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Digitalization in Education and Student Readiness for Industry 4.0: Critical Analysis and Strategic Recommendations

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A B S T R A C T

This study critically examines the impact of digitalization in education on students' readiness to face the transformative demands of the Industrial Revolution 4.0, with specific attention to the Indonesian context. Although international research highlights the role of digital tools in enhancing 21st-century skills, studies in Indonesia remain scarce and often overlook how digital education directly influences student preparedness for Industry 4.0. This gap is particularly urgent given the persistent digital divide, uneven teacher digital competence, and disparities in access to technological infrastructure across Indonesian schools. Adopting a qualitative design, the research employs a triangulation method involving in-depth interviews with five teachers and two students, participatory observation, and document analysis at SMPN 1 Kotabaru. The findings reveal that digitalization significantly enhances student readiness by fostering interactive, personalized, and flexible learning environments. The use of e-learning platforms, AI-based applications, and immersive technologies such as VR/AR not only improves student engagement and self-paced learning but also develops critical competencies, including creativity, communication, collaboration, and critical thinking.This research contributes to filling the gap in Indonesian educational studies by demonstrating how digital transformation can align classroom practices with the competency demands of Industry 4.0. The study provides strategic recommendations for policymakers and educators to strengthen digital infrastructure, improve teacher capacity, and promote inclusive access to technology in order to optimize student readiness for the future world of work.

Keywords: *Digitalization in Education, Industrial Revolution 4.0, Student Preparedness, Qualitative Triangulation, Indonesia, Policy Recommendations*

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INTRODUCTION

Education is the main pillar in the development of quality and competitive human resources in the era of globalization. Along with the rapid development of technology, especially since the emergence of the Industrial Revolution 4.0, the world of education has undergone a major transformation that has not only changed learning methods, but also demanded the development of new competencies for students. The Industrial Revolution 4.0 is characterized by the integration of advanced digital technologies such as artificial intelligence, Internet of Things (IoT), big data, and cloud computing that are transforming the way humans work, communicate, and learn (Gunawan et al., 2020) (Syerlita & Siagian, 2024). In this context, the digitalization of education is a necessity to prepare the younger generation who are able to compete and contribute to the increasingly complex and technology-based world of work.

In Indonesia, education has grown rapidly from the traditional system to the digital era. In the past, learning still relied on conventional methods that placed teachers as the main source of information and students as passive recipients (Agusta et al., 2022). However, advances in information technology have changed this paradigm to more interactive, flexible, and personalized learning through various digital platforms, such as e-learning, learning applications, as well as Virtual Reality (VR) and Augmented Reality (AR) technologies that provide a more contextual and engaging learning experience (Setiadi & Purwanto, 2021). The

COVID-19 pandemic has become a momentum for the acceleration of the digitalization of education in Indonesia, where distance learning (PJJ) is widely applied to maintain the sustainability of the teaching and learning process.

Digitization of education opens up great opportunities in equitable access and improves the quality of learning. Online learning platforms allow students from different regions, including remote areas, to access global learning resources easily and cheaply. In addition, digital technology allows for personalization of learning, where materials and methods can be adjusted to the needs and characteristics of each student. Teachers can also leverage analytics data to monitor student learning progress in real-time and provide appropriate interventions (Studi et al., 2024).

However, despite these advancements, the readiness of Indonesian students to meet Industry 4.0 demands remains a major challenge. Several factors explain this paradox. First, the digital divide between urban and rural schools is still stark. Many regions lack adequate internet connectivity, computer devices, and supporting infrastructure. Second, digital literacy among teachers and students remains uneven, which makes the use of technology in classrooms suboptimal (Siahaan, 2022). A curriculum that is not fully adaptive to the needs of industry 4.0 and the lack of collaboration between educational institutions and the industrial world also widen the gap between graduate competencies and the needs of the modern job market.

Third, the curriculum is not yet fully aligned with Industry 4.0 needs, as it still emphasizes rote knowledge rather than 21st-century competencies such as critical thinking, creativity, communication, and collaboration (Aslamiah et al., 2021). Fourth, weak collaboration between schools and industry has widened the gap between what students learn and the actual skills demanded by the labor market (Agusta & Noorhapizah, 2020). Digital literacy is a basic competency that must be mastered by teachers and students so that the learning process can run effectively and relevant to the needs of the times (Dalle et al., 2021) (Syerlita & Siagian, 2024). Therefore, ongoing training for educators and curriculum development that is responsive to technological developments is essential.

The Government of Indonesia has initiated various strategic programs to support the digitalization of education, including the development of technology infrastructure in schools, teacher training, and the development of digital learning platforms such as Rumah Belajar, Google website, Google Workspace for Education (Novitawati & Yulius, 2023). The Independent Campus and Teaching Campus programs are also examples of efforts to strengthen synergy between the world of education and industry to prepare graduates who are ready to work and innovative. However, the success of the program relies heavily on strong collaboration between stakeholders and a commitment to addressing the digital divide that still exists.

Based on these phenomena or circumstances, this study aims to critically analyze the influence of education digitalization on students' readiness to face the transformation of Industry 4.0. Most previous research has focused on infrastructure or digital literacy aspects partially, with few comprehensively examining the integration of infrastructure readiness, curriculum, human resources, digital literacy, and industrial partnerships in the context of education digitalization in Indonesia. This research also identifies gaps and challenges faced in the implementation of education digitalization and formulates strategic recommendations that can be implemented by the government, educational institutions, and industry to increase the effectiveness of education digital transformation in Indonesia.

METHOD

This study uses a qualitative approach equipped with triangulation techniques to increase the validity and credibility of the data. The qualitative method was chosen to gain an in-depth understanding of the phenomenon of educational digitalization and its impact on students' readiness to face the transformation of industry 4.0. Through this approach, the researcher explored the perspectives, experiences, and interpretations of relevant informants,

including five teachers from SMPN 1 Kotabaru with diverse subject backgrounds (science, ICT, English, and Mathematics) and two students who experienced the digitalization process firsthand. Data collection involves structured interviews that focus on the application of the technology, its impact on students' skills, barriers, curriculum readiness, and recommendations for industry collaboration. In addition, participatory observations were carried out in the school environment and a study of curriculum documentation, policies, and reports related to digital education. This combination of interviews, observations, and document analysis forms the basis of the triangulation method, while involving multiple informants—teachers, students, and education managers—constitutes source triangulation, both of which serve to reduce bias and improve data accuracy. Primary data from interviews is enriched and validated by secondary sources such as official documents, policy reports, scientific journals, and relevant articles, ensuring a comprehensive and reliable dataset.

Data analysis was carried out using qualitative thematic analysis, which involves organizing data into categories and themes, coding to identify patterns and relationships, and interpreting findings in relation to existing theories and literature on education digitalization and Industry 4.0 readiness. This repetitive and reflective process guarantees depth and accuracy in understanding the phenomena studied. To further ensure the validity and reliability of the data, cross-examination was carried out between various data sources and informants. This research is limited to the context of secondary schools in specific regions of Indonesia, focusing on the influence of digitalization on student readiness, the challenges faced by educators and learners, and strategies to strengthen digital education, without including quantitative or large-scale survey methods. The research process begins with the planning and selection of triangulation methods, followed by data collection and thematic analysis, which culminates in strategic conclusions and recommendations aimed at advancing the digitalization of education in Indonesia.

FINDINGS AND DISCUSSION

Student Engagement and Motivation

One of the strongest findings is that digitalization significantly enhances student engagement. Teachers reported that interactive platforms, multimedia resources, and gamified applications fostered higher levels of student enthusiasm, reducing passive learning habits. Observation showed that students were more participatory during digital-based lessons compared to traditional methods.

This finding is consistent with who argue that digital learning not only provides flexibility but also increases intrinsic motivation by fostering more interactive learning environments (Murtopo et al., 2023). In the Indonesian context, where rote memorization often dominates classrooms, digitalization represents a shift toward more student-centered learning. However, engagement is uneven across socio-economic backgrounds students with better device access display higher motivation compared to those relying solely on shared or low-capacity devices. This gap reflects broader structural inequalities in Indonesian education.

Personalized Learning and Digital Competencies

Digitalization facilitates personalized learning, allowing students to progress at their own pace through AI-based platforms and adaptive e-learning systems. In interviews, students expressed appreciation for the ability to revisit materials independently, which increased confidence and reduced learning anxiety. Teachers also noted that digital platforms supported differentiated instruction, particularly for students struggling with abstract concepts in mathematics and science.

Highlights that digitalization can act as a corrective mechanism to Indonesia's "one-size-fits-all" education model, which often overlooks individual learning differences (Ajizah, 2021). Furthermore, this study aligns with who emphasize that digital tools enhance 21st-century competencies critical thinking, creativity, collaboration, and communication if applied in a pedagogically sound manner (Syahid et al., 2022). However, there remains a lack of

systematic integration of these competencies into the national curriculum, meaning their development depends largely on teacher initiative rather than structured policy.

Transformation of Teaching Practices and Teacher Roles

Teachers' experiences revealed that digitalization has shifted their role from "knowledge transmitters" to "learning facilitators." Digital tools allow for project-based learning, flipped classrooms, and collaborative assignments. Teachers reported feeling more empowered to experiment with innovative pedagogies, such as integrating VR simulations in science classes or using digital storytelling in language learning.

This transformation mirrors findings by international studies on teacher professional identity in the digital era, but it also reflects a specific challenge in Indonesia: many teachers lack continuous training and rely on short-term workshops. Argue that without systematic professional development, teachers risk being "technologically equipped but pedagogically unprepared" (Syahid et al. 2022). Thus, while digitalization opens new pedagogical opportunities, sustaining them requires institutional support and long-term investment in teacher training.

Student Readiness: Independence, Collaboration, and Critical Thinking

Digital learning was found to strengthen student autonomy, collaboration, and problem-solving. Students at SMPN 1 Kotabaru developed habits of independent study, often using online tutorials and peer discussion forums beyond the classroom. This aligns with the 4C framework of Industry 4.0 readiness. Teachers confirmed that students showed improved collaborative behavior in group projects facilitated by digital platforms like Google Classroom and Zoom breakout rooms.

However, the readiness level varies: high-achieving students benefit more, while low-achieving students sometimes struggle with self-discipline and digital distractions. This reinforces concern about the "double-edged sword" of digitalization: while it empowers learners, it may also exacerbate inequalities if not supported by proper scaffolding and guidance (Ajizah, 2021). In this sense, student readiness cannot be assumed as an automatic outcome of digital exposure but must be cultivated through guided digital pedagogy.

Challenges in Implementation

Despite promising benefits, implementation challenges persist:

Infrastructure inequality: Internet instability and device shortages remain major barriers, particularly in rural Indonesia. This confirms study on the "digital divide," which disproportionately affects disadvantaged schools (Ajizah, 2021).

Limited digital literacy: Teachers and students often demonstrate basic operational skills but lack deeper competencies such as digital citizenship, online ethics, and critical evaluation of digital sources (Syahid et al., 2022).

Administrative burden: Teachers criticized that digital platforms imposed by government programs focus more on bureaucratic reporting than pedagogical innovation.

Cultural resistance: Traditional mindsets still dominate in some classrooms, with skepticism toward digital tools perceived as distractions rather than learning aids.

Curriculum gaps: The national curriculum does not fully integrate digital literacy or Industry 4.0 competencies, resulting in a mismatch between classroom learning and labor market expectations.

Weak industry–education linkages: Unlike vocational education systems in countries such as Germany, Indonesian schools rarely collaborate with industry, limiting students' practical exposure to real-world applications of digital competencies (Murtadho, 2019).

Strategic Recommendations

Addressing these challenges requires comprehensive reform:

Infrastructure Equity: Government initiatives must prioritize digital infrastructure in rural and underprivileged regions to ensure equitable access (Ajizah, 2021).

Continuous Teacher Training: Professional development should go beyond technical skills, focusing on pedagogical innovation and critical digital literacy (Syahid et al. 2022.

Curriculum Reform: Integrating coding, data science, cybersecurity, and digital ethics into the national curriculum will better prepare students for Industry 4.0 (Syerlita and Siagian, 2024).

Industry Partnerships: Schools should develop collaborations with industry to ensure students gain relevant skills and experiences beyond classroom learning (Murtadho, 2019).

Supportive Policy Framework: Policies must reduce administrative burdens on teachers and shift digital platforms from bureaucratic tools to pedagogical enablers.

This study confirms that digitalization enhances student engagement, personalized learning, teacher innovation, and 21st-century skills development in Indonesia. Yet, readiness for Industry 4.0 remains constrained by infrastructural inequality, limited digital literacy, and insufficient systemic support. These findings underscore that digital transformation in education cannot be reduced to technological adoption alone—it requires structural reforms, sustained teacher training, and stronger industry–education linkages. By addressing these systemic barriers, Indonesia can leverage digitalization as a transformative force for creating a generation of students who are not only technologically literate but also critically engaged, collaborative, and future-ready.

CONCLUSIONS

This study shows that the digitalization of education has a strong impact on students' readiness to face Industry 4.0. It improves engagement, motivation, and active participation, while also enabling personalized learning that develops essential skills such as critical thinking, creativity, collaboration, and communication. Teachers have shifted roles from knowledge transmitters to facilitators, fostering more interactive and student-centered learning. However, challenges remain in terms of unequal infrastructure, limited digital literacy, heavy administrative demands, and a curriculum that is not fully aligned with the needs of Industry 4.0. Without addressing these issues, the benefits of digitalization will not be evenly distributed. Overall, digitalization holds great potential to transform education in Indonesia. With stronger infrastructure, continuous teacher training, curriculum reform, and closer collaboration with industry, it can create a generation of students who are adaptive, innovative, and ready to compete in the global digital era.

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