory, interactive learning environment. PJBL engages students in real-world problem-solving, an activity that not only enhances their analytical and synthesizing skills but also fosters creativity and collaboration. In addition to PJBL, technology instruments such as augmented reality and interactive digital spaces have also proven useful in facilitating active learning experiences that support higher-order thinking and student engagement.[8] The instruments enable students to experience immersive spaces where they can actively navigate intricate concepts, which contributes to enhanced comprehension and motivation to learn.

However, despite these encouraging approaches, there remain gaps in the literature for the real-world application of effective, meaningful learning strategies, particularly in low-resource settings. While evidence of the benefits of technological integration exists, studies fail to fully capture the significant issues confronting teachers, such as insufficient access to resources, weak training, and the challenge of reconciling PJBL with the dictates of standard curricula.[9] Moreover, while PJBL has been proven to stimulate critical thinking, no large-scale study of its long-term impact, especially in inclusive educational environments, exists. Further research is needed to better understand how these methods can be effectively implemented in elementary education, especially in areas with limited resources, and how the challenges to their success can be overcome.[10]

The purpose of this study is to explain the efficacy of meaningful learning approaches—specifically project-based learning and technology integration—on enhancing students' engagement, comprehension, and critical thinking in elementary education. This study aims to fill gaps in existing literature by exploring how these approaches can be adapted and implemented in resource-poor environments, where challenges such as a shortage of proper teacher training and access to technology are prevalent. The study hypothesizes that in using the mixture of PJBL and technology, one can attain higher student participation and critical thinking skills even where classrooms lack necessary resources. The study targets the extent of primary education, particularly in schools where access to technologically equipped rooms is limited, so as to see how all these practices could be efficiently rolled out regardless of the prevailing impediments. By means of this study, we seek to offer useful insights and

[8] A W A Vilchez, T.S.M.L. Soto, and G S Atuncar, "Mobile Application with Augmented Reality Applying the MESOVA Methodology to Improve the Learning of Primary School Students in an Educational Center," *International Journal of Advanced Computer Science and Applications* 15, no. 5 (2024): 593–600, doi:10.14569/IJACSA.2024.0150559.

[9] M S Fitzgerald and K B Evans, "Integrating Digital Tools to Enhance Access to Learning Opportunities in Project-Based Science Instruction," *TechTrends* 68, no. 5 (2024): 882–91, doi:10.1007/s11528-024-00975-w.

[10] S E Grapin et al., "Multilingual Learners' Epistemologies in Practice in the Context of Computational Modeling in an Elementary Science Classroom," *Journal of Research in Science Teaching* 60, no. 9 (2023): 1998–2041, doi:10.1002/tea.21850.

recommendations to overcome the obstacles to significant learning in primary classrooms, thereby contributing to the establishment of a more efficient and equitable education system.

B. Research Methods

The study employs a qualitative method of researching teachers' and students' experience with meaningful learning strategies in An-Nawawiyyah Islamic School. Qualitative research is important in the study of the subtleties of how effective learning strategies are implemented in real classroom settings. It offers a close scrutiny of teachers' and students' perspectives, which are shaped by the specific contexts and concerns they face in their learning environments. This was the design used to uncover insights that could not be revealed through quantitative approaches, providing detailed, in-depth data that are crucial in formulating pedagogical practices.

This study used two primary data collection methods: semi-structured interviews and classroom observations. Semi-structured interviews facilitated flexibility in the data, allowing respondents to provide responses in their own words without compromising the ability to address critical research questions. Open-ended methods encouraged deeper insights into how teachers and students experience and understand effective learning approaches. Teacher interviews focused on their thoughts about challenges and successes in using active learning techniques, while student interviews examined their engagement and understanding through these methods. Classroom observations complement the interviews by providing contextual data on how the learning strategies are implemented in practice. Observing classroom life enables the researcher to see real student-teacher interactions and the impact these interactions have on learning outcomes in real time. The observations enable the interview findings to be linked to real classroom practice and demonstrate how theoretical concepts are realized in day-to-day learning activities. This combined use of observation and interviews enhances the validity and richness of the data so that the educational process can be comprehended more deeply.[11]

The information obtained from the interviews and the observations in class are coded with thematic analysis. Thematic analysis refers to a qualitative method of research that involves identifying, analyzing, and reporting patterns (themes) in data. This method is particularly useful in education research in providing rich insights into the participants' experiences and perceptions of instructional strategies and academic achievements. Thematic analysis involves several crucial steps: getting familiar with the data, coding, creating themes, and refining themes to ensure that they reflect the story of the data accurately.[12]

In this study, thematic analysis is employed to identify the emerging themes of the implementation of meaningful learning strategies. For example, researchers will look for

[11] T Boz et al., "Empowering Elementary Students with Community-Based Engineering: A Teacher's Experience in a Rural School District," *Education Sciences* 13, no. 5 (2023), doi:10.3390/educsci13050434; Y.-C. Liao et al., "Voices of Elementary Computer Science Teachers: Computer Science Integration Rationales and Practices," *ACM Transactions on Computing Education* 24, no. 4 (2024), doi:10.1145/3688854.

[12] Boz et al., "Empowering Elementary Students with Community-Based Engineering: A Teacher's Experience in a Rural School District."

patterns in how teachers describe challenges in adopting PJBL and technology, and how students describe their learning and engagement experiences. This analysis will also take into account the perceived impact of these strategies on learning outcomes at the level of critical thinking development, problem-solving skills, and motivation. Through the determination of these themes, the study will attain comprehensive insight towards the dynamics of significant learning in elementary classrooms, with insights into how effectively the incorporation of these strategies can be made a part of practice.[13]

C. Results and Discussion

Impact on Student Learning

Project-based learning (PJBL) makes a significant contribution to enhancing students' engagement, understanding, and problem-solving skills in elementary schools. Through engaging students in practical, real-world learning, PJBL stimulates student interest and promotes deeper understanding of academic content. Research indicates that PJBL facilitates active learning and intrinsic motivation because students work together on relevant problems. Not only does this enhance their critical thinking, but also their ability for creative knowledge application.[14] The results of the interview with the science teacher are as follows:

> *The implementation of project-based learning (PjBL) provides students with the opportunity to investigate compelling materials and topics, which in turn enhances their motivation to learn and fosters active engagement in the educational process. For instance, in an eighth-grade science class, students were tasked with conducting a practical experiment focused on transverse and longitudinal waves to elucidate the characteristics of these wave types. This collaborative project not only stimulated their enthusiasm for the learning process but also facilitated a deeper understanding of the fundamental properties of transverse and longitudinal waves.*[15]

The teacher of mathematics communicated the same text, as shown by the following interview results:

> *Following the implementation of project-based learning, I observed a notable increase in student engagement, creativity, and enthusiasm. Students demonstrated heightened motivation as they assumed active roles in the learning process. For instance, during a project focused on producing natural pesticides from onion skins,*

[13] L Y Tay, S.-S. Lee, and K Ramachandran, "Implementation of Online Home-Based Learning and Students' Engagement During the COVID-19 Pandemic: A Case Study of Singapore Mathematics Teachers," *Asia-Pacific Education Researcher* 30, no. 3 (2021): 299–310, doi:10.1007/s40299-021-00572-y; I D Hastuti, "Interaction Pattern of Inquiry Learning on Data Collection and Presentation Material at SDN 13 Ampenan," *Universal Journal of Educational Research* 8, no. 3 (2020): 942–47, doi:10.13189/ujer.2020.080328.

[14] A Reznitskaya and I A G Wilkinson, "Truth Matters: Teaching Young Students to Search for the Most Reasonable Answer," *Phi Delta Kappan* 99, no. 4 (2017): 33–38, doi:10.1177/0031721717745550; B Rayan et al., "Integrating PhET Simulations into Elementary Science Education: A Qualitative Analysis," *Education Sciences* 13, no. 9 (2023), doi:10.3390/educsci13090884.

[15] Interview with Siska Irenia Nur Leoni, An-Nawawiyyah Islamic School Rembang, 26 September 2024

> *students exhibited considerable enthusiasm in gathering materials, developing products, and documenting the entire process. This approach contrasts sharply with traditional learning methods, which often result in students passively receiving information through lectures.*[16]

According to the above-mentioned interview results, the observations show that students seemed to enjoy the learning process more during project learning, as seen by their eagerness to participate in every learning phase.[17] This is in line with what one of the students at the An-Nawawiyyah Islamic school felt, as seen in the following interview results:

> *I favor learning through direct engagement, particularly via the Project-Based Learning (PjBL) model. This approach, which emphasizes hands-on practice, group discussions, collaborative project work, and the presentation of results, enhances the educational experience. Consequently, this method fosters greater comprehension and enthusiasm for the subject matter.*[18]

Furthermore, students who engage in PJBL also learn to retain information more effectively compared to students who have been subjected to traditional approaches to teaching because they are directly engaged in constructing their own knowledge rather than passively receiving it.[19] According to results derived from interviews carried out with teachers in the subjects of science and mathematics, the following insights emerged:

> *Project-based learning significantly enhances students' comprehension of the material. This pedagogical approach enables learners to move beyond mere memorization of theoretical concepts, allowing them to apply these concepts directly to real-world situations. Consequently, the depth of their understanding is likely to be more enduring compared to traditional instructional methods that rely solely on passive listening to classroom explanations.*[20]
>
> *Project-based learning (PjBL) facilitates a more comprehensive and meaningful educational experience, enabling students to connect academic content with real-world contexts, thereby enhancing their understanding. This approach presents a marked distinction from traditional learning methodologies.*[21]

Integration of technology is imperative in facilitating PJBL by enabling students to view and interact with complex academic concepts. Computer programs, such as simulations and interactive software, provide means for students to explore and manipulate information,

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[16] Interview with Siti Noor Komairah, An-Nawawiyyah Islamic School Rembang, 26 September 2024.

[17] Observation, An-Nawawiyyah Islamic School Rembang, 24 - 26 September 2024.

[18] Interview with Vania Nikmah, An-Nawawiyyah Islamic School Rembang, 26 September 2024.

[19] T C Liu, "A Case Study of the Adaptive Learning Platform in a Taiwanese Elementary School: Precision Education from Teachers' Perspectives," *Education and Information Technologies* 27, no. 5 (2022): 6295–6316, doi:10.1007/s10639-021-10851-2.

[20] Interview with Siti Noor Komairah, An-Nawawiyyah Islamic School Rembang, 26 September 2024

[21] Interview with Siska Irenia Nur Leoni, An-Nawawiyyah Islamic School Rembang, 26 September 2024

making abstract concepts concrete and tangible.[22] These technology instruments also foster cooperative learning, and they inspire learners to exchange data and work in groups, thereby improving their problem-solving capabilities and confirming interaction with material.[23] Together, PJBL and technology create an immersive, interactive educational environment that engages higher-order thinking and reinforces elementary school students' overall learning process. According to the following interview findings:

> *Technology plays a critical role in facilitating project-based learning (PjBL) by offering a diverse array of interactive learning resources and fostering the development of 21st-century skills.*[24]
>
> *In my view, technology plays a crucial role in facilitating project-based learning. It aids students in various aspects, including data retrieval, collaborative efforts with peers, and the effective presentation of their work.*[25]

Figure 1. Implementation of project-based learning

[22] A.-F. Lai, C.-H. Chen, and G.-Y. Lee, "An Augmented Reality-Based Learning Approach to Enhancing Students' Science Reading Performances from the Perspective of the Cognitive Load Theory," *British Journal of Educational Technology* 50, no. 1 (2019): 232–47, doi:10.1111/bjet.12716.

[23] N Hasanah, Y Hayashi, and T Hirashima, "An Analysis of Learner Outputs in Problem Posing as Sentence-Integration in Arithmetic Word Problems," *Research and Practice in Technology Enhanced Learning* 12, no. 1 (2017), doi:10.1186/s41039-017-0049-5; P Kosmas et al., "Integrating Artificial Intelligence in Literacy Lessons for Elementary Classrooms: A Co-Design Approach," *Educational Technology Research and Development*, 2025, doi:10.1007/s11423-025-10492-z.

[24] Interview with Siska Irenia Nur Leoni, An-Nawawiyyah Islamic School Rembang, 26 September 2024

[25] Interview with Siti Noor Komairah, An-Nawawiyyah Islamic School Rembang, 26 September 2024

Teacher Challenges and Feedback

Some of the same impediments face teachers when attempting to implement project-based learning (PJBL) and technology integration in elementary school. One of the most principal issues is the limited availability of necessary resources, such as appropriate materials and technology, which barriers effective implementation of PJBL activities. According to the following interview findings:

> *Limited resources, including materials and technology, significantly impact the quality of learning, particularly in the sciences. Effective science education relies heavily on direct experimentation and the visualization of abstract scientific concepts. Currently, many schools are still in the process of constructing science laboratories, and access to laboratory equipment remains limited. Consequently, educators have turned to the PhET application as a means to facilitate experimental learning.*[26]

The majority of teachers mention the difficulty of obtaining the necessary materials to create engaging and interactive projects as the primary challenge, which indirectly affects the quality of learning.[27] According to the following interview findings:

> *The deficiency of resources, including materials and technological devices, significantly impacts the quality of the learning process. For instance, when students are unable to access online learning materials or applications that facilitate project work, the effectiveness of collaboration within groups is undermined.*[28]

In addition, the lack of professional development is a significant issue. Teachers do not typically have appropriate training to adequately integrate technology into the classroom or use instructional methods that facilitate active learning.[29] This absence of professional growth prevents them from adopting innovative pedagogies wholly.

Institutional resistance also prevents it, as most education systems prefer standardized testing and traditional instruction to more interactive methods like PJBL. Teachers also feel constrained by the need to meet performance levels, which discourages them from innovating with new pedagogies.[30] In addition, limited access to technology resources is more prevalent in schools in lower socioeconomic areas, exacerbating educational inequalities and hindering the potential for meaningful learning opportunities.[31] These concerns highlight the need to

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[26] Interview with Siska Irenia Nur Leoni, An-Nawawiyyah Islamic School Rembang, 26 September 2024

[27] A Urbina and D Polly, "Examining Elementary School Teachers' Integration of Technology and Enactment of TPACK in Mathematics," *International Journal of Information and Learning Technology* 34, no. 5 (2017): 439–51, doi:10.1108/IJILT-06-2017-0054.

[28] Interview with Siti Noor Komairah, An-Nawawiyyah Islamic School Rembang, 26 September 2024

[29] E Anderson and A Hira, "Loss of Brick-and-Mortar Schooling: How Elementary Educators Respond," *Information and Learning Science* 121, no. 5–6 (2020): 401–8, doi:10.1108/ILS-04-2020-0085.

[30] C J Trexler, A J Hess, and K N Hayes, "Urban Elementary Students' Conceptions of Learning Goals for Agricultural Science and Technology," *Natural Sciences Education* 42, no. 1 (2013): 49–56, doi:10.4195/nse.2013.0001.

[31] A R Carvalho and C Santos, "The Transformative Role of Peer Learning Projects in 21st Century Schools—Achievements from Five Portuguese Educational Institutions," *Education Sciences* 11, no. 5 (2021), doi:10.3390/educsci11050196.

make systemic changes to enhance teachers' capacity to apply purposeful learning strategies and technology integration.

Technological Integration

Technology integration is equally essential in enhancing student motivation and understanding, especially in science and mathematics. Technology, when well-integrated into the curriculum, motivates students and increases their engagement in learning. For instance, gamification technology like Kahoot! has been seen to establish interactive learning environments, increasing students' engagement and memorization of abstract concepts, hence improving an improved understanding of the subject.[32] Interactive simulations also assist students in visualizing intangible concepts, making difficult subjects such as science more understandable.[33]

Nonetheless, incorporating technology in resource-constrained classrooms poses a major challenge. Teachers usually experience poor infrastructure, including unstable internet connectivity or obsolete devices, limiting the proper application of digital resources.[34] Moreover, minimal professional development activities render teachers ill-prepared to incorporate technology into pedagogically sound practices.[35] According to the following interview findings:

> *The primary challenges include the school's inadequate infrastructure, teachers' insufficient proficiency in integrating technology into their pedagogical practices, a lack of professional development opportunities for educators regarding technological tools, the substantial administrative workload imposed on teachers, and the restricted time available for instructional activities.*[36]
>
> *Educators frequently encounter challenges in the integration of technology into the learning process, particularly in institutions that possess limited tools and resources. The primary issues include inadequate infrastructure and insufficient training in technological applications. Numerous schools continue to grapple with unstable internet connectivity, a lack of sufficient devices, and facilities that are ill-equipped to support digital learning initiatives.*[37]

Schools may counter such obstacles by investing funds in professional development that increases the digital competence of teachers and also seeking innovative substitutes, for

[32] Rayan and Watted, "Enhancing Education in Elementary Schools through Gamified Learning: Exploring the Impact of Kahoot! On the Learning Process."

[33] Rayan et al., "Integrating PhET Simulations into Elementary Science Education: A Qualitative Analysis."

[34] Anderson and Hira, "Loss of Brick-and-Mortar Schooling: How Elementary Educators Respond."

[35] P K Gibson, D A Smith, and S G Smith, "A Scenario That Works: Adapting the Army's Soldier Skills Training Model to Teach K-12 Teachers Technology," in *Handbook of Research on Positive Scholarship for Global K-20 Education*, 2018, 184–91, doi:10.4018/978-1-5225-5667-1.ch013.

[36] Interview with Siska Irenia Nur Leoni, An-Nawawiyyah Islamic School Rembang, 26 September 2024.

[37] Interview with Siti Noor Komairah, An-Nawawiyyah Islamic School Rembang, 26 September 2024.

instance, mobile learning initiatives or joint ventures with external agencies to access additional funds.[38]

Despite such challenges, there is little doubt regarding the potential benefits of technology in enabling project-based learning (PJBL). Platforms like Khan Academy and iReady, where individualized learning paths and instant feedback are enabled, are found to be highly beneficial in enhancing student motivation and understanding.[39] To fully leverage such benefits, schools need to ensure that teachers are provided with proper training and that there is infrastructure to enable integration of technology in the classroom.

Figure 2. Integration technology in learning at An-Nawawiyyah Islamic School

The findings of this study provide a strong picture of the impact and challenge of implementing effective meaningful learning strategies, particularly project-based learning (PJBL) and technology integration, in elementary education. The findings are consistent with contemporary theories of meaningful learning, particularly those rooted in constructivist learning theories. The research focuses on how effective learning, when created through PJBL and supported by technology, not only enhances the level of comprehension among learners but also raises their participation and memory retention. The results are straight in alignment with Vygotsky's and Piaget's theories, who both underscored the function of social interaction and active involvement in the process of learning.[40] The study highlights the pivotal role of cooperative learning environments where students construct their own knowledge through experiential learning. This is in line with Vygotsky's social

[38] P K Gibson, D A Smith, and S G Smith, "A Scenario That Works: Adapting the Army's Soldier Skills Training Model to Teach K-12 Teachers Technology," in *Handbook of Research on Positive Scholarship for Global K-20 Education*, 2018, 184–91, doi:10.4018/978-1-5225-5667-1.ch013..

[39] Urbina and Polly, "Examining Elementary School Teachers' Integration of Technology and Enactment of TPACK in Mathematics."

[40] S Wibowo, M N Wangid, and F M Firdaus, "The Relevance of Vygotsky's Constructivism Learning Theory with the Differentiated Learning Primary Schools," *Journal of Education and Learning* 19, no. 1 (2025): 431–40, doi:10.11591/edulearn.v19i1.21197.

constructivism, where learning is understood as a social process where students engage with others to co-construct knowledge.[41]

From the curricular design viewpoint, this study highlights the necessity for education systems to incorporate authentic learning methods in elementary school curriculum. The pairing of PJBL and technology serves as a design for the advancement of student interest and cooperation, both essential elements for building intensive learning. Curricular developers should prioritize active learning methods that enable students to transfer theoretical concepts into real-life scenarios. Such integration does not only aim to facilitate learning support for students' academic outcomes; it is also relevant in developing critical thinking, problem-solving, and interpersonal skills required in the 21st-century student.[42] Through this study, curriculum reforming is also addressed to be dovetailed with programs for teacher professional development so teachers can adequately train to implement such strategies in practice in their teaching rooms. Closing the loop between theoretical knowledge and actual implementation has the potential to make the transition easier for teachers, which helps them to apply PJBL and technology effectively in a manner that facilitates positive learning experiences.[43]

Despite such optimistic implications for curriculum development, however, the research also highlights certain impediments to the efficient deployment of strategies of meaningful learning, especially within limited-resource contexts. Among these central impediments is inadequate access to resources and facilities within the majority of schools, which restricts the effective integration of technology within instruction. This issue is particularly prevalent in schools that serve lower-income populations, where access is very low to stable internet, newer digital hardware and software, and learning software.[44] In these settings, teachers often lack the hardware necessary to fully interact with students through interactive technologies, hindering their ability to create dynamic and interactive learning spaces.

Moreover, the study reveals that many teachers are facing issues related to insufficient professional development. Without appropriate training, teachers cannot implement technology in their teaching practices in an effective way. Professional development programs that focus on hands-on training, ongoing assistance, and effective use of digital tools are necessary to resolve such issues.[45] Teachers need to be equipped not only with technical proficiency but also with plans for utilizing technology in ways that facilitate active learning and collaboration. High-quality professional development programs need to be invested in

[41] Ibid.

[42] Fitzgerald and Evans, "Integrating Digital Tools to Enhance Access to Learning Opportunities in Project-Based Science Instruction."

[43] Ibid.

[44] Urbina and Polly, "Examining Elementary School Teachers' Integration of Technology and Enactment of TPACK in Mathematics."

[45] Liu, "A Case Study of the Adaptive Learning Platform in a Taiwanese Elementary School: Precision Education from Teachers' Perspectives."

to improve teachers' digital skills and increase their ability to use technology in order to engage students.[46]

For addressing these constraints, educational policymakers must prioritize giving utmost importance to the provision of necessary resources and infrastructures for the schools such that each student could have access to the machinery necessary for productive learning. Along with the physical arrangement, policymakers must also invest in institutionalizing a culture of cooperation among the teachers. Having chances for teachers to share best practices, share materials, and cooperate on lesson planning can have a significant impact in the application of effective learning tactics.[47] This cooperative method can alleviate personal obstacles for teachers, enhance teaching creativity, and develop a more empathetic professional culture.

The implications of future research are also significant. How elementary school education can be transformed by the revolutionary force of technology and active learning methodologies must be further explored. The long-term effects of the inclusion of technology on students' motivation, performance, and enhancement of critical thinking skills can be studied in future research. Future research can examine these effects in various learning settings with consideration of different demographic variables and available resources. In addition, one can suggest subsequent research that determines the most effective types of technology tools utilized to involve students in meaningful learning, particularly in settings of constrained resources.[48] It is also feasible for researchers to examine how various technology tools can be tailored to meet the specific needs of teachers and students in such settings to bridge the digital divide that is common in the majority of schools.

Another area that can be researched in the future could be examining the combination of active learning methods like PJBL with technology. Design of learning on how these elements can be weighed to achieve more cohesive and effective learning environments could provide significant recommendations for teachers and policymakers. By examining the synergy of active learning and technology, researchers can gain insight into best practices on bringing these methods into the classroom to maximize student engagement and learning outcomes.[49]

In conclusion, this study offers valuable lessons on the potential of effective learning strategies, namely PJBL and technology integration, in fostering student motivation, comprehension, and critical thinking. Effective implementation of these strategies, however, requires overcoming formidable challenges like inadequate resources, limited professional development, and organizational resistance. Addressing these challenges through strategic

[46] Carvalho and Santos, "The Transformative Role of Peer Learning Projects in 21st Century Schools—Achievements from Five Portuguese Educational Institutions."

[47] Ibid.

[48] Reznitskaya and Wilkinson, "Truth Matters: Teaching Young Students to Search for the Most Reasonable Answer."

[49] Fitzgerald and Evans, "Integrating Digital Tools to Enhance Access to Learning Opportunities in Project-Based Science Instruction"; A Hidayati, A Bentri, and N Arina, "Improving Science Learning Competence through Advance Organizer Model Innovation Based on Authentic and Real Worlds Activities for Elementary School Student," in *Journal of Physics: Conference Series*, vol. 2582, 2023, doi:10.1088/1742-6596/2582/1/012049.

investment in infrastructure, teacher training, and collaborative culture is key to establishing an environment in which learning of substance can gain traction. Additional research is necessary to more fully understand the long-term implications of these strategies and how they can be implemented effectively in a range of educational contexts so that all students can enjoy these transformative education practices.

D. Conclusion

This study examined the effectiveness of PJBL and technology integration in enhancing students' interest, comprehension, and critical thinking at the primary level. The findings highlight the significance of these approaches in promoting academic success through active, experiential learning. PJBL enables students to solve real-world problems, boosting motivation and mastery of concepts. Additionally, technology tools like interactive simulations and gamification increase engagement by making abstract concepts more accessible. However, challenges such as limited technology access, insufficient teacher training, and resistance to non-traditional methods hinder the full potential of these strategies. To maximize effectiveness, these barriers must be addressed. The study underscores the importance of incorporating PJBL and technology into the elementary curriculum and stresses the need for targeted professional development programs to equip teachers with the necessary skills. Furthermore, policymakers must ensure adequate resources and infrastructure, especially in schools with limited technology access. This research contributes valuable empirical evidence on the impact of active learning strategies in primary education and emphasizes their role in fostering 21st-century skills. Future research should explore the long-term effects of these strategies, particularly in low-resource environments, and identify the most beneficial technologies for enriching learning experiences.

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Interviews

Interview with Siti Noor Komairah, An-Nawawiyyah Islamic School Rembang, 26 September 2024.

Interview with Siska Irenia Nur Leoni, An-Nawawiyyah Islamic School Rembang, 26 September 2024.

Interview with Vania Umimatun Nikmah, An-Nawawiyyah Islamic School Rembang, 26 September 2024.