The Diffusion of Innovation in Utilizing Educational Technology During and After the Pandemic in Elementary Schools

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Abstract
The COVID-19 pandemic brought significant changes to the education system, especially in elementary schools, which transition to online learning as a solution to maintain continuity in education. Technology played a crucial role during the pandemic, providing various platforms and applications that supported remote learning. However, as we move into the post-pandemic period, The use of technology is also evolving in terms of its function, intensity, and application models. This article aims to analyse the adoption process of educational technology used during and after the COVID-19 pandemic in elementary schools. The method used is a literature study of 30 articles indexed in SCOPUS and SINTA. Data were analysed descriptively to identify technology used during the pandemic and post-pandemic periods, as well as to identify the challenges and opportunities that arose in each period. The findings from the literature study indicate that there was a diffusion of innovation in the adoption of technology used in Indonesia during the COVID-19 pandemic, which has continued into the post-pandemic period. The innovation adoption process has impacted the sustainability of open learning with the use of technology as both a learning resource and medium, tailored to current students' needs.

Keywords: Diffusion, Innovation, Learning Technology, COVID-19 Pandemic, Post-Pandemic, Elementary Schools

1. Introduction

The education sector is significantly impacted by the COVID-19 pandemic. Previously conducted through face-to-face interactions, the education system was transformed into distance learning, commonly known as online learning. This approach allows educators and students to engage in the learning process without in person interaction, instead using devices such as smartphones, laptops or computers (Rompegading et al., 2022). Herman et al. (2023) explain that information and communication technology has an important role in supporting the learning process in education. Educational technology provides facilities and enhances productivity through the efficient use and management of resources (Yasin et al., 2023).

The challenge faced by educators today is to identify students' needs and understand the changing conditions from time to time. In the digital era, educators must understand and manage the influence of technological advances and modern lifestyles within their teaching practises to make learning interesting and meaningful (Dasna et al., 2022). To address these evolving challenges, there is a process of adopting the use of technology in learning. Educators need to be aware that their roles in teaching and knowledge transfer must align with current advancements, ensuring that learning alliance with future demands. After the pandemic was brought under control and school started to reopen, technology continued to be integrated into learning, with a focus on hybrid models. This transformation provides an opportunity to integrate technology more effectively in learning, creating an educational model that is more flexible and adaptive to change. The demands of technology, information and communication in the digital era, as well as the development of the industrial

revolution era requires us to keep pace with the times, as technology is now essential for making learning more efficient and effective (Ibda, 2022).

According to research by Deka et al. (2021), titled "*Utilisation of Media in the Online Based Learning Process During the Pandemic at SD Negeri 5 Bengkulu City,"* teachers and students effectively utilised online media, such as WhatsApp in the learning process. Similarly, research by Supardi and Sennen (2022) titled, "*Technology Adoption Strategy in Post-COVID-19 Interactive and Collaborative Learning,"* highlights that distance learning models that incorporating technology became essential during COVID-19 pandemic, despite widespread challenges in adopting technological innovations. In the post-pandemic period, educators are urged to create strategies for adopting technology integrative learning which are considered essential in accordance with current conditions. Based on this description, it is necessary to analyse the process of adopting the use of technology during the pandemic and post-pandemic in elementary schools, as well as identifying the challenges and opportunities faced in each period.

2. Method

The method used in this research is literature study. In this method, researchers collect data from various secondary sources, such as scientific articles, research journals, reports from educational institutions, as well as other relevant academic publications (Safitri, et al., 2023). All references are taken from trusted websites and journals such as Google Scholar, ResearchGate, and journal portal, indexed by national and international institutions (SCOPUS, SINTA, DOAJ). This approach allows researchers to understand the role of technology in education in an in-depth context, especially at the elementary school level, as well as to identify different obstacles, challenges and opportunities between the pandemic and post-pandemic periods. The collected data is organised into several categories as in the following table:

Table 1
Data Organizing

Main Categories	Description
Type of Technology Used	Online platforms, communication applications, hybrid learning, blended learning, Learning Management System (LMS), and social media are used to support the distance learning process .
Function and Effectiveness of Technology	The use of technology to support online learning, facilitate interaction between teachers and students, and provide support for the learning evaluation process.
Challenges and Obstacles	Various obstacles are faced, including technical problems, limited infrastructure, technological skills among students and teachers, as well as parental involvement in supporting the online learning process
Changes in the Post-Pandemic Period	Identify how appropriate technology is used and adapted to support hybrid

Main Categories	Description
	learning models and increase digital literacy among students and teachers.
Technology Adoption Process	Analysis of the five stages of the technology adoption process during the pandemic and post-pandemic period based on Rogers' theory of innovation adoption, which includes stages such as awareness, interest, evaluation, trial, and widespread technology adoption

By using literature study method, researchers can evaluate diverse perspectives and identify general patterns in the adoption of educational technology during and after the pandemic. This research aims to provide a comprehensive understanding of technology's role in education, especially at the elementary school level, as well as to provide recommendations for teachers and education stakeholders to maximise the potential of technology in future learning. The analysis is carried out in several stages, from data collection to literature evaluation, to gain insight into the use of technology in education during and after the pandemic.

Table 2
Analysis Stage

Stages	Description
Data Collection	Collecting relevant articles from journal databases. Keywords such as "educational technology during the pandemic", "hybrid learning", and "diffusion of innovation", "post-pandemic learning", were used to narrow the search.
Data Categorization	Organising data into main categories, namely: type of technology used, effectiveness and function of technology, as well as challenges during the pandemic and post-pandemic.
Descriptive Analysis	Conducting descriptive analysis on each category to describe comparisons of the technology adoption process and identifying patterns of technology used in each period
Literature Evaluation	Evaluating literature to ensure the continuity of adaptive learning and use of technology relevant to post-pandemic conditions.

Stages	Description
Results	Gaining an in-depth understanding of the challenges and opportunities teachers face in implementing technology during the pandemic and post-pandemic.

3. Results and Discussion

Use of Technology During the Pandemic

During the COVID-19 pandemic, technology has become the main instrument for educational continuity. Several important aspects of using technology during the pandemic in elementary schools are as follows:

Online Learning Platform

With the rapid development of technology, many applications have emerged that support activities in the learning process, such a Zoom, Google Meet, YouTube, Kahoot, Quizizz, Google Classroom, and more (Rahmawati et al., 2022). Various online platforms have become essential tools in distance learning (online learning), enabling teachers to deliver instruction both synchronously (live) and asynchronously (recorded material). These platforms allow teachers to present material with flexibility, even with physical limitations. They also enable teachers to provide resources, hold discussions, and assess student work results in real-time (Salsabila et al., 2023).

According to research by Mishra et al. (2020), this online platform allows teachers to interact directly with students, provide quick feedback, and monitor student progress in real-time. This contributes significantly to creating an interactive and responsive learning environment, especially when face-to-face meetings is not possible. Additionally, research conducted by Meduri et al. (2022) shows that the use of website application-based learning tools, such as Google sites show significant potential in increasing students interest in learning. This application can be used as an effective supporting medium, not only in delivering material, but also in providing additional learning resources that can be accessed by students outside school hours. The use of this website helps teachers and students build a more structured and flexible learning experience, which becomes very relevant during the COVID-19 pandemic when learning activities must adapt to distance learning conditions.

Use of Social Media and Communication Applications

During the COVID-19 pandemic, social media and communication applications, particularly WhatsApp and Telegram, were rapidly used as tools for fast communications between teachers, students, and parents. These applications became essential in supporting the online learning process, facilitating the delivery of teaching materials, sending assignments, and providing announcements regarding learning activities and schedules. According to Rompegading et al. (2022), WhatsApp played a crucial role in online learning because it allowed teachers to share teaching materials efficiently and directly. This application is also easily accessible to various groups, making it effective for facilitating educational communication during the pandemic. Additionally, Ds et al. (2022) noted that the group feature of WhatsApp made it easier for teachers to deliver lessons flexibly and in a variety of ways. In these groups, materials such as documents, learning videos, digital textbooks, and voice notes could be shared quickly and easily by the students. Tthese features help teachers deliver lessons in a more dynamic and interactive form, even in a remote setting.

Using WhatsApp as an online learning medium offers various advantageous, such as easy accessibility and cost efficiency. WhatsApp has benefits in terms of saving Internet data and allowing the combination of various learning features, such as text, images, videos, and voice messages, which

supports diverse learning styles (Budiyanti et al., 2021). Another study by Setyaningrum (2021) highlights the improvements of online learning quality during the COVID 19 pandemic through the use of social media platforms like WhatsApp groups and YouTube. This research shows that the use of social media can enhance students learning achievements, with a significant increase in the present age of students reaching the "Very Well Developing" category from the first cycle to the second cycle. This confirms that the effective use of social media can support the online learning process during the pandemic. According to Prasetya et al. (2021), the online learning process during the COVID-19 has become a major shift in the pedagogical competence that elementary school teachers must master. Teachers had to innovate in each learning lesson to keep students engaged and motivated about the material. The online learning process via WhatsApp involves three main stages: communication, material delivery, and assignment collection. Teachers maintain interaction with students to achieve optimal learning outcomes by using various supporting applications.

However, there are several challenges in using WhatsApp as an online learning platform. For example, limited face to face interaction can affect the quality of learning, as it does not occur directly or in real time. Additionally, because WhatsApp is not specifically designed for educational purposes, its features may not be sufficient for more complex learning needs. This contrasts with specially designed platforms, such as Learning Management Systems (LMS) or video conferencing applications which offer interactive and structured learning features.

Challenges

The main obstacle faced in using technology during the pandemic is limited Internet access and devices. Many students from low-income families struggle to participate in online learning because they do not have adequate devices (Gunawan & Amaludin, 2021). Additionally, limited internet access, particularly in rural areas, further hinders the use of technology during the pandemic. Not all students have the proper devices to engage in online learning, and teachers were less familiar with technology also face difficulties in using learning platforms (Hasanah, 2021). Moreover, parental involvement is crucial, as many students are not independent in participating in online learning. This issue is echoed by Ds et al (2022), Who explained that the use of technology during the COVID-19 pandemic was hindered by factors such as students lacking cell phones, parents not understanding technology, inadequate internet networks, and teachers lack of proficiency in online learning. The role of teachers and parents in online learning during the COVID-19 pandemic has been critical. "The challenges faced include limited access to technology, low understanding of technology among parents, and the need for more intense interaction between teachers and parents to support students learning process " (Al Hakim & Azis, 2021).

According to research by Lumbantobing et al. (2020), online learning during the COVID-19 pandemic faced several significant challenges. One of the main obstacles was limited access to internet and devices among students, particularly those from low-income families. Many students struggled to participate in online learning because they lacked adequate devices, such as laptops or smartphones, and stable Internet access. This issue was further exacerbated in rural areas, where network infrastructure was patchy, leading to unstable or even unavailable internet connections. Another challenge was the technology skills of teaching staff. Teachers who were less familiar with digital technology faced difficulties operating online learning platforms, such as video conferencing applications or Learning Management System (LMS), which required a solid technical understanding. This difficulty slowed down the adaptation process and reduced the effectiveness of the expected interactive learning. Despite these challenges, the situation also provided opportunities for teachers to develop new skills in using technology and to create more flexible learning methods tailored to student's needs (Paseleng & Sanoto, 2021).

Use of Technology in the Post-Pandemic Period

With the pandemic easing, most elementary schools in Indonesia have returned to face-to-face learning, but technology continues to play a role as a learning support. In the post-pandemic era, technology is used with a more structured and planned approach, including:

Hybrid Learning and Blended Learning

Hybrid learning, which combines face-to-face and online learning, has become an ideal and adaptive model for meeting diverse learning needs. In this model, technology plays a crucial role as the main supporting tool, which allows students who are unable to attend in person to participate in lessons from home. It also provides flexibility for students who need additional time to grasp the material presented (Yunus & Hidayat, 2022).

There is a difference between hybrid learning and blended learning. Hybrid learning refers to a model that integrates face-to-face and online learning simultaneously, while blended learning places greater emphasis on combining face-to-face learning with the use of online technology as a supplementary tool in the teaching and learning process (Sulthoniyah et al., 2022). The implementation of these two models in elementary schools depends largely on the available technological infrastructure. Schools with internet access can implement a hybrid E-learning model, while schools that do not have an internet network, blended learning can be carried out offline using previously downloaded media (Wulandari et al., 2021).

Learning Management System (LMS)

LMS platforms such as Moodle and Edmodo are increasingly being adopted by elementary schools as systems that facilitate assignment distribution, storage of teaching materials, and assessment management. LMS also allows students to access teaching materials at anytime, promoting more independent and personalised learning (Budhayanti, 2023). The implementation of LMS technology in elementary schools also involves appropriate pedagogical approaches, such as TPACK (Technological Pedagogical Content Knowledge). This approach is designed to help teachers integrate technology effectively into their teaching, thereby enhancing the quality of learning (Yulhendri et al., 2023).

Meanwhile, Dewi et al. (2023), explained that the use of LMS in elementary schools is highly relevant to current technological developments, given its benefits, such as supporting effective individual learning in basic education and creating interactive and enjoyable learning experiences for students. The use of an LMS promotes a more engaging and enjoyable learning experience, providing opportunities for students to become more involved in their learning while developing digital skills from an early age. Additionally, the benefits of LMS in supporting students skill development through various and engaging activities are seen as effective in increasing learning motivation, which can lead to improved and higher quality learning outcomes.

Increasing Students and Teacher Digital Literacy

Increasing digital literacy among students and teachers is a primary focus in the post-pandemic era, with technology serving as a tool to strengthen basic digital skills essential for students future development (Hermawan et al., 2021). Digital literacy is now considered as a crucial competency, especially as the demand for digital skills grows in response to global challenges and the fulfilling dynamics of the digital workforce. According to Salsabila et al. (2024), digital literacy improvement programmes that involve teacher training led to significant changes in students technology usage skills. The research shows that students engaged in technology-based learning not only experience improvements in technical skills but also demonstrate higher motivation and engagement in the learning process, which positively impacts overall learning outcomes.

In addition, increasing digital literacy does not only focus on the ability to operate digital devices, but also on the critical ability to use and manage information wisely. Romadloni et al. (2024) revealed that efforts to enhance digital literacy among teachers and students should

be viewed as part of creating a learning environment that is more collaborative, adaptive, and responsive to changing times. With strong digital literacy, students and teachers are able to utilise technology for scientific exploration, collaborate more effectively, and build critical thinking skills needed to face future challenges.

Application of Augmented Reality (AR), Virtual Reality (VR) technology, interactive learning applications, and e-learning platforms

The application of Augmented Reality (AR) and Virtual Reality (VR) technologies in education, especially in elementary schools, has shown significant potential to enhance the learning experience. This technology is not only enriching teaching methods but also foster student engagement and mastery of the material. Additionally, teachers increasingly use AR and VR to boost students motivation and interest in learning, helping them grasp concepts more easily, solve scientific problems more effectively, and strengthen their understanding. Moreover, students can learn according to their individual needs and develop the ability to learn independently (Fatimah et al., 2024). This aligns with the findings of Ratu & Talakua (2024), who reported that AR based Android application can help visualise spatial shapes with curved sides more interactively, making it easier for students to understand and visualise these shapes while increasing their interest in learning. Overall, the application of AR and VR in elementary education offers an innovative approach to more interactive, engaging, and effective learning. With the right implementation strategy, this technology has the potential to revolutionise the way students learn and understand world around them.

Meanwhile, E-learning is widely used to support the learning process as advances in time and technology create learning patterns that require adjustments in educational innovation. E-learning facilitates easier access to information for both teachers and students, helping teachers organise lessons more effectively (Puspitoningrum et al., 2024). E-learning relies on various technology-based learning media, such as animated videos and multimedia presentations. These media not only capture students attention but also make it easier to understand the material (Cipta et al., 2023). The integration of E-learning in elementary schools is a crucial step in adapting to 21st century technological advancements. By effectively utilising information technology, education at the elementary level can be enhanced, preparing students for the challenges of an increasingly digital future. Through this innovative approach, it is hoped that students will not only become consumers of information but also creative and critical content creators.

Challenges Faced

The main challenge in the post-pandemic period is securing funding for the procurement of additional technological devices and training for teachers to effectively utilise technology in hybrid learning. Other challenges in implementing technology include limited technological infrastructure in schools, unstable Internet connections, and a lack of teachers readiness and skills in adopting and integrating technology into learning (Fatimah et al., 2024). Despite the numerous benefits, there are additional challenges such as a dependence on traditional teaching methods. The solution to this problem lies in teacher training and the development of engaging teaching materials (Nirmala et al., 2024).

Limited access to adequate infrastructure such as Internet networks and online learning tools, particularly in remote areas, remains the main obstacle in post-pandemic learning, especially in the implementation of hybrid learning. This results in some students experiencing difficulties in participating fully in learning. In implementing hybrid learning, teachers face new challenges that require specialised training to integrate technology effectively into the learning process. Teachers need trainings to create content that is relevant and tailored to

student's needs, ensuring that instructional goals are successfully achieved (Rusyada & Nasir, 2022).

Technology Adoption Process during the Pandemic and Post-Pandemic Period

The use of technology during the pandemic and post-pandemic reveals noticeable differences in the way learning was implemented. The comparison of technology used during the pandemic and post-pandemic is shown in the following table:

Table 3
Comparison of Technology Utilization

Aspect	During Pandemic	Post-Pandemic
Learning Model	Online with technology as the main solution	Hybrid learning with technology as complementary
Main Platform	Zoom, Google Classroom, WhatsApp	LMS, YouTube, social media for digital literacy, augmented reality (AR), virtual reality (VR), interactive learning app, and E-learning platforms
Main Challenge	Limited Internet and device access lack of understanding from parents and teachers	Funding and training for teachers, as well as teachers readiness in adopting and integrating technology in learning
Teachers Roles	Online learning facilitator	Digital literacy and independent learning mentors
Parents Roles	Actively involved in supporting online learnin.	Limited to digital literacy support

Based on the table comparing the use of technology during the pandemic and post-pandemic, it is clear that there are significant differences in its use. During the pandemic, technology was primarily utilised to support distance learning (online), while in the post-pandemic period, technology served as both a medium and a resource to enhance in person classroom learning. The main platforms used during the pandemic were limited to general technologies such as Zoom, Google Classroom, and WhatsApp. In contrast, the post-pandemic period saw a greater variety of platforms being employed.

This reflects the process of innovation adoption by teachers from the pandemic to the post-pandemic period, here the use of technology in education has significantly increased. According to Rogers, the diffusion of innovation occurs through a communication process that involves specific channels within a certain time span between members of a societal system (Winaputra et al., 2016). In this context, the COVID-19 pandemic acted as the primary driver

that accelerated the communication and dissemination of information regarding educational technology. In the post-pandemic era, teachers have become more open to using technology in learning because they have recognised it significant benefits and importance for developing students skills. Technology is no longer viewed as just an additional tool but as an essential component to support effective and relevant teaching and learning processes, helping to form a generation that is prepared to face future challenges. This awareness has motivated teachers to more actively explore and adopt new technologies that enhance learning and adapting their teaching methods to ensure students develop the necessary digital competences.

The following table outlines the connection between the use of technology during and post-pandemic in relation to Roger's theory of diffusion of innovation, which explains that the process of adopting an innovation by recipients goes through five stages, (Suciati et al., 2022) namely:

Table 4
Rogers Adoption Process Stages During the Pandemic and Post-pandemic Period

Five Stages of the Adoption Process (Rogers)	Adoption Process During the Pandemic and Post-Pandemic Period
Awareness of the existence of certain innovations	At this stage, teachers during the pandemic already know about technological innovations for learning, but they do not understand how to use this technology and are hampered by limited Internet and supporting devices.
Interest Arises	At this stage, teachers during the pandemic begin to become interested and try to find out about innovative uses of technology to support distance learning activities.
Evaluate innovation	At this stage, teachers make the decision to use technological innovation in learning because they consider the needs and conditions during the pandemic
Innovation Trial	At this stage, teachers in the post-pandemic period are more open to technological media and begin to utilise technology that is integrated with learning. Then, when the independent curriculum appeared, teachers followed the decision to continue using technological vision in learning because they felt it was in line with the demands of the times.

Five Stages of the Adoption Process (Rogers)	Adoption Process During the Pandemic and Post-Pandemic Period
Full adoption	At this stage, teachers use technological innovation in learning continuously and are integrated according to learning. Teachers are increasingly open to various kinds of learning technology innovations to support students' needs.

The table above shows that the process of adopting technology in education has continued seamlessly from the pandemic into the post-pandemic period, with technology adoption strategies evolving and improving. Educators, students, and parents have become more receptive to using technology for learning activities due to a more open attitude towards technology and a recognition of its benefits in preparing for future challenges. The role of teachers in leveraging technology has also expanded; they now act not only as facilitators but also as mentors for digital literacy and independent learning. Teachers have gained valuable insights from rapidly advancing technological innovations which they can now incorporate into 21st century learning for students.

This research aims to encourage meaningful changes in education by promoting the effective and efficient use of technology. The strategy for adopting technology is advancing with encouragement from the government which has promoted many technology-based teacher training programmes in learning. The role of schools and learning communities is also important in making innovative uses of technology in the world of education. With their support, existing obstacles can be addressed, allowing for more optimal implementation of technology adoption

4. Conclusion

The transformation of technology in elementary education in Indonesia has been strongly influenced by the COVID-19 pandemic. During the pandemic, technology served as an emergency solution to support distance learning (online), with significant access limitations. Meanwhile, in the post-pandemic era, the use of technology is more focused on hybrid learning and digital literacy. Face-to-face learning remains dominant, but with technology support to facilitate flexible and adaptive access to knowledge. This shift supports the diffusion of innovation in adopting technology in Indonesian education. Technological advancements have broadened teachers perspectives on integrating learning in ways that meet students' needs and align with contemporary demands. In the post-pandemic era, the potential for technology in education is substantial. Thus, supporting infrastructure, teacher training and strengthening students digital literacy should be prioritised in educational policy to ensure sustainable adoption of technological innovation.

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