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ARE WE USING EDUCATION TECHNOLOGY IN OUR TEACHING?

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Abstract

Digital transformation is increasingly evident in Indonesia's education sector, particularly in the teaching and learning processes at the school level. This study examines several Indonesian schools navigating digital transformation despite facing infrastructure challenges. This study aims to assess the impact of teaching STEM using educational technology through project-based learning without adequate infrastructure support and to document both challenges and success factors.

The experiment took place in Naringgul, Cianjur, involving four state junior high schools: SMPN 3, SMPN 6, SMPN 8, and SMPN 9. These schools were randomly selected based on their technological limitations and low socioeconomic status. Each school received educational technology devices and teacher training on integrating this technology into their STEM curriculum using a project-based learning strategy. The study comprised: 1) a situational analysis of the four schools, involving 44 STEM teachers and 633 students; 2) a professional development workshop to introduce STEM PBL lesson plans and digital media development; 3) a second workshop focusing on lesson study, ICT-based learning, and microteaching; and 4) pilot teaching sessions following the workshops for observation.

The findings revealed that, despite infrastructure deficiencies, technology use in STEM teaching can be implemented creatively, enriching the learning environment and fostering student engagement and interaction. Once teachers mastered digital competencies, project-based learning methods, and STEM content, they confidently utilized technology in their teaching. Teachers reported that integrating technology into project-based STEM teaching enhanced students' teamwork, problem-solving, creativity, and digital skills, maintaining engagement throughout the learning process. However, some teachers faced challenges in aligning technology use with learning objectives, creating engaging activities for diverse learning styles, and ensuring technology enhanced rather than detracted from the learning experience.

To sustain these positive practices, ongoing professional development for teachers is recommended to keep them updated on teaching strategies and new technologies. Additionally, support from the government and stakeholders is crucial to provide the necessary infrastructure, learning resources, and incentives for exemplary teaching practices

Keywords: Naringgul, Indonesia, STEM, education technology, project-based learning.

1 INTRODUCTION

Indonesian education has undergone significant transformation in recent years, accelerated by the pandemic. This digital transformation is evident in various policies and regulations under the "Merdeka Belajar" initiatives. A key component of this broader educational transformation is the Merdeka Curriculum, introduced in 2022 and gradually being implemented nationwide. This curriculum promotes student-centered learning, allowing students to progress at their own pace and according to their interests. A notable feature of this curriculum is the implementation of project-based learning (PjBL), aimed at building students' character in alignment with Pancasila values (Merdeka Belajar, https://id.wikipedia.org/wiki/Merdeka_Belajar)

Teachers play a crucial role in this transformation. To support them in effectively implementing the Merdeka Curriculum, including PjBL, the Merdeka Mengajar platform has been introduced (Platform Merdeka Mengajar, n.d.). This platform provides teachers access to a wealth of resources for their professional development. According to the "standard process" regulation, teachers are expected to reform their teaching methods to focus on students' needs and enhance their engagement in learning (Permendikbudristek No. 16, 2022). Additionally, teachers must provide ample opportunities for innovation and creativity based on students' talents.

A key factor in this educational transformation is the advancement of students' digital literacy. According to the Ministry of Communication and Informatics and Katadata Insight Center, Indonesia's National Digital Literacy score increased from 3.49 in 2021 to 3.54 in 2022 (Antara, February 2023). Research by East Ventures highlighted improvements in human resources readiness scores, reflecting the growing number of mobile phone owners and better internet access. However, this research also pointed out the uneven distribution of infrastructure, leading to disparities in digital literacy across the nation (East Ventures, 2023) .

In terms of student performance, Indonesia's results in the 2022 Programme for International Student Assessment (PISA) showed some improvement compared to the 2018 assessment (OECD, 2022). This improvement reflects the government's efforts to mitigate learning disruptions during the pandemic. Despite this progress, Indonesian students' mathematics, science, and reading scores remain below the OECD average, indicating significant room for improvement.

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pandemic. Despite this progress, Indonesian students' scores in mathematics, science, and reading remain below the OECD average (PISA, n.d.), indicating that there is still significant room for improvement.

The implementation of Merdeka Belajar presents an opportunity to enhance the quality of learning, particularly in STEM subjects. Teaching Science, Technology, Engineering, and Mathematics (STEM) as integrated subjects fosters students' 21st-century skills (Megawati, 2022). Various constructive approaches, such as Inquiry-based learning, Problem-based learning, and Project-based learning, have been used to teach STEM subjects. Among these, Project-based Learning (PjBL) is considered the most effective as it focuses on practical, collaborative projects (Baran, et.al., 2021). Students work in groups to solve real-world problems, gather information, conduct experiments, analyze options, and synthesize the best solutions (Diana, Yohanes, and Sukma, 2020). Research has confirmed the benefits of STEM-PjBL approaches in improving problem-solving skills (Purwaningsih, 2020) (Parno, 2020), creativity (Saefullah, 2021), and metacognition (Wangguway, et.al., 2019).

Effective STEM-PjBL (Project-Based Learning) approaches are implemented through five stages: reflection, research, discovery, application, and communication (Laboy-Rush, 2010). Initially, students are introduced to real-world problems, connecting these issues to familiar contexts. They gather relevant information and resources, collaborate with peers to identify necessary resources, design projects based on the gathered information, create and test solution models, and finally present their projects to their peers. Technology plays a crucial role in this process, as digital learning positively impacts learning outcomes (Baran et al., 2021).

Given the disparities in technological infrastructure across different regions, it is recommended to utilize more offline digital learning methods and ensure that content can run on low-end computing devices and older software (Johansen, Johansen, & Noll, 2018). While technology can enhance effective teaching, it cannot compensate for poor teaching practices (Innovation Unit, 2018). Therefore, teachers must undergo proper professional development and planning to successfully implement technology-based learning through PjBL in STEM subjects (World Bank, 2018).

Implementing technology-based PjBL in STEM subjects faces several challenges, particularly in remote schools. Limited infrastructure, such as electricity and internet connectivity, hampers the adoption of technology for learning. Teachers need support to access professional development and digital instructional materials, and students require more practice in using

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technology. Addressing these challenges ensures students benefit from the *Merdeka Belajar* policy.

This study examined the impact of teaching STEM using educational technology through PjBL without adequate infrastructure support, documenting the challenges and success factors of technology-based teaching and learning in several remote schools during the initial stage of the *Merdeka Curriculum*. These schools faced multiple challenges related to infrastructure, teachers' competencies, and students' digital literacy. Despite these difficulties, after intensive professional development programs and close support, teachers were able to use educational technology to deliver STEM project-based learning. These efforts have equipped students with essential 21st-century skills, such as problem-solving, creativity, and collaboration, as required by the *Merdeka Belajar* initiative.

2 METHODOLOGY

This study utilized action research to focus on four state junior high schools in Naringgul: SMPN 3, SMPN 6, SMPN 8, and SMPN 9. These schools were randomly selected due to their limited access to connectivity, despite being only 215 kilometers from Jakarta. Each school has an enrollment of fewer than 300 students, the majority of whom come from low-income families. Although electricity is available at these schools, it is prone to outages during heavy rainfall. The school profile is depicted in Table 1.

Table 1. Schools Profile

Schools	**SMPN 3 Naringgul**	**SMPN 9 Naringgul**	**SMPN 8 Naringgul**	**SMPN 6 Naringgul**
Area	7.000 m2	5.830 m2	2.640 m2	2.500 m2
Number of Classrooms	15	16	6	3
Number of Teachers	19	10	11	8
Number of Science and Math Teachers	3	2	2	2
Number of Students	283	147	108	83
Electricity	2.200 W	900 W	900 W	900 W
Accessible Mobile broadband providers	Indosat, Telkomsel, XL	Indosat, Telkomsel, XL	XL (only at the school's entrance)	Not Available

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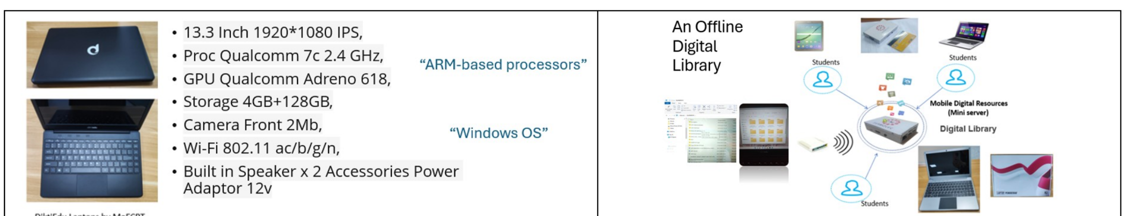
The intervention commenced with three professional development workshops for teachers, focusing on the introduction of the Merdeka Curriculum and the STEM-PjBL concept, the design of STEM-PjBL lesson plans, and the assessment of 21st-century skills. Essential devices, including laptops, LCD projectors, microphones, and other electrical equipment, were provided to the schools and properly installed with the necessary software and applications.

Due to the lack of reliable internet connectivity, a portable digital library was established, allowing students to access digital content within the local network. The Learning Passport (https://www.learningpassport.org/), an initiative by UNICEF powered by Microsoft Community Training, also employs this offline learning model to facilitate digital learning in areas with limited or no connectivity. A hub device, acting as a server, creates a local area network within the classroom. This study utilizes Raspberry Pi (https://www.raspberrypi.com/) as the content server because of its compact size, portability, low power consumption, and ability to charge portable batteries or power banks. The Raspberry Pi supports various operating systems and can serve multiple documents, images, music, and video formats (Jolles, 2021). Network-attached storage (NAS) is integrated into the Raspberry Pi, enabling teachers and students to easily drag and drop digital content. NAS systems offer an effective and low-cost storage solution, allowing users to store and share data locally (Affandi, 2022).

Figure 1. Laptops and specification, and Offline Digital Library



DiktiEdu laptops and its specification

In addition, online support was provided through several synchronous meetings and a WhatsApp group to assist teachers in preparing to deliver the technology-based STEM-PjBL experience. Observation and interview sessions were conducted during the implementation phase.

SMPN 3 Naringgul was designated as the experimental school, while SMPN 9 Naringgul served as the control school. Both schools have access to mobile broadband networks, allowing students with mobile phones and internet subscriptions to easily access digital learning materials. Conversely, SMPN 6 Naringgul was the control school for SMPN 8 Naringgul, the

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experimental school, both located in areas with limited connectivity. The study targeted Grade 8 students, with each class comprising 15 to 20 students.

Teachers and students were observed during the experiment, focusing on their engagement in the technology-based STEM-PjBL process. Students were specifically monitored for their teamwork, problem-solving abilities, creativity, and digital skills, using several indicators (Table 2).

Table 2. Indicators for Observation Components

1. Teamwork	**1.1 Communication**	**1.2 Collaboration**	**1.3 The Opennes**
	1.1.1 Explain in a clear and structured manner	1.2.1 Share their knowledge when doing a project	1.3.1 Active listener
	1.1.2 Write the summary of the knowledge	1.2.2 Divide the work and responsibilities in the project	1.3.2. Willing to give and receive feedback
	1.1.3 Use EdTech for communication	-	-
2. Problem-Solving Skills	**2.1 Problem Analysis**	**2.2 Defining the Goal**	**2.3 Implementing the solution**
	2.1.1 Collect data and required information for problem identification	2.2.1 Able to identify required stages to implement solution	2.3.1 Identify required steps to implement the selected solution
	2.1.2 Able to distinguish between opinions and facts based on the given example	2.2.2 Able to define criteria for measuring and evaluation goals or desired results in a project	2.3.2 Organized and managed required resources to effectively implement solutions in a project
	2.1.3 Able to identify possible alternative solutions	-	2.3.3 Evaluate implementation results
	2.1.4 Able to generate recommendations	-	2.3.4 Make adjustments to ensure the implemented

	based on the possible solutions		solution meet the desired goals
3. Creativity Skills	**3.1 Generating creative Idea**	**3.2 Improvisation**	-
	3.1.1 Ideas proposed by students based on their own reasoning	3.2.1 Adapt with changing situations (flexibly change their strategy or teactics)	-
	3.1.2 The proposed idea contains relevant solutions to solve the problem	3.2.2 The risks in making decisions i.e. acting without waiting for complete information/approval	-
4. Digital Skills	**4.1 Technology Utilization**	**4.2 Digital Literacy**	**4.3 Digital Security**
	4.1.1 Students spend more than one hour using technology	4.2.1 Demonstrate the ability to read and write using digital media	4.3.1 Use strong passwords for their accounts and avoid using passwords that are easy to or simple
	4.1.2 Technology is used by students for learning	4.2.2 Use keywords and special syntax when searching for information	4.3.2 Understand digital security threats and ways to reduce the risks associated with these threats
	4.1.3 Able to identify and utilize the various type of technology based on student's learning need	4.2.3 Able to distinguish between opinions and facts based on the given case	4.3.3 Understand the importance of safeguarding their personal information and take the necessary measures to protect their personal information
	4.1.4 Proficiency in using technology	4.2.4 Can show evidence of online communication or collaboration	-

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The teachers' and students' interviews followed the observation of teaching and learning.

For the implementation, the schools were categorized as follows (Table 3).

Table 3. Experiment Design

School	Technology Exposure	Role	Intervention	Workshops
SMPN 3	Highest	Experiment	Provided with technology and gadget	1. Introduction to the Merdeka Curriculum and STEM-PjBL concept 2. Design the STEM-PjBL lesson plan, 3. Construct 21st-century skills assessments
SMPN 9	Moderately high	Control	No technology/gadget	
SMPN 8	Moderately low	Control	Provided with technology and gadget	
SMPN 6	Lowest	Experiment	No technology/gadget	

3 FINDINGS AND DISCUSSION

3.1 Workshops

Three workshops were conducted for all participating science and mathematics teachers to introduce the Merdeka Curriculum and the STEM-PjBL (Project-Based Learning) concept, design STEM-PjBL lesson plans, and develop and implement 21st-century skills assessments.

During these workshops, teachers reported encountering challenges in designing projects and preparing comprehensive lesson plans, learning materials, and student worksheets necessary for implementing technology-based STEM-PjBL. Additionally, they faced difficulties in effectively designing student engagement strategies.

A key feature of the workshops was the modeling component, where a model science teacher was invited to demonstrate effective science teaching practices. This approach successfully engaged teachers’ interest in science teaching and provided a real, authentic example of effective science instruction. Overall, the workshops effectively facilitated teachers’ preparation for their lessons.

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3.2 Intervention

Table 3 depicts the general picture of the technology-based STEM-PjBL intervention through the anecdotal records of the observation.

Table 3 Anecdotal Records of the Observation

SMPN 9 Naringgul
Initially, students were shy but eventually engaged in discussions and problem-solving on the Worksheet. No questions were asked during the group presentation session, and some students struggled with problem-solving.
The lesson began with a magic trick, which caused students to be serious, curious, and motivated. However, they later appeared confused and unfocused, possibly due to tiredness and unfamiliarity with LibreOffice on laptops.
SMPN 8 Naringgul
The facilitator effectively delivered a lesson despite the students' shyness and lack of confidence. Technology has enhanced learning, but students struggled to come to conclusions. Technology boosts enthusiasm and ignites the learning spirit, making students more active and engaged.
A game-based warm-up activity impressed students. However, during discussions on the worksheet, students appeared confused due to their perceived difficulty in mathematics, as 70 percent of students in my school find mathematics difficult.
SMPN 6 Naringgul
The facilitator emphasized effective science teaching methods, resulting in student enthusiasm and a focus on learning with IT.
The adding-summing technique is effective, but students seem confused in the beginning, the worksheet is difficult, and they lack an understanding of IT tools. Strengthening their ability to answer calculation questions and triggers is necessary.
SMPN 3 Naringgul
The facilitator inspired the classroom, emphasizing the importance of explaining concepts in everyday life before discussing them. Group discussion was less active. Smartphone usage is more prevalent among students. Practice sessions often involve conflict.
At the beginning of the math lesson, it seemed that the students were still "blank," but after being given a laptop, the children focused on the laptop like they had a new toy, working with Libre and formulas.

The implementation of the technology-based STEM-PjBL (Fig. 2) illustrates the outcomes observed during the teaching and learning process. While some teachers successfully delivered the STEM-PjBL, others require further improvement. Further, as depicted in Fig. 2, students exhibited varying levels of teamwork, problem-solving skills, creativity, and digital proficiency. SMPN 3, which has high technology exposure and received intervention through the provision of technology, demonstrated intensive teamwork, problem-solving, and digital skills. However, their pursuit of creativity skills remains relatively low. Conversely, SMPN 8, a control school with moderately low technology exposure and receiving gadgets, exhibited moderate implementation of problem-solving skills, teamwork, and digital skills, with creativity skills being the lowest.

SMPN 6, with the lowest technology exposure and no provision of technology, showed some implementation of problem-solving skills and teamwork, but creativity and digital skills were notably low. SMPN 9, another control school with moderately high technology exposure but no gadgets, did not utilize or develop students' digital skills. Their implementation of problem-solving and teamwork was minimal, and creativity skills were the lowest observed.

Figure 2. Classroom Observation Results

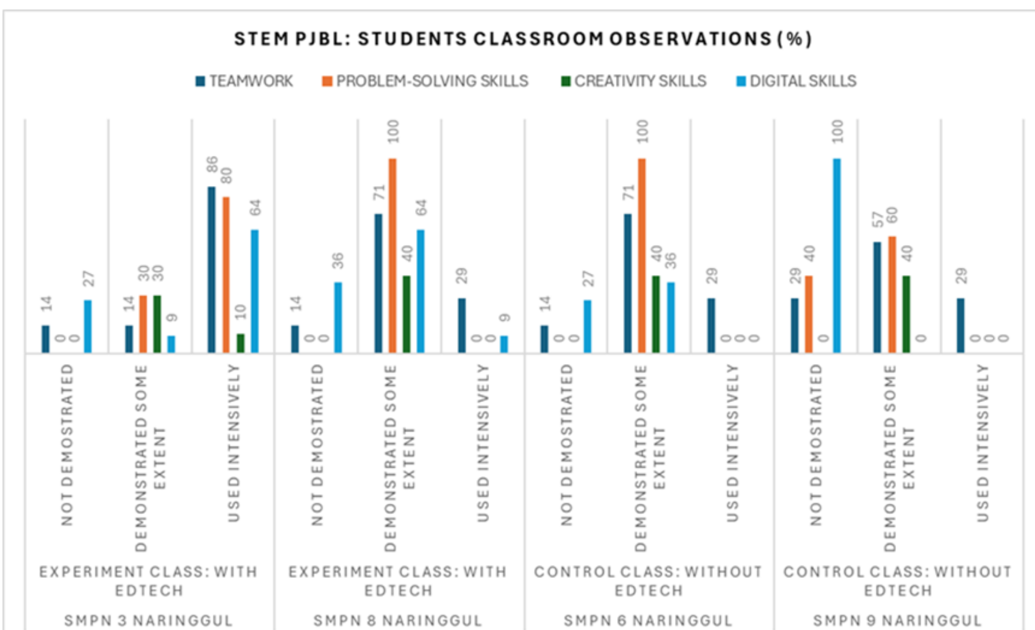

Fig. 2 illustrates that teamwork and problem-solving skills are the most implemented skills in technology-based STEM-PjBL teaching and learning across all schools, regardless of

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technology exposure. Teamwork skills encompass communication, collaboration, and openness (Table 2). Observations revealed that some students in each school could articulate and structure their ideas clearly, while others remained silent, took notes, did not use their mobile phones for communication, or only focused on the teacher's explanations. An exception was noted in SMPN 3, where students used WhatsApp for communication. Collaboration skills were particularly evident among group leaders who shared their knowledge during projects. SMPN 3 and SMPN 9 students demonstrated more extensive collaboration, especially in organizing tasks and delegating group responsibilities. Openness was observed in most students who actively listened during lessons, although only some could give and receive constructive feedback. Students showed competencies in various problem-solving skills, including competencies to analyze problems, define goals, and implement solutions. Some students were able to collect data and required information for problem identification. Students in SMPN 3 extensively demonstrated their competency in information searching from several sources accessible in the digital library. Some students were observed using Google to search for additional answers. While some students could distinguish between opinions and facts based on the given example, others struggled to connect examples to the theoretical concept. Some students could identify possible alternative solutions and generate recommendations, particularly SMPN 3 students who demonstrated a higher level of proficiency. Students in SMPN 3 demonstrated their ability to identify the required stages to implement a solution. They could define criteria for measuring and evaluating goals or desired results in a project. However, only some students could do it in SMPN 8 and SMPN 6, which was not yet demonstrated in SMPN 9. For implementing solutions, students in SMPN 3 stood out in organizing resources and managing project implementation. They were also able to evaluate outcomes and make necessary adjustments to meet project goals, a skill that was only partly demonstrated in SMPN 8 and SMPN 6, and not at all in SMPN 9.

Creativity skills among students were relatively observed, especially when they were to generate creative ideas and improvisation. Some students could propose ideas for relevant solutions, but it was noted that these were not solely the result of their thinking. For instance, one group in SMPN 3 came up with unique ideas for developing their projects, while the others found ideas directly from Google. Regarding improvisation, some students quickly adapted to changing situations and demonstrated flexibility in their strategies, while a few were willing to take risks in their decision-making.

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Digital skills were varied significantly between schools. Based on the research design, only SMPN 3 and SMPN 8, as experiment schools, were exposed to and utilized technology. SMPN 3 students extensively demonstrated all indicators of technology utilization. They spent more than one hour using technology for learning. They could identify and utilize various types of technology based on their needs and effectively use technology to search for information, with some students already utilizing WhatsApp for communication. On the other hand, only some students in SMPN 8 could do so, and their ability to identify and utilize various types of technology was constrained due to the limited availability of digital media. Regarding digital literacy, SMPN 3 students displayed proficiency in reading and writing using digital media, effectively using keywords and syntax for information searches and distinguishing between opinions and facts. SMPN 8 students, however, showed limited ability in these areas and did not demonstrate other digital literacy skills. None of the students from any schools demonstrated an awareness of digital security, indicating the area that needs improvement.

It was observed that teachers demonstrated high competency in utilizing technology, such as employing equipment to create lesson plans in a word processor, developing slide presentations, utilizing LCD projectors in the classroom, and accessing open educational resources (OER) in a digital library. This situation marked a reversal from the original condition before the workshops and intervention, when teachers had little to no competency in using technology.

In addition to classroom observations, interviews were conducted to understand teachers' perspectives on technology-based STEM-PjBL teaching. The results of the interviews are as follows:

1. Technology-Based Teaching and Learning: Teachers reported the benefits of using digital tools to enhance interactivity and student engagement. They expressed satisfaction with using such technology, although some still need to improve their digital competencies. Challenges include finding strategies to enhance both teachers' and students' digital competencies and integrating ICT into the curriculum, which requires extensive planning and preparation. Overall, teachers expect to continuously improve their skills in using technology to increase the effectiveness and enjoyment of learning.
2. Student Engagement and Interest: Teachers noted that technology-based STEM-PjBL teaching and learning experiences increased student interest and engagement. They were relatively satisfied with this teaching approach, which has brought positive changes to students' learning experiences. However, they also recognized the need to continually

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improve their knowledge and skills through training and exposure to suitable teaching materials.

3. Workshop Series: Teachers appreciated the three-workshop series, which improved their knowledge and skills regarding technology-based STEM-PjBL teaching and learning. While some teachers were satisfied with the online workshop format, others preferred face-to-face workshops for more participant interaction and discussion. Teachers also acknowledged challenges during the technology-based STEM-PjBL implementation. Recommendations for enhancing continuous professional development include training on teaching strategies and technology use involving more teachers. These activities are believed to contribute to improving the quality of the learning experience in schools.

Additionally, it was apparent that teachers enjoyed getting to know each other during the workshops, collaborating, and networking. Such collaborative efforts among teachers and support from schools and other educational institutions are essential for continuously improving teaching practices and achieving better student outcomes.

4 CONCLUSION

This study has shown the important role of technology in teaching STEM, especially using project-based learning approaches, especially in the four schools in Naringgul. Students with high exposure to technology indicated higher competency in teamwork, problem-solving skills, creativity, and digital skills. Students with moderate or low exposure to technology have, to some extent, developed their competency in teamwork, problem-solving skills, creativity, and digital skills after being provided access to technology. Technology has increased students' engagement, and knowledge and skills acquisition. Another note taken that although technology ecosystem has not been perfect, but technology-based STEM PjBL teaching learning can still be delivered effectively.

Despite the positive picture depicted by the intervention's results, it was evident that all teachers encountered challenges during the implementation of the technology-based STEM PjBL in the four schools. Analyses reveal that teachers are aware of the importance of integrating technology into learning, the need to implement STEM project-based approaches, and the need for continuing professional development to enhance teaching effectiveness in the classroom. As such, there remains ample room for improvement in their capabilities. Effective technology utilization can elevate student engagement and knowledge acquisition. Thus, if technology is unavailable, good teachers may not successfully deliver technology-based STEM PjBL.

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Nevertheless, it is crucial to recognize that technology is not the only component for good technology-based STEM PjBL teaching and learning, as it must be combined with pedagogical strategies and compelling content.

Providing more targeted professional development sessions on technology-based project-based learning methodologies and STEM integration would be valuable in supporting teachers in overcoming these challenges and improving the effectiveness of STEM PjBL. Moreover, collaboration and sharing of best practices among teachers can enhance their skills in designing and implementing engaging STEM projects. Creating a supportive and encouraging learning environment for teachers and students will foster an atmosphere of continuous improvement and innovation in STEM education.

The findings of this study depict only a small portion of the study on the use of technology in teaching STEM in schools with low exposure to technology, including no internet connection. The bigger picture of the study with wider school coverage needs further exploration and research.

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