Technology Optimization in 21st Century Skills Learning: Infrastructure Challenges and Strategies for Equitable Digital Access

[1]Eli Masnawati, [2]Yulius Kurniawan

[1]*STKIP PGRI Bangkalan, Madura, Indonesia*
[2]*Widya Kartika University of Surabaya, Indonesia*

A R T I C L E I N F O

Article history:
Received 13 March 2021
Revised 4 May 2021
Accepted 18 June 2021

Key words:
Education technology,
21st century skills,
Digital divide,
Education infrastructure,
Learning innovation,
Education equity,
Educators training.

A B S T R A C T

The development of technology has brought significant changes in education, especially in learning 21st century skills such as programming, creativity and collaboration. Technology offers various opportunities to improve learning effectiveness, but its application still faces a number of challenges. Infrastructure limitations, digital access gaps, and lack of educator competence to utilize technology are the main obstacles in equalizing the quality of education. This study uses a literature review approach to analyze the role of technology to support 21st century skills learning and the factors that influence the effectiveness of its implementation. The results show that although technology can increase student engagement and enrich the learning experience, without adequate support in terms of policy, funding and training for educators, the benefits cannot be optimized equally. The digital divide that occurs in various regions further widens inequalities in the quality of education. Therefore, a more comprehensive strategy is needed, including infrastructure improvement, educators training and inclusive technology-based curriculum development. Technology can function optimally to improve 21st century skills and create equitable access to education for all students. This study is expected to provide insights for education policy makers and practitioners to design more effective solutions to utilize technology in learning.

INTRODUCTION

Technology has become an integral part of many aspects of life, including education. This phenomenon can be seen from the increasing use of digital devices, online learning platforms, and artificial intelligence to support the teaching-learning process. The 21st century skills such as problem solving, creativity, communication and collaboration are increasingly considered essential competencies that students must possess in order to compete in an increasingly dynamic world of work (Häkkinen et al., 2017). Governments and educational institutions in various countries have adopted policies to integrate technology in learning to improve educational effectiveness (Grimus, 2020). Global trends show that technology-based learning methods, such as flipped classroom, project-based learning, and the use of digital simulations, are increasingly applied to build skills that are relevant to the demands of the times (Darvin, 2019).

This phenomenon is also increasingly visible with the implementation of the Merdeka Curriculum, which emphasizes the importance of technology utilization in education of Indonesian. The use of Learning Management System (LMS), artificial intelligence-based applications, and interactive media is increasingly being used by educators and students to support the learning of 21st century skills, such as programming, critical thinking, and team collaboration (Surve & Londhe, 2020). The ability to use technology wisely and effectively is an important skill to prepare students face the challenges of global. Challenges are still found in its implementation, such as limited infrastructure, educator readiness, and disparities in access to technology in various regions. Further studies are needed on how technology can be used effectively to support the teaching of 21st century skills so that it can provide optimal benefits for students to face future challenges (Grimus, 2020).

** Corresponding author, email address:* ***dr.elimasnawati@gmail.com***

The implementation of technology in 21st century skills learning faces a number of complex issues. One of the main challenges is the lack of adequate infrastructure and internet access (Ghavifekr et al., 2016). Many schools, especially in remote areas, still do not have adequate technology facilities, such as computers and stable internet connections. This hinders the integration of technology in learning and limits students' access to digital learning resources (Schmidt & Tang, 2020). The lack of digital competence among educators is a significant barrier. Many educators have not received adequate training to utilize technology to support teaching 21st century skills. The learning process tends to be conventional and less interactive, unable to accommodate the development of skills such as programming, creativity and collaboration.

Another challenge is the digital divide between students. Differences in access to and mastery of technology between students from different economic backgrounds can create disparities in academic achievement. Students who do not have access to technology devices or the internet at home will be left behind compared to those who have full access, widening the education gap.

The importance of observing the role of technology in learning 21st century skills is based on the need for an education system that is adaptive to the times (Grimus, 2020). Skills such as programming, creativity and collaboration are becoming increasingly crucial for students' readiness to face the challenges of the world of work and social life (Trilling & Fadel, 2009). Various problems such as limited infrastructure, low digital competence of educators, and disparities in access to technology among students hinder the optimization of technology utilization in education. Research on this aspect is needed to understand the factors that influence the effectiveness of technology in learning as well as the implications of the digital divide on the quality of education.

The urgency of this study is increasing along with the global demand to improve the quality of human resources with 21st century skills. Many countries have integrated technology into their education systems to accelerate the transformation to more innovative and inclusive learning (Redecker & Punie, 2017). Without an understanding of the challenges, the gap in technology implementation will continue to widen, leading to inequalities in learning opportunities. This research not only contributes to the development of technology-based education theory, but can also serve as a basis for policy makers to design more effective and equitable education strategies.

This research aims to analyze the role of technology to support the learning of 21st century skills, particularly to address the challenges of infrastructure limitations and digital access gaps. It also aims to identify factors that influence the effectiveness of technology implementation in education and its impact on equalizing learning quality.

RESEARCH METHOD

This research uses a literature study approach to analyze the role of technology in learning 21st century skills. Literature study is a research method conducted by reviewing various academic sources, such as scientific journals, books, and relevant research reports (Snyder, 2019). Various literatures that discuss the implementation of technology in education, the challenges faced, and its impact on 21st century skills will be systematically collected and analyzed. This approach was chosen as it allows researchers to identify trends, challenges and opportunities that have been documented in previous research (Kitchenham & Charters, 2007).

The data collection process was conducted by searching and sorting sources from academic databases such as Google Scholar, ScienceDirect, and Springer. The articles and books reviewed were selected based on relevance to the topic, credibility of the source, and recent publication to ensure the accuracy of the information (Boell & Cecez-Kecmanovic, 2015). Once the data was collected, thematic analysis was conducted to group the information according to the main categories, such as technology utilization in learning, implementation challenges, and the impact of technology on 21st century skills. This analysis aimed to gain a comprehensive understanding of how technology can be effectively utilized in education.

The reliability of the research is ensured through the use of verified sources and a critical approach to analyzing the results of previous studies. With this literature study method, the research can reveal broader findings compared to other methods, as it is not limited to one specific location or population (Xiao & Watson, 2019). The literature review also enables the identification of research gaps that still need to be explored further so as to provide insights for future research development.

RESULT AND DISCUSSION

The Role of Technology to Support 21st Century Skills Learning Amidst the Challenges of Infrastructure Limitations and Digital Access Gaps

Technology has a very important role in learning 21st century skills, such as programming, creativity and collaboration. Students can access a variety of

interactive and innovative digital learning resources, enabling them to develop the skills needed in the modern world of work (Voogt et al., 2013). Online learning platforms such as Codecademy and Scratch have been widely used to teach programming independently, while various artificial intelligence and augmented reality (AR)-based tools help enhance students' creativity (Zhang et al., 2022). However, while technology can support the learning of these skills, there are still major challenges to overcome, particularly regarding infrastructure limitations and digital access gaps (Darvin, 2019).

One of the main challenges is the limited technological infrastructure, especially in areas that do not have adequate internet access. Technology-based learning often relies on a stable internet connection, yet many regions, especially in developing countries, still experience problems with this accessibility (Hilbert, 2016). Many learning materials, including learning videos, e-books and interactive resources, are only accessible online. Infrastructure limitations cause a digital divide that prevents students from accessing technology-based learning materials. Without stable internet, students find it difficult to utilize online resources, take online courses, or participate in global collaborative projects that require digital communication (Grimus, 2020).

Besides infrastructure limitations, another significant challenge is the digital access gap caused by economic and social factors. Many students, especially from low economic backgrounds, do not have adequate devices to access technology-based learning (van Dijk, 2020). Laptops, tablets or smartphones needed to access learning applications are often not available to those from low-income families. This limitation makes it difficult for these students to keep up with the technology-based learning that is increasingly relied upon. This exacerbates educational inequality, where students from better-off neighborhoods have an advantage to access more advanced resources and technology (Schmidt & Tang, 2020).

Differences in digital literacy are also a barrier to utilizing technology for 21st century skills learning. Not all educators and students have sufficient skills to use technology effectively in the teaching-learning process (Hämäläinen et al., 2021). Educators who are not familiar with technology may have difficulty integrating digital tools into learning, hindering the effective use of technology to support skills such as programming and collaboration (Grimus, 2020). Meanwhile, students who have no prior experience of using technology may find it difficult to adapt to digital-based learning methods.

Another obstacle is the lack of locally and culturally appropriate educational content and resources. Many technology-based learning platforms are developed in English and with approaches more suited to educational contexts in developed countries (Selwyn, 2021). Students in developing countries often face difficulties understanding the material or feel a lack of connection with the content. In addition, some of the available learning technologies may not take into account the infrastructure conditions and specific needs of resource-constrained regions, making their implementation less effective (Schmidt & Tang, 2020). Without adjusting to local needs, the implementation of educational technology can be less effective and not provide optimal results.

Although the challenges in applying technology for 21st century skills learning are complex, technological advances still offer great opportunities to improve access, effectiveness and relevance of education. The role of technology in learning is not only limited to providing access to digital educational resources, but also to building an adaptive and personalized learning ecosystem. With the utilization of artificial intelligence (AI) and learning analytics, technology can help structure curricula tailored to individual needs, accelerate skill acquisition, and provide more accurate feedback to students. However, gaps in digital access and skills remain a significant obstacle, especially for students in areas with limited technological infrastructure. Therefore, education policies should be designed inclusively to ensure that technology can truly be used by all students, including those from underserved groups. This includes providing adequate devices, stable internet connectivity, and training for educators to optimize the use of technology in learning.

The implementation of technology in education requires the involvement of various stakeholders, including the government, educational institutions, the private sector and the community. The government has a role to play in establishing regulations that support the adoption of technology in a fair and equitable manner, as well as allocating budgets for adequate digital infrastructure in schools. Educational institutions are responsible for integrating technology into the curriculum and ensuring that the teaching methods used do not only rely on technology as a tool, but also as a medium that enriches students' learning experience. The private sector can contribute through technological innovation, provision of affordable educational software and hardware, and

partnership programs with schools. Without synergy among these stakeholders, technology will only be an exclusive tool for those who have access, while the disadvantaged groups will be left further behind. Therefore, a systemic and inclusive approach is needed that ensures that technology can truly be a tool of educational transformation, enabling all students to acquire the 21st century skills they need to face the global challenges ahead.

Key Factors Influencing the Effectiveness of Technology Implementation in Education and its Impact on Equitable Quality of 21st Century Skills Learning

The implementation of technology in education is influenced by various factors that determine its effectiveness to support the learning of 21st century skills. One of the main factors is the readiness of technology infrastructure, including stable internet access and adequate devices (Bebell & O'Dwyer, 2010). Inequality in infrastructure leads to a digital divide, where students in urban areas have easier access to technology than those in rural areas. Lack of access to devices and internet connectivity limits equal learning opportunities, making equitable education quality difficult to achieve. This risk creating a chasm of inequality in the education system, which could exacerbate social and economic disparities in the future.

The competence of educators to integrate technology into the learning process is also a crucial factor in determining the effectiveness of technology use in the education sector. Many educators do not have sufficient technological skills to utilize various digital platforms effectively (Ertmer & Ottenbreit-Leftwich, 2013). Without adequate training, technology becomes just an additional tool without any significant impact on the quality of learning. According to Grimus (2020), educators with high digital competence are likely to be able to create a more interactive learning environment and support collaboration, while those with less training will face difficulties adjusting to developments in educational technology.

Another influential factor is the availability of relevant and quality learning content. Technology will only be effective if it is supported by learning materials that match the curriculum and students' needs (Mishra & Koehler, 2006). Many materials are available in foreign languages or not adapted to the local context, making it difficult for students and educatos to adapt. The lack of appropriate materials can hinder the effectiveness of technology to enhance 21st century skills, such as programming, creativity and collaboration (Schmidt & Tang, 2020).

Policy and funding support from the government and educational institutions determine the success of technology implementation in learning. Governments that have a strong commitment to the development of digital education tend to provide greater investment in infrastructure, educators training, and technology-based curriculum development (Selwyn, 2021). This investment is not only limited to the provision of hardware and software, but also to strengthening the capacity of human resources in education. Darvin (2019) emphasizes that without adequate policy support, efforts to implement technology in education tend to be sporadic and unsustainable, widening the gap in access and quality of learning. Without supportive regulations, each school or educational institution may take different steps in adopting technology, which may lead to disorganization and lack of coordination in the application of educational technology. This not only reduces the effectiveness of technology use in learning but also increases the gap in technology access between schools that have more support and schools that do not have sufficient resources.

Socio-economic aspects also play an important role in determining the effectiveness of technology use in education. Students from families with lower economic status often face limitations in acquiring technological devices required for digital learning (Livingstone & Helsper, 2007). This economic disparity has direct implications for inequalities in equalizing the quality of education, where those who are able to access technology have an advantage to develop 21st century skills over those who do not have similar access. It is important for the government and various stakeholders to address these socio-economic factors by providing more inclusive and affordable technology access solutions for all students.

The impact of technology implementation on equitable education quality depends largely on how the above factors are managed. If access to technology and educators training is unequal, then gaps in learning will increase. If technology is only accessible to a handful of students who come from higher income families or live in urban areas, while students from poor families or remote areas cannot access it, then inequality in the quality of education will continue. However, if policies and infrastructure can support more inclusive implementation, technology can be an effective tool to equalize educational opportunities for all students, regardless of their socio-economic background (Warschauer, 2004).

The effectiveness of technology implementation in education is the result of the interaction of various interrelated factors, not merely dependent on the availability of digital devices. While the provision of devices and stable internet access are basic prerequisites, the successful use of technology in education is not only determined by the devices available. Adequate infrastructure, such as stable internet access and the availability of technological devices in schools, are basic prerequisites for technology to be optimally utilized. However, without the competence of educators to adapt technology to support learning, technology will only become a less valuable tool in the educational process. Educators with good technology skills are better able to utilize various digital platforms and applications to make learning more engaging and interactive. Therefore, capacity building of educators through continuous training is essential to enable them to integrate technology effectively in their teaching methods.

The quality of technology-based learning materials must also be continuously improved to be relevant to the needs of students and in line with the development of science and the world of work. A curriculum that accommodates technology in learning 21st century skills should be designed not only to improve academic understanding, but also to hone students' critical thinking, collaboration, communication and creativity skills. The use of technology can enrich students' learning experience in a more interactive and immersive way, allowing them to collaborate digitally, access various learning resources and develop creative solutions to problems. By ensuring infrastructure readiness, improving educators' competencies, and developing quality learning materials, technology can serve as an effective tool to support an education system that is more adaptive and responsive to the needs of the times.

Furthermore, the successful implementation of technology in education is also greatly influenced by policy support and the surrounding socio-economic factors. The government has a key role to play in designing regulations that enable the adoption of technology equally across all levels of education, including in remote areas that often experience limited access. Without supportive policies, the digital divide in education will further widen social inequality, where only students from better-off families can access technology-based learning. Apart from policy, socio-economic factors such as the level of digital literacy in society are also key determinants in the effectiveness of technology in education.

Digital inclusion programs that engage communities, including parents and students' social circles, are important so that technology is not only applied in the classroom, but also supported in everyday life. parents and the social environment are involved in the digital education process so that technology can be utilized more optimally. The private sector also has a significant role to play in creating a more inclusive technology-based learning ecosystem, both through innovations in more affordable educational software and hardware, and through partnerships with schools to provide training and technical support. With a comprehensive strategy and cross-sector collaboration between the government, educational institutions and the private sector, technology can truly become a transformational tool that accelerates education equity and improves the quality of 21st century skills learning in a more equitable and inclusive manner.

CONCLUSION

Technology has a crucial role to play in supporting the learning of 21st century skills, such as programming, creativity and collaboration. This learning can be more interactive and engaging, utilizing various digital learning platforms that can stimulate students' active participation with technology. However, the effective implementation of technology in education still faces various challenges, including infrastructure limitations, digital access gaps, lack of educator competencies to utilize technology, and socio-economic factors that limit the equitable distribution of learning quality. Without adequate support in terms of policy, funding, and relevant content development, technology cannot optimally function to improve 21st century skills equitably.

Therefore, a more comprehensive and sustainable strategy is needed to overcome these challenges. Governments and educational institutions must collaborate to provide adequate infrastructure, ensure technology training for educators, and develop digital-based curricula that meet the needs of students. It is important to minimize the digital divide by providing more inclusive access to disadvantaged groups. This could include providing affordable devices, subsidizing internet access, as well as developing digital inclusion programs that involve parents and surrounding communities. With these strategic steps, technology can truly be an effective transformation tool to improve the quality and equity of education so that all students, without exception, can develop the skills needed to face the challenges of the future.

REFERENCES

Bebell, D., & O'Dwyer, L. M. (2010). Educational Technology and 21st-Century Skills: A Review of Research Findings. *Journal of Technology, Learning, and Assessment*, 9(1), 5-23.

Boell, S. K., & Cecez-Kecmanovic, D. (2015). On Being 'Systematic' in Literature Reviews in IS. *Journal of Information Technology*, 30(2), 161-173.

Darvin, R. (2019). Youth, Technology, and the Hidden Curriculum of the 21st Century. *Youth and Globalization*, 1(2), 210-229.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2013). Removing Obstacles to the Pedagogical Changes Required by Technology Integration. *Educational Technology Research and Development*, 61(2), 261-284.

Ghavifekr, S., Kunjappan, T., Ramasamy, L., & Anthony, A. (2016). Teaching and Learning with ICT Tools: Issues and Challenges from Teachers' Perceptions. *Malaysian Online journal of educational technology*, 4(2), 38-57.

Grimus, M. (2020). Emerging Technologies: Impacting Learning, Pedagogy and Curriculum Development. *Emerging Technologies and Pedagogies in the Curriculum*, 127-151.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2017). Preparing Teacher-students for Twenty-first-century Learning Practices (PREP 21): A Framework for Enhancing Collaborative Problem-solving and Strategic Learning Skills. *Teachers and Teaching*, 23(1), 25-41.

Hämäläinen, R., Cincinnato, S., Malin, A., & De Wever, B. (2021). The Role of Digital Problem-Solving Skills in the Acquisition of 21st Century Skills. *Computers & Education*, 168, 104-195.

Hilbert, M. (2016). Digital Inequality: Research and Policy of the Digital Divide. *Telecommunications Policy*, 40(6), 568-581.

Kitchenham, B., & Charters, S. (2007). Guidelines for Performing Systematic Literature Reviews in Software Engineering. *EBSE Technical Report*, 1(1), 1-57.

Livingstone, S., & Helsper, E. J. (2007). Gradations in Digital Inclusion: Children, Young People, and the Digital Divide. *New Media & Society*, 9(4), 671-696.

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, 108(6), 1017-1054.

Redecker, C., & Punie, Y. (2017). *European Framework for the Digital Competence of Educators: DigCompEdu*. Publications Office of the European Union

Schmidt, J. T., & Tang, M. (2020). Digitalization in Education: Challenges, Trends and Transformative Potential. *Führen Und Managen in Der Digitalen Transformation: Trends, Best Practices Und Herausforderungen*, 287-312.

Selwyn, N. (2021). *Education and Technology: Key Issues and Debates*. Bloomsbury Publishing.

Snyder, H. (2019). Literature Review as a Research Methodology: An Overview and Guidelines. *Journal of Business Research*, 104, 333-339.

Surve, B. C., & Londhe, B. R. (2020, January). Artificial Intelligence Based Assessment and Development of Student's Non-cognitive Skills in Professional Education Through an Online Learning Management System. In *2020 Fourth International Conference on Inventive Systems and Control (ICISC)*, 329-336.

Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. Jossey-Bass.

Van Dijk, J. A. G. M. (2020). *The Digital Divide*. Polity Press.

Voogt, J., Erstad, O., Dede, C., & Mishra, P. (2013). Challenges to Learning and Schooling in the Digital Networked World. *Journal of Computer Assisted Learning*, 29(5), 403-413.

Warschauer, M. (2004). *Technology and Social Inclusion: Rethinking the Digital Divide*. MIT Press.

Warschauer, M., & Matuchniak, T. (2010). New Technology and Digital Worlds: Analyzing Evidence of Equity in Access, Use, and Outcomes. *Review of Research in Education*, 34(1), 179-225.

Xiao, Y., & Watson, M. (2019). Guidance on Conducting a Systematic Literature Review. *Journal of Planning Education and Research*, 39(1), 93-112.

Zhang, M., Li, Y., & Liu, X. (2022). The Impact of AI-Based Learning Platforms on Student Creativity and Engagement. *Computers in Human Behavior*, 130, 107-194.

***Masnawati, E. & Y. Kurniawan. (2021). Technology Optimization in 21st Century Skills Learning: Infrastructure Challenges and Strategies for Equitable Digital Access, *Journal of Social Science Studies*, 1(2), 131 – 136.**