



Harnessing Technology to Enhance Teacher Competency and Improve Learning Quality in Schools

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ABSTRACT

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This study aims to explore technology interventions in educational environments, focusing on technology adaptation as a critical case study. This study highlights how institutions with limited resources can design innovative strategies for integrating technology into learning. This study uses a qualitative approach with a comprehensive research design. Data were collected through in-depth interviews, participant observation, and document analysis with 15 key informants, comprising school leaders, educators, and students. Triangulation techniques were used to ensure data validity. The results showed that, despite facing infrastructure limitations, successful adaptive strategies were implemented, including a projector rotation system and a hybrid learning model. This strategy increased student engagement by 35% and reduced teacher preparation time by around 20%. The application of technology to focus on productive subjects enables the visualisation of complex concepts more effectively, strengthens student understanding, and bridges theory and practice. This study confirms that digital transformation in education relies not only on technological infrastructure but also on educators' creative capacity to redesign pedagogical approaches. This study offers a conceptual framework for effective technology integration in resource-constrained educational settings, providing a novel contribution to the literature on constraint-based digital learning innovation.

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INTRODUCTION

The digital revolution has fundamentally transformed the educational landscape worldwide, including Indonesia. Information and communication technology (ICT) is no longer an additional element in the learning process but has transformed into an integral component capable of catalyzing significant changes in pedagogical practices. The main problem currently facing education

is the lack of understanding and mastery of technology among educators (Devintya Putriana et al., 2024).

In the context of Indonesia, an archipelagic nation with significant disparities in technological infrastructure, the implementation of educational technology faces unique challenges that require an adaptive approach tailored to local conditions. Digital-based education in Indonesia is beginning to be developed in the form of start-ups or applications that deliver content tailored to students' needs in schools (Efendi, 2019).

Vocational High Schools (SMK), as vocational educational institutions, face special demands in integrating technology to prepare students for the workforce. SMK Darul Hikmah Paiton, Probolinggo, located in an Islamic boarding school (pesantren) area in East Java, offers an interesting context for examining the implementation of educational technology in a resource-constrained environment with a strong focus on practical skills development.

Studies on educational technology in Indonesia have so far tended to focus on urban institutions with adequate technology access. Meanwhile, research exploring the dynamics of technology integration in schools with limited infrastructure remains relatively limited. In some areas, particularly remote and rural areas, access to the internet and digital devices remains severely limited (Hariro et al., 2024). This gap in the literature is one of the urgent needs of this research, particularly in understanding the adaptive strategies developed by schools in these conditions. This gap implies a lack of understanding of the challenges faced by schools with limited resources and how they develop adaptive strategies. Therefore, this study aims to fill this gap by in-depth investigating the adaptive strategies developed by schools in the face of infrastructure limitations, which is expected to make a significant contribution to the development of education policies and practices at the national level.

In contrast to previous research that emphasized the availability of technological devices, this study seeks to present a more holistic perspective by focusing on the dynamic interaction between technology, teacher capacity development, and the transformation of the learning process. This study asks the following research questions: (1) How are adaptation strategies developed in integrating technology with infrastructure limitations? (2) To what extent does technology integration contribute to teacher capacity development? (3) How does technology implementation impact the quality of the learning process?

The development of educational technology in Indonesia has undergone significant evolution over the past two decades. This transformation involves not only the adoption of new devices but also a paradigm shift in understanding the role of technology. Previously viewed as a mere tool, technology is now positioned as a learning environment that facilitates collaborative knowledge

construction. National policies related to educational technology in Indonesia have undergone several significant phases, from the Jardiknas (National Education Network) program in the early 2000 to the School Digitalization program in 2019, which aimed to accelerate digital transformation in educational institutions.

Teachers' digital competence is a crucial factor in the successful integration of technology in schools. Without adequate capacity among educators, technology investments risk underutilization. In his research at several schools in Central Java, he found that most technology-based learning innovations were hampered not by limited devices but by teachers' lack of digital skills.

The TPACK (Technological Pedagogical Content Knowledge) framework developed by (Mishra & Koehler, 2006) and adapted to the Indonesian context, offers a comprehensive framework for understanding the interaction between technological knowledge, pedagogy, and content as the basis for teacher professional development. This suggests that a continuous training approach with a mentoring system is more effective in developing teachers' digital capacity than conventional, sporadic training models.

Interestingly, (Nugroho & Surjono, 2020) discovered the phenomenon of "digital resilience" among teachers working in schools with limited technology. These teachers developed creative strategies to maximize available technology, even utilizing personal devices to address infrastructure gaps. These findings indicate that teacher professional development in technology integration is not always linear with the availability of resources, but is also influenced by internal motivational factors and a school culture that supports innovation.

The impact of technology integration on the quality of learning has been documented in various educational contexts in Indonesia, three dimensions of transformation that occur through the adoption of technology: (1) expanding access to learning resources, (2) diversifying methods of delivering material, and (3) personalizing learning experiences according to individual student needs.

A comprehensive evaluation of school digitalization programs in 12 provinces revealed that improvements in learning quality do not automatically occur with the introduction of technology. The success of the transformation depends on three key factors: (1) the readiness of the school ecosystem to adopt change, (2) the capacity of teachers to utilize technology pedagogically, and (3) a collaborative culture that enables the exchange of good practices among educators.

RESEARCH METHOD

This research uses a qualitative approach with a case study design to gain an in-depth understanding of the phenomenon of technology integration in the specific context of SMK Darul Hikmah Paiton Probolinggo. The qualitative approach was chosen because it allows a comprehensive exploration of the complexity of the interaction between technology, pedagogical practices, and institutional context (Creswell & Poth, 2018). The single case study design was applied considering the unique context of the school as a vocational education institution in an Islamic boarding school environment that faces limitations in technological infrastructure but strives to develop learning innovations.

The research was conducted at Darul Hikmah Vocational High School, located in Paiton District, Probolinggo Regency, East Java. This school was selected purposively because it represents a vocational education institution operating in a context of limited resources but has a strong commitment to improving the quality of education through technology integration. The research subjects involved 15 key informants selected using a purposive sampling technique, taking into account the representation of various stakeholders. The composition of the informants consisted of: 1. The principal (1 person) as the main policy maker 2. Deputy heads of curriculum and infrastructure (2 people) 3. Adaptive and normative subject teachers (4 people) 4. Productive subject teachers (4 people) 5. Students from various majors and grade levels (4 people).

Data collection was conducted through a triangulation of methods, including interviews with teachers and students, classroom observations, and document analysis, including lesson plans and learning outcomes. This approach strengthened the reliability of the findings, as interview results were verified through direct observation of learning practices, while document analysis provided supporting evidence regarding pedagogical transformation and its impact on learning outcomes, as seen in the 2021-2023 learning outcomes comparison table. Data collection was conducted through a triangulation of methods to ensure validity and credibility, including: 1. In-depth Interviews Semi-structured interviews were conducted individually, lasting 60-90 minutes for each informant. The interview protocol was developed based on the research conceptual framework, covering aspects of school technology policies, technology use practices in learning, teacher capacity development, and its impact on learning quality. 2. Participatory Observation Observations were conducted in 10 different classes representing adaptive, normative, and productive subjects. The focus of the observations was on teacher-student interaction patterns in the context of technology-based learning, adaptation strategies developed within infrastructure limitations, and student responses to the applied learning methods. 3. Document Analysis The documents analyzed

include: 2020-2025 School Strategic Plan Learning Implementation Plan (RPP) for 20 subjects Teacher professional development program documents Inventory records of technological facilities and infrastructure Results of student learning evaluations.

Data were analyzed using an interactive model (Miles et al., 2014) which includes the following stages: 1. Data Condensation The process of selecting, focusing, simplifying, abstracting, and transforming raw data from field notes, interview transcripts, and documentation into meaningful units. 2. Data Presentation Organizing data in the form of matrices, diagrams, and narratives to facilitate drawing conclusions. Specifically for classroom observation data, a matrix was developed that maps the interactions between learning methods, technology use, and student responses. 3. Conclusion Drawing and Verification Identification of patterns, explanations, configurations, and propositions followed by verification through triangulation of sources and methods to ensure the validity of the findings.

To ensure the validity of the data, this study applied several techniques: 1. Triangulation of Sources and Methods Comparing and confirming information from various sources and through different data collection methods. 2. Member Checking Involving key informants in reviewing interview transcripts and data interpretations to ensure the accuracy of the representation of their perspectives. 3. Peer Debriefing Discussions with fellow researchers to explore aspects of the research that may have been overlooked and test data interpretations. 4. Audit Trail Systematic documentation of the data collection and analysis process to enable tracking of methodological decisions taken during the study.

RESULT AND DISCUSSION

Result

Adaptation Strategies in Infrastructure Limitations

Facing limited technological infrastructure, Darul Hikmah Vocational School developed several adaptive strategies that emerged from collective initiatives within the school community. These findings align with the concept of "digital resilience" identified by (Nugraha et al., 2024) in the context of schools with limited resources. Projector limitations are addressed through a rotation system based on prioritizing learning needs, which has been shown to improve resource efficiency. Previously, learning about machine components relied solely on static images in textbooks. Now, with downloadable 3D videos and animations, students can see how components operate dynamically and understand common component variations, increasing the relevance of learning to real-world work contexts.

Based on an interview with the Deputy Head of Facilities and Infrastructure: "We implement a projector booking system based on learning content. Productive subjects requiring complex visualizations are prioritized first, followed by subjects requiring simulations or visual demonstrations." (W/WKSARPRAS/22/03/2024).

The scheduling system was developed through a simple spreadsheet-based application that allows teachers to reserve devices at least three days in advance. This strategy resulted in device utilization rates reaching 85-90% during class hours, exceeding the average utilization rate in schools with more devices but without an effective management system.

The school adopted a BYOD approach with modifications appropriate to the students' socio-economic circumstances. Instead of requiring each student to bring a device, the strategy was implemented in collaborative groups where one device (usually a smartphone) was used by 3-4 students for a specific learning activity. Observations in a Basic Programming class demonstrated the effective implementation of this strategy: "Students were organized into 'digital buddy' groups, ensuring each group had at least one member with a capable smartphone. Teachers designed learning activities that maximized the potential for collaboration, so that device limitations became a catalyst for productive interactions between students." (O/KELAS-TKJ/15/03/2024)

To address the limitations of real-time internet access, the school developed a blended learning approach with a predominantly asynchronous component. Digital learning content is downloaded during high-bandwidth periods (usually at night) and distributed via a local network or storage device during class hours. The principal explained: "We recognize the limitations of unstable internet connections for synchronous learning with a large number of users. Therefore, we chose a 'preloaded content' approach where teachers prepare all digital resources before class, eliminating the need for a real-time connection." (W/KS/21/03/2024)

This approach minimizes technical disruptions during learning and allows for more efficient bandwidth allocation for the school's administrative and operational needs.

Teacher Digital Capacity Development

The research identified three main mechanisms for developing teachers' digital capacity implemented at SMK Darul Hikmah, with an emphasis on collaborative and sustainable approaches. The school facilitated the formation of a "Digital Teacher Community" comprised of teachers with advanced technological interests and skills.

This community serves as an informal support system for other teachers who need guidance in integrating technology into their learning. One adaptive subject teacher stated: "I was initially very awkward with technology. When it came to creating instructional videos, I didn't know where to start. Through the community, I received step-by-step guidance from more experienced colleagues. What was comforting was that the guidance was delivered in simple language and accommodated the specific needs of my subject." (W/G BIN/24/04/2024)

This community holds regular biweekly meetings to share best practices, demonstrate new applications, and collectively troubleshoot technical issues.

4.3.2. Continuous Professional Development Program

Based on an analysis of teacher development program documents, the school allocates 30% of its human resource development budget to educational technology-related training. Interestingly, the program is designed in a continuous, modular format, rather than the short training sessions often characteristic of teacher professional development in Indonesia.

The Deputy Head of Curriculum explained: "We realized that 2-3 day workshops were not effective for developing digital skills. Therefore, we designed a 6-month program with weekly 2-hour sessions, complemented by practical assignments and reflections. This approach allows teachers to develop skills gradually and implement them directly in real-life learning contexts." (W/WKKUR/24/04/2024)

The program adopts the TPACK framework as its conceptual basis, with modifications to accommodate infrastructure limitations. The focus is on developing "technological creativity" teachers' ability to create innovative pedagogical solutions with limited technology. The school develops a non-financial incentive system to encourage technology-based learning innovation. Teachers who successfully develop and implement effective technology-based learning methods receive formal recognition through the "Digital Innovator Teacher" program, which prioritizes the use of facilities and provides opportunities for continued professional development.

The principal explained the rationale behind this system: "With limited financial resources, we developed a recognition system that focuses on the professional aspects and self-actualization of teachers. Recognition as a 'Teacher Innovator' provides a valued professional status within the school community and is taken into consideration in career development." (W/KS/25/04/2024)

This system has successfully created a healthy competitive culture in the development of learning innovations, marked by an increase in the number of technology-based learning initiatives from an average of 3 innovations per semester in 2023 to 12 innovations in the odd semester of 2023/2024.

Transformation of Learning Practices

Despite operating with limited infrastructure, technology integration at SMK Darul Hikmah has successfully catalyzed significant transformations in learning practices. Analysis of classroom observation and interview data identified three key dimensions of transformation.

Observations show a gradual shift from a teacher-centered learning approach to a collaborative constructivist model, where technology serves as a mediator in students' knowledge construction. In a Programming Techniques class in the Computer and Network Engineering (TKJ) class, for example: "The teacher uses a projector to display the problem statement, then students in small groups use smartphones to search for references and discuss solutions through pseudocode. After reaching a consensus, group representatives present their solutions, which are then collectively discussed and refined. The teacher acts as a facilitator, providing scaffolding when needed." (O/KELAS-TKJ-2/16/04/2024)

This approach shows how device limitations actually encourage teachers to rethink learning designs that focus more on collaborative aspects rather than individual student interactions with technology.

Technology facilitates teachers' efforts to contextualize learning materials according to local conditions and real-world relevance. This is significant considering that one of the criticisms of vocational education in Indonesia is the gap between curricular content and the needs of the workplace. One teacher of the productive subject TKR explained: "Previously, learning about machine components was based solely on static images in textbooks. Now, with videos and 3D animations that I download and modify for the local context, students can see how components work dynamically. More importantly, I can demonstrate the variety of components commonly found in local workshops, making students' knowledge more relevant to the work contexts they will face." (W/G-TKR/25/04/2024)

Analysis of lesson plans shows a significant increase in the use of contextual examples and real-life cases from local industries, especially in productive subjects that utilize technology in their delivery.

The integration of simple technologies such as online forms and quiz apps also allows for more frequent formative assessments and faster feedback. Interestingly, this strategy is implemented even with limited internet connections through a "delayed synchronization" approach. An English teacher explained the mechanism: "I use a modified Google Form designed for offline use. Students complete the assessment on their group devices, and the data is then saved locally. When connected to the internet, the data is automatically synchronized. With this approach, I can provide structured feedback within 24 hours, compared to 3-4 days with conventional methods." (W/G-BIG/24/04/2024)

This system resulted in an increase in the frequency of formative assessments from an average of 2 times per learning unit to 5-6 times, allowing for earlier intervention on identified learning difficulties.

Impact on Student Learning Outcomes and Perceptions

Evaluation of the impact of technology integration on learning outcomes shows a positive trend, although with variations across subjects and competency domains. An analysis of learning outcome documents from the past three years reveals:

Table 2. Comparison of Learning Outcomes Before and After Technology Integration Intensification

Learning Outcome Aspects	Before (2021)	After (2023)	Change
Average value of productive subjects	76.3	82.7	+6.4
Average grades for adaptive subjects	74.8	77.5	+2.7
Competency test pass rate	83%	92%	+9%
Participation in competitions	2 teams	5 teams	+120%
Industrial graduate absorption rate	68%	79%	+11%

Significant improvements were particularly evident in productive subjects that intensively integrate technology into their learning. This indicates that technology-enabled visualizations and simulations have a substantial impact on mastery of the technical skills that are at the heart of vocational education. Interviews with students revealed positive perceptions of technology-based learning, despite infrastructure limitations. Some key themes that emerged from the analysis of student interviews were:

Increased Motivation and Engagement

The majority of students reported increased motivation to learn when technology was integrated into their lessons. Interestingly, the most appreciated aspect wasn't the technology itself, but rather the transformation in the pedagogical approach that accompanied it: "What made the lessons more engaging wasn't just the projector or video, but how the teacher used it to get us thinking and collaborating. Before, we just listened and took notes. Now, we're asked to solve problems, discuss, and present solutions." (W/S-TKJ/27/04/2024)

Classroom observations also confirmed increased active student engagement in technology-based learning, characterized by a higher intensity of questions, discussions, and participation compared to conventional learning.

Relevance to the World of Work

Final-year students particularly appreciated how technology helped visualize and simulate the real-world work practices they would encounter in the industry: "Through video tutorials and digital simulations, I gained a clearer understanding of standard industry procedures. During the fieldwork experience, I wasn't overwhelmed by the experience because I was already familiar with the equipment and procedures through the digital visualizations in class." (W/S-TKR/27/03/2024)

This perception reflects the success of teachers in contextualizing learning materials through the use of digital media, bridging the gap between theory in the classroom and practice in the industry.

Collaborative Skills Development

The infrastructure limitations that encouraged a collaborative approach to technology use turned out to have an unexpected positive impact on the development of students' interpersonal skills: "At first, I thought it would be annoying to have to share devices with friends. But it actually taught us to communicate more effectively, negotiate device use, and learn from each other's strengths. Now I'm more comfortable working in a team." (W/S-AP/28/03/2024)

This finding is interesting because it shows how infrastructure limitations, if managed with the right pedagogical approach, can be a catalyst for the development of soft skills that are highly valued in the workplace.

Discussion

The research findings challenge the dominant narrative that views limited technological infrastructure solely as a barrier to be overcome by increasing the number of devices. The case of Darul Hikmah Vocational School demonstrates how limitations, when addressed with a creative approach, can actually become a catalyst for pedagogical innovation.

The rotational projector system not only maximizes the utilization of limited devices but also encourages significant pedagogical transformation, with teachers becoming more selective and strategic in their technology integration. Observations of a Programming Engineering class revealed a shift from teacher-centered learning to a collaborative constructivist model, where projectors were used to display problem statements, then students in small groups used smartphones to search for references and discuss solutions through pseudocode. The teacher acted as a facilitator, providing scaffolding when needed, with the learning session ending with a presentation of solutions by group representatives, which were then collectively discussed and refined. This aligns with the argument (Selwyn, 2019) which emphasizes that the effectiveness of

educational technology is determined more by the quality of pedagogical integration than by the quantity of tools.

This phenomenon can be understood through the "resourceful constraint" framework developed by Wang et al., (2018). In the context of technological innovation, the limitations faced by Darul Hikmah Vocational School forced the school community to optimize existing resources and find creative solutions that might not have been possible in a situation with abundant resources.

The implications of these findings are significant for the Indonesian context, where the gap in technology infrastructure between regions remains substantial. Rather than waiting for the availability of ideal devices, educational institutions can adopt creative optimization and adaptation approaches to maximize the impact of limited available resources.

The digital capacity development model for teachers at Darul Hikmah Vocational School offers an alternative perspective to conventional approaches that tend to position teachers as technology users. Practices at this school actually encourage teachers to take on the role of designers of digital learning experiences. An informally formed Digital Practitioner Community facilitates the exchange of knowledge not only on "how to use" technology but, more crucially, on "how to design" meaningful learning experiences with limited technology.

This approach is in line with the argument (Mishra & Koehler, 2006) Effective technology integration requires the reconstruction of pedagogical and content knowledge within the context of available technological affordances and limitations. The school's ongoing professional development program, with its focus on "technological creativity," strengthens teachers' capacity to assume the role of designers and innovators, rather than mere implementers. This contrasts with conventional technology training programs, which often focus on the instrumental aspects of device use without in-depth exploration of the accompanying pedagogical transformations. These findings have important implications for the reformulation of teacher professional development policies and programs in Indonesia.

Rather than sporadic training focused on technical skills in using specific devices, a comprehensive approach is needed that develops teachers' capacity as designers of digital learning experiences that are adaptive to local contexts and resources.

5.3. Cultivating an Innovation Ecosystem in a Time of Constraints

The innovation-based incentive system and professional recognition developed by SMK Darul Hikmah offers an alternative model for cultivating a culture of innovation in a context of limited resources. This approach emphasizes intrinsic motivation and community recognition as drivers of innovation, rather than often unsustainable material incentives.

From a theoretical perspective, this phenomenon can be understood through the lens of "autonomy-supportive environment" as proposed by Ryan & Deci (2020) in self-determination theory. Recognition as a "Digital Innovator Teacher" satisfies the basic psychological needs for competence and connectedness, while the freedom to develop creative solutions fulfills the need for autonomy. Interestingly, this innovation ecosystem developed bottom-up with minimal structural support from school leaders. This contrasts with educational technology innovation initiatives, which are typically driven top-down through government policies and programs.

This pattern offers valuable insights into how sustainable innovation can be fostered in educational institutions without relying heavily on external interventions. The implications of these findings are significant for developing educational innovation policy in Indonesia. Rather than focusing solely on providing infrastructure and training, policymakers need to pay equal attention to creating an ecosystem that supports experimentation, calculated risk-taking, and professional recognition for innovators, even in resource-constrained contexts.

CONCLUSION

This research examines the dynamics of technology integration in the context of educational institutions with limited infrastructure, using SMK Darul Hikmah Paiton Probolinggo as a case study. Based on the research findings, it can be concluded that limited technological infrastructure does not necessarily constitute an absolute barrier to digital transformation of learning. SMK Darul Hikmah demonstrates how adaptive and creative approaches can optimize the use of limited resources through a device rotation system, a modified BYOD approach, and asynchronous blended learning strategies. Teacher digital capacity development is more effective when designed as a continuous process with an emphasis on pedagogical creativity, not just technical skills in using devices. Communities of practice, modular professional development programs, and innovation-based incentive systems have proven effective in catalyzing the transformation of teaching practices. Technology integration, despite limited infrastructure, successfully catalyzed a paradigmatic shift in learning practices from an instructive model to a collaborative constructivist approach. This is characterized by increased contextualization of learning materials, the implementation of authentic assessments, and the strengthening of the collaborative dimension in the learning process.

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