Digital Transformation of Learning In Madrasahs: Leveraging IoT For The Future of Education 5.0 In Kabupaten Bandung

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ABSTRACT

The digital transformation era has brought significant changes across various aspects of life, including the education sector. This article explores the utilization of the Internet of Things (IoT) in the learning process at madrasahs in Kabupaten Bandung. By integrating IoT technology, these madrasahs have created more interactive, efficient, and responsive learning environments that cater to students' needs. This research employs a qualitative approach, using case studies of several madrasahs implementing IoT in their educational processes. The findings reveal that IoT implementation not only enhances the quality of education but also prepares students to face challenges in the Industry 5.0 era. Moreover, IoT adoption in madrasahs has facilitated more efficient management of educational resources, such as student attendance monitoring, energy management, and learning environment supervision. The article also discusses the challenges and barriers to IoT implementation, such as infrastructure limitations and educators' digital literacy. Additionally, the study highlights the role of IoT in fostering a more personalized learning experience, enabling educators to tailor instruction to individual student needs. Thus, this article provides insights into the importance of digital transformation strategies in education and how IoT can be optimized for a better future in education in Kabupaten Bandung. The study underscores the necessity for ongoing support and training to ensure the successful integration of IoT in educational settings.

Keywords: Internet of Things (IoT), Digital Transformation, Education 5.0.

1). INTRODUCTION

Era 5.0, or Society 5.0, emphasizes integrating advanced technology with humans as its centre to create harmony between technology and human needs (Calp & Bütüner, 2022). This era supports digital transformation in education, which is now an urgent need along with the rapid development of information technology (Bygstad et al., 2022). This transformation aims to build an education ecosystem that is more inclusive, adaptive, and responsive to change and improve the quality of

education (McCarthy et al., 2023). Technologies like the Internet of Things (IoT) are essential in transforming digital education.

IoT is a network of physical devices connected via the internet, enabling the collection and sharing of data in real-time without direct human interaction (Tran-Dang et al., 2020). IoT increases efficiency and effectiveness in education by unifying learning environments, managing energy, and supporting security (Tomazzoli et al., 2023). IoT also promotes interactive learning, such as sensor-based educational tools and e-learning platforms that adapt materials to student needs (Alhazmi et al., 2022). In madrasahs, IoT enables a more adaptive and modern learning environment, facilitating school management, data-driven learning, and a more engaging and relevant learning experience (Adhicandra et al., 2024).

Madrasahs continue to innovate despite the constraints of limited infrastructure, resources, and access to technology. They adopt technologies such as IoT and innovative learning methods to create a more engaging learning environment (Musolin et al., 2024). These efforts include staff training, interactive material development, and technology implementation based on available resources (Saniuk et al., 2023). With dedication and innovation, madrasahs prepare students for the future despite limited conditions. Many schools in Bandung Regency face limitations that affect the quality of education, including technological infrastructure issues and limited budgets (Aisah et al., 2021). These challenges are exacerbated by the need for staff training and resistance to change (Endrejat et al., 2021). Government support, collaboration with other institutions, and ongoing training are needed to overcome these challenges (Nsanzumuhire & Groot, 2020). Despite the challenges, there is an excellent opportunity to integrate IoT technology to support digital transformation and improve the quality of education in madrasahs (Mahsusi et al., 2024).

The Ministry of Religious Affairs has initiated a digital transformation program to improve the quality of education in madrasahs by implementing advanced technologies such as IoT (Mahsusi et al., 2024). This program modernizes the learning process and school management, focusing on technology access, teacher training, and infrastructure development (Abuselidze et al., 2022). Support is provided in the form of hardware and educational information systems, and the digital capacity of madrasahs is increased (Santosa & Jazuli, 2022). Although facing budget and infrastructure limitations, this program opens up opportunities to accelerate technology adoption, improve the quality of education, and prepare students for future challenges (Indrawati & Kuncoro, 2021). Previous research

provides essential insights into digital transformation and technology integration in madrasahs, including potential challenges (Falahuddin, 2022). The studies discuss technology adoption, the concepts of "digital natives" and "digital immigrants," and the need to adapt teaching methods (Kesharwani, 2020). Several studies highlight challenges such as teacher infrastructure and training and how IoT can improve the learning experience and teaching efficiency (Rana & Rana, 2020). Studies in Indonesia, including in Bandung Regency, identify challenges in technology access and training in madrasahs, providing an in-depth understanding of IoT implementation locally.

This study has several unique features that set it apart from previous studies. First, it explores the adoption of the Internet of Things (IoT) in madrasahs, a new area in the digitalization of education in Indonesia, focusing on the specific needs of faith-based institutions. Second, it highlights Bandung Regency, providing a rarely explored local perspective and identifying particular challenges and opportunities for madrasahs related to IoT implementation. The study also prioritizes student well-being, personalization of learning, and accessibility in line with the principles of the 5th Industrial Revolution (Adel, 2024). It evaluates the readiness of infrastructure and competency of teaching staff in madrasahs. In addition to providing data-driven recommendations for IoT policies and implementation models, this study offers new insights into integrating technology in religious education.

This study explores the Internet of Things (IoT) use in madrasahs in Bandung Regency, assessing its impact on creating a more interactive, efficient, and student-centred learning environment (Annur & Febriansyah, 2023). Through qualitative case studies, the research demonstrates how IoT can enhance education quality and prepare students for the challenges of the Industrial Revolution 5.0 (Erlinawati et al., 2019). It also evaluates IoT's role in managing educational resources and addresses challenges like infrastructure limitations and educators' digital literacy (Tlili et al., 2021). The study highlights the importance of digital transformation in education, provides an IoT implementation model for other madrasahs, and offers strategies to overcome challenges to support digital policies and inspire future research in this area.

2) METHODS

This study aims to explore the application of Internet of Things (IoT) technology in the learning process at madrasahs in Bandung Regency, focusing on the challenges and opportunities faced in integrating this technology. The methodology used is a qualitative approach through case studies, allowing researchers to understand how IoT can be implemented in religious-based education (Mustari & Rahman, 2020). This study was conducted in several madrasahs that have adopted IoT technology, selected based on disparities in access to technology and the potential for IoT application in the area. The research participants consisted of madrasah principals, teachers, and students (Zaini et al., 2023). In-depth interviews were conducted with madrasah principals and teachers to understand their views on implementing IoT and the challenges and expectations for this technology (Khusnood et al., 2020). In addition, students were involved through focus group discussions to gain their perspectives on learning experiences influenced by technology (Tümen Akyildiz, 2020; Yates et al., 2021). By involving various stakeholders, this study seeks to provide a comprehensive picture of the conditions needed for successful IoT integration in madrasahs.

Data were collected through interviews, observations, and questionnaires. Interviews were conducted in a semi-structured manner, allowing researchers to dig deeper into the experiences and views of participants (Ruslin et al., 2022). Observations were conducted in the classroom to see firsthand how IoT technology is applied to learning. A questionnaire was used to collect quantitative data on the level of digital literacy and technology accessibility among students and teachers (Abichandani et al., 2022). Data analysis was conducted using a thematic analysis approach, where key themes were identified from qualitative data and linked to quantitative data (Christou, 2022). The validity and reliability of the study were ensured through data triangulation, where information from multiple sources was compared to ensure consistency (Santos et al., 2020). In addition, member checking was conducted by asking participants to review the study's initial findings so they could provide feedback and ensure that their opinions were accurate. The principles of research ethics were also adhered to by obtaining informed consent from all participants and guaranteeing the data collected.

The study results are expected to provide in-depth insights into how IoT can improve the quality of education in madrasahs, creating a more interactive, efficient, and responsive learning environment to students' needs (Maulidin et al., 2024). This study also aims to identify challenges that are applied

in implementing IoT, such as infrastructure limitations and educators' level of digital literacy (Falloon, 2020). This study can provide data-based recommendations for educational policies and effective IoT implementation models by understanding these challenges (Albreem et al., 2021). In addition, this study is expected to be a source of inspiration and reference for further studies in the digitalization of education and IoT technology. By combining technology with Islamic teaching, this study provides new insights into integrating technology in religious education, which needs to be explored in the existing literature. Thus, this study contributes to the development of science and provides practical benefits for madrasahs in facing the challenges of the Industrial Revolution 5.0 era. Through the application of IoT, madrasahs are expected to increase the efficiency and effectiveness of learning and prepare students to face future challenges with relevant and modern skills.

3) RESULTS AND DISCUSSION

The results of this study indicate that implementing Internet of Things (IoT) technology in madrasahs in Bandung Regency has excellent potential to improve the quality of education but is also faced with various limitations that affect its effectiveness. The findings from the questionnaire indicate that integrating IoT in learning in madrasahs can create a more interactive, efficient, and responsive learning environment for student needs. However, the effectiveness of this implementation is greatly influenced by several limiting factors that must be considered.

First, the condition of the technological infrastructure in many madrasahs is still a significant obstacle. Many madrasahs in Bandung Regency need help with problems related to adequate hardware and software availability and stable internet connectivity. These limitations have an impact on the ability of madrasahs to utilize IoT technology optimally. Inadequate infrastructure limits the use of more sophisticated IoT devices and causes disruptions in the implementation of technology-based learning processes.

Second, the readiness and training of teaching staff are also essential factors that affect the implementation of IoT. Although some teachers have received training in the use of technology, many educators still feel they need more preparation and comfort in integrating IoT into their teaching methods. These limitations include a need for more understanding of new technologies and difficulties adapting the curriculum to existing digital tools. Therefore, ongoing training and technical support are essential to address these challenges.

Third, student responses to IoT indicate benefits in terms of interactivity and personalization of learning. However, the questionnaire results also indicate variations in student acceptance of the technology. Some students showed increased motivation and engagement in learning. In contrast, others needed help adapting to new technologies, especially if they needed to familiarize themselves with digital devices or if there was instability in access to technology. In addition, the study found that educational resource management, such as student attendance monitoring, energy management, and monitoring of the learning environment, can become more efficient with the adoption of IoT. However, more technical support limitations can be needed to improve the features' full benefits. Many madrasahs still rely on manual methods and require more automated systems that can improve managerial efficiency.

In the broader context of digital transformation, the results of this study emphasize the need for ongoing support and training to ensure successful IoT integration in madrasahs. To achieve maximum results, efforts must be made to address infrastructure limitations and improve the competence of teaching staff through more comprehensive training programs. The study also suggests developing better digital policies and strategies should include plans to address these challenges systematically. Overall, this study shows that while the implementation of IoT in madrasahs offers excellent potential to improve the quality of education, challenges of infrastructure, educator training, and student adaptation must be addressed to maximize the benefits of this technology in supporting more effective and efficient learning.

RESEARCH RESULT

Measured Criteria	**Knowledge and Understanding of IoT**	**Implementation of IoT in Madrasah**	**Impact of IoT on Digital Transformation**	**Challenges in IoT Implementation**	**Expectations for IoT Development in the Future**
Percentage	77.07317	68.90244	84.14634	84.87805	82.92683

This study focuses on digital transformation in learning in madrasahs by utilizing the Internet of Things (IoT) as an innovative means for the future of education. Based on the study's results, several main criteria have been measured to assess how IoT has influenced education in madrasahs in

Bandung Regency. The questionnaire results show that teachers and students in madrasahs have a 77.07% knowledge and understanding of IoT. This shows that most students and teachers already have a basic understanding of IoT technology, although there is still room for improvement, especially in terms of understanding the practical application of IoT in education.

Implementation of IoT in Madrasahs shows a percentage of 68.90%. This figure reflects that although there is a desire to implement IoT in the learning process, the realization in the field is still in the development stage and needs to be fully optimal. This may be due to several factors, including limited resources, infrastructure, or technical knowledge. Respondents stated that the Impact of IoT on Digital Transformation IoT has been shown to have a significant impact on digital transformation in madrasahs with a percentage of 84.15%. These results show that in madrasas that have begun to integrate IoT, there has been an increase in the quality of learning and operational efficiency. IoT technology enables automation, more effective data collection, and a more interactive and personalized student learning experience.

As for the challenges felt by education actors in madrasas, which significantly affect implementation in madrasas, the Challenges in IoT that occurred in the study recorded a figure of 84.88%. These challenges include inadequate technological infrastructure, resistance to change, budget constraints, and the need to improve competence among teachers and students. However, there is much hope for the development of IoT in the Future. There are very high hopes for the development of IoT in the Future, with a percentage of 82.93%. This reflects the optimism of stakeholders in madrasas towards the potential of IoT to continue to improve the quality of education, expand access to learning, and encourage innovation in teaching in the Future.

DISCUSSION

This study highlights the importance of utilizing the Internet of Things (IoT) in the digital transformation of learning in madrasahs. As one of the innovative technologies, IoT offers great potential to revolutionize teaching and learning methods, making them more interactive, efficient, and data-driven. This study reveals that the implementation of IoT in madrasahs in Bandung Regency has had a significant impact, although several challenges still need to be overcome. Based on the questionnaire results, the knowledge and understanding of teachers and students in madrasahs regarding IoT is at 77.07%. This percentage shows that most students and teachers have a fairly good

basic understanding of IoT technology. This is a positive indication that IoT technology is starting to be recognized and understood as an important part of digital transformation in education. This level of understanding shows that efforts to introduce IoT in educational environments have begun to bear fruit. Teachers and students are starting to recognize the basic concepts of IoT, such as devices that can be automatically connected via the internet network and how this technology can be used to support the learning process. This sufficient basic understanding is an essential foundation for developing further skills to integrate IoT into teaching and learning activities effectively. Although the results show significant progress, the percentage of 77.07% also indicates considerable room for improvement, especially in understanding the practical applications of IoT in education. Most of the understanding is still conceptual and has yet to be fully translated into everyday practice in the classroom. For example, an understanding of how IoT devices can be used to collect real-time student learning data or how IoT can be integrated with the curriculum to create a more interactive learning experience. Improving the understanding of the practical applications of IoT is essential to ensure that this technology can truly bring real benefits to the learning process. Teachers need to be trained more on how to apply IoT in the context of teaching, such as using IoT sensors for science experiments or using smart devices for collaborative projects. Students also need to be guided to understand how IoT can be used in their daily lives, especially in the context of education, so that they can become active participants in this digital transformation. To achieve this improvement, a strategy that includes intensive training for teachers, curriculum development that provides for the use of IoT, and adequate resources for IoT implementation in the classroom is needed. In addition, a more practical approach to IoT learning, such as IoT-based projects or technology labs, can help students and teachers translate their theoretical knowledge into practical skills. The implementation of IoT in madrasas, with a recorded percentage of 68.90%, shows that integrating this technology into education is still in the development stage. Although various parties have a strong desire to utilize IoT in learning, the realization in the field has yet to be fully optimal. This indicates that although the foundation has been laid, many challenges still need to be overcome to ensure a wider and more effective implementation of IoT. The figure of 68.90% reflects that most madrasas have begun to adopt IoT technology, but its implementation still needs to be fully integrated into daily learning. Many madrasas are only in the early stages of using IoT devices, such as sensors or smart devices, for specific purposes, such as

monitoring or experimental activities. However, the use of IoT as a comprehensive and structured learning tool is still in the development process.

One of the main factors hindering IoT implementation optimization in madrasahs is limited resources and infrastructure. IoT implementation requires a significant investment in hardware, such as sensors, a stable internet network, and compatible computer devices. In addition, the technological infrastructure needed to support IoT connectivity is often only evenly available in some madrasahs, especially in more remote areas. This limitation is a major barrier to IoT's effective and comprehensive implementation. In addition to infrastructure, limited technical knowledge is also an obstacle to IoT implementation. Teachers and education personnel in madrasahs may need help understanding how to operate and integrate IoT technology into learning. Although there is a desire to implement IoT, the implementation process can only be effective with sufficient knowledge. Intensive and ongoing training is needed to ensure that teachers not only understand the basic concepts of IoT but can also utilize them to improve the quality of learning. To improve the implementation of IoT in madrasahs, a holistic and targeted development strategy needs to be implemented.

Steps that can be taken include:

- Increasing investment in technological infrastructure.
- Providing more in-depth technical training for teachers and students.
- Developing a curriculum that explicitly includes the use of IoT.

In addition, partnerships with the private sector and government to gain support for resources and expertise can also help accelerate the IoT implementation process. Although the current implementation of IoT still needs to be optimal, the potential for the future is enormous. With the development of technology and increasing understanding of the importance of IoT in education, madrasahs have an excellent opportunity to become centers of innovation in digital learning. If the existing challenges can be overcome, IoT can serve as a powerful tool to increase student engagement, personalize learning, and prepare students for an increasingly digital workforce. However, much more must be done to ensure this technology can be used effectively. By overcoming the existing challenges, madrasahs can leverage IoT to improve the quality of education and support the ongoing digital transformation.

The impact of IoT on digital transformation in madrasahs reveals that this technology significantly influences the quality of education. With a percentage of 84.15%, this study confirms that in madrasahs that have started integrating IoT, there has been an improvement in various aspects of learning and operations. IoT is a technological tool and a significant driver of fundamental changes in education and management in the educational environment.

The implementation of IoT in madrasahs has had a real impact on improving the quality of learning. By utilizing IoT devices, such as sensors and connected devices, teachers can create more interactive and contextual learning experiences. For example, using sensors in science labs allows students to conduct experiments more accurately and in real-time, while smart devices support collaborative project-based learning. IoT also enables access to a broader range of digital educational resources so students can learn at their own pace and learning style. In addition to improving the quality of learning, IoT also plays a role in increasing operational efficiency in madrasahs. IoT technology enables the automation of various administrative tasks, such as managing student attendance, monitoring facility usage, and managing school resources. With IoT, data that previously had to be collected and analyzed manually can now be obtained and processed automatically, reducing administrative workload and allowing staff to focus on more critical aspects of education. This efficiency also means that madrasahs can better allocate resources, improving overall operational effectiveness.

One of the critical advantages of IoT is its ability to collect and analyze data in real time. In schools, this data can be used to monitor student performance, identify learning patterns, and assess the effectiveness of teaching methods. This more effective data collection allows schools to make more informed decisions based on evidence and tailor learning approaches to students' needs. Data collected through IoT can also be used to design more targeted intervention programs, which can help students who need additional support. IoT enables the development of more interactive and personalized learning experiences. With this technology, students can engage in more engaging and participatory learning. For example, IoT devices can create simulations that allow students to explore abstract concepts visually and interactively. In addition, IoT enables more personalized learning by automatically adapting to each student's learning needs, ensuring that each student receives the attention that is appropriate to their abilities. IoT is changing the way learning is conducted and moving schools towards a more data-driven approach to learning. With data obtained from IoT

devices, teachers can better understand students' needs and progress, allowing for a more individualized and results-oriented approach. This transformation brings madrasah education closer to a modern and adaptive education model, where decisions are based on evidence and learning outcomes can be optimized. This study shows that IoT significantly impacts digital transformation in madrasahs. With the implementation of IoT, madrasahs can improve the quality of learning, increase operational efficiency, and provide a more interactive and personalized learning experience for students. The potential of IoT in education is enormous, and with proper management, this technology can continue to support the development of education that is more advanced and responsive to the challenges of the times.

The challenges faced in implementing the Internet of Things (IoT) in madrasahs reveal that although the potential of this technology is very large, the realization of its implementation is still possible. The study noted that education actors felt this challenge, with a percentage of 84.88%, indicating that most madrasahs still face significant obstacles in integrating IoT into their learning and operational processes.

One of the main challenges faced in implementing IoT in madrasahs is inadequate technological infrastructure. Many madrasahs, especially those in remote or resource-limited areas, still lack access to stable internet connections, compatible hardware, and other essential supporting facilities to support an IoT ecosystem. With adequate infrastructure, the full potential of IoT can be realized, preventing madrasahs from implementing this technology effectively.

Resistance to change is also a significant challenge. IoT implementation requires a change in the way we think and approach education, which often faces resistance from those who are used to traditional methods. Teachers, students, and even school administrators may be reluctant to adopt new technologies due to the uncertainty or discomfort that the change brings. This resistance can slow the IoT adoption process and reduce the effectiveness of its implementation in madrasahs.

Another challenge is budget constraints. IoT implementation requires a significant initial investment to purchase devices, develop infrastructure, and train teachers and students. Many madrasahs have limited budgets, making it difficult to set aside sufficient funds for these needs. Even when there is a willingness to invest in technology, limited funds are often a significant barrier that hinders full IoT implementation.

The need to build competency among teachers and students is also a significant challenge. IoT is a relatively new technology in education, and many teachers and students still need to gain the skills or knowledge to use this technology effectively. More in-depth and ongoing training is required to ensure that all parties involved can understand and operate IoT devices and integrate them into the learning process correctly and efficiently.

To overcome these challenges, a comprehensive and collaborative strategy is needed:

1. Improving technological infrastructure must be a priority, with a focus on improving internet access, providing adequate devices, and developing other supporting facilities.
2. A training program specifically designed to help teachers and students overcome resistance to change and improve their competence in using IoT is needed.
3. Budget constraints can be addressed through partnerships with the government, private sector, and non-profit organizations that can provide financial support and resources.
4. To reduce resistance and encourage wider adoption, awareness and education campaigns on the benefits of IoT in education must be strengthened.

While the challenges are significant, potential innovative solutions can also be explored. For example, developing an IoT learning model that does not require sophisticated infrastructure can help madrasahs in areas with limited resources. In addition, a community-based learning approach can encourage collaboration between madrasahs, local governments, and communities to overcome infrastructure and resource constraints jointly. Although the challenges in implementing IoT in madrasas are quite significant, with a percentage of 84.88%, strategic and collaborative steps can help overcome these obstacles. With the right approach, madrasas can overcome these challenges and harness the full potential of IoT to improve the quality of education and accelerate digital transformation in their educational environment. Despite the challenges and obstacles, many hopes are pinned on the use of IoT in education in madrasas.

The hope for the future development of IoT in madrasas shows strong optimism among stakeholders. With a percentage of 82.93%, the results of the study reflect the belief that IoT technology has excellent potential to bring about broader and deeper positive changes in the world of education, especially in the madrasa environment. This hope is rooted in various factors that indicate that IoT can be a significant tool in improving the quality of teaching and innovation in the future.

One of the main reasons behind the high hopes for the development of IoT is the belief that this technology can significantly improve the quality of education in madrasas. IoT offers a variety of tools and platforms that can enrich the learning process, from the use of smart devices that can be customized to the needs of individual students, to a more accurate and comprehensive data-based evaluation system. With the rapid development of technology, IoT can help madrasas continue to update their teaching and learning methods, ensuring that students always get relevant and quality education.

In addition to improving quality, IoT is also seen as a solution to expand access to learning, especially in areas that are difficult to reach or have limited infrastructure. IoT technology enables distance and collaborative learning, connecting not only students and teachers within one madrasah but also across schools and even across regions. With IoT, madrasahs can provide learning materials that are accessible anytime and anywhere, allowing more students to receive quality education even in remote locations.

High hopes also arise from the potential of IoT to drive innovation in teaching. With IoT, teachers can develop more creative and interactive teaching methods tailored to technological developments and the needs of today's students. For example, IoT can support virtual reality (VR) and augmented reality (AR) in the classroom, creating a more profound and immersive learning experience. In addition, IoT also enables the development of a more dynamic curriculum, where learning materials can be updated in real time based on data and feedback obtained from the use of IoT devices.

Stakeholders in madrasahs also hope that over time, the technological infrastructure needed to support IoT will improve, and the competence of teachers and students in utilizing this technology will continue to increase. With government, private sector, and education community support, madrasahs can overcome existing obstacles, such as limited resources and technical knowledge, so that IoT can be implemented more optimally throughout madrasahs.

Another expectation is that IoT will be critical in accelerating digital transformation in madrasahs. As technology advances, IoT can help madrasahs adopt more sophisticated and efficient digital systems in the learning process and overall school management. This includes managing student data, administration, and using resources more effectively and efficiently. This digital transformation is

expected to increase the competitiveness of madrasahs and prepare students to face challenges in the digital era. The potential for partnerships and collaborations between madrasahs and other parties, such as technology companies, governments, and non-profit organizations, also drives high optimism. This collaboration is expected to provide additional resources, training, and support needed to implement IoT more effectively. These partnerships can also help disseminate best practices and innovations in the use of IoT so that they can be adopted more widely and consistently across madrasahs. Despite high expectations, challenges still need to be overcome to realize the full potential of IoT. These include developing adequate infrastructure, ongoing training for teachers and students, and addressing security and privacy issues related to the use of IoT technology. These challenges can be managed with the right strategy, and the hope for a better future through IoT development can be realized.

4). CONCLUSIONS

This study reveals that the Internet of Things (IoT) is crucial in the digital transformation process in madrasahs in Bandung Regency. Teachers and students in the area have developed a solid basic understanding of this technology. However, the implementation of IoT in the field is still in the development stage. It faces several challenges, including limited infrastructure, resistance to change, and the need for competency enhancement. Despite the obstacles, IoT has proven effective in improving the quality of learning and operational efficiency in madrasahs. Expectations for the advancement of this technology in the future are very high, with the belief that IoT will continue to drive innovation and strengthen education in madrasahs. With the implementation of strategic steps to overcome existing challenges, IoT has the potential to become a key pillar in realizing sustainable educational transformation.

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REFERENCES

Abichandani, P., Sivakumar, V., Lobo, D., Iaboni, C., & Shekhar, P. (2022). Internet-of-Things Curriculum, Pedagogy, and Assessment for STEM Education: A Review of Literature. *IEEE Access*, *10*, 38351–38369. https://doi.org/10.1109/ACCESS.2022.3164709

Abuselidze, G., Mohylevska, O., Kompanets, N., & Iushchenko, L. (2022). Modern concepts and methodological recommendations for teaching economic disciplines: tasks of the course" Digital Management of Transport Infrastructure". *Transportation Research Procedia*, *63*, 2759–2766.

Adel, A. (2024). The convergence of intelligent tutoring, robotics, and IoT in smart education for the transition from industry 4.0 to 5.0. *Smart Cities*, *7*(1), 325–369.

Adhicandra, I., Khasanah, F. N., Sabri, S., & Maharaja, C. H. (2024). The Impact of Integrating Internet of Things (IoT) Technology in Learning on Class Management Efficiency. *Journal of Computer Science Advancements*, *2*(3), 9–30.

Aisah, I., Achmad, A., Khoeriah, N. D., & Sudrajat, A. (2021). Management of infrastructure in improving the quality of vocational high school graduates. *Journal of Industrial Engineering & Management Research*, *2*(4), 172–189.

Albreem, M. A., Sheikh, A. M., Alsharif, M. H., Jusoh, M., & Yasin, M. N. M. (2021). Green Internet of Things (GIoT): Applications, practices, awareness, and challenges. *IEEE Access*, *9*, 38833–38858.

Alhazmi, A. K., Kaed, E., Al-Hammadi, F., Alsakkaf, N., & Al-Hammadi, Y. (2022). The Internet of Things as a Tool Towards Smart Education: A Systematic Review. *Proceedings of the Future Technologies Conference*, 633–648.

Annur, F., & Febriansyah, H. (2023). Proposed Human Capital Management Strategy to Improve Elementary School Teachers' Competencies in Rahuning, North Sumatra, Indonesia (Case Study of SDIT Ar-Rahmah). *International Journal of Current Science Research and Review*, *6*(08).

Bygstad, B., Øvrelid, E., Ludvigsen, S., & Dæhlen, M. (2022). From dual digitalization to digital learning space: Exploring the digital transformation of higher education. *Computers & Education*, *182*, 104463.

Calp, M. H., & Bütüner, R. (2022). Society 5.0: Effective technology for a smart society. In *Artificial Intelligence and Industry 4.0* (pp. 175–194). Elsevier.

Christou, P. A. (2022). How to use thematic analysis in qualitative research. *Journal of Qualitative Research in Tourism*, *3*(2), 79–95.

Endrejat, P. C., Klonek, F. E., Müller-Frommeyer, L. C., & Kauffeld, S. (2021). Turning change resistance into readiness: How change agents' communication shapes recipient reactions. *European Management Journal*, *39*(5), 595–604.

Erlinawati, C. E., Bektiarso, S., & Maryani, M. (2019). Model pembelajaran project based learning berbasis STEM pada pembelajaran fisika. *Fkip E-Proceeding*, *4*(1), 1–4.

Falahuddin, F. (2022). Transforming Madrasah Education: Public Service Delivery and Digital Integration in Kemenag Sleman. *Journal of Islamic Education Management Research*, *1*(2), 23–30.

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*, *68*(5), 2449–2472.

Indrawati, S. M., & Kuncoro, A. (2021). Improving competitiveness through vocational and higher education: Indonesia's vision for human capital development in 2019–2024. *Bulletin of Indonesian Economic Studies*, *57*(1), 29–59.

Kesharwani, A. (2020). Do (how) digital natives adopt a new technology differently than digital immigrants? A longitudinal study. *Information & Management*, *57*(2), 103170.

Khusnood, M., Bilal, M., & Jahangir, T. (2020). Digital Ascendancy and Madrasah Education: The Influence of Media Technology on the Life-worlds of Female Madrasah Students. *Global Mass Communication Studies Review, VI*.

Mahsusi, Hudaa, S., Fahmi, M., Kusen, Haryanti, N. D., & Wajdi, M. B. N. (2024). Achieving excellence: the role of digital transformation in madrasah management and Islamic culture. *Cogent Arts & Humanities*, *11*(1), 2304407.

Maulidin, S., Rohman, M., Nawawi, M. L., & Andrianto, D. (2024). Quality Management in Improving Competitiveness in the Digital Era at Madrasa. *Journal of Advanced Islamic Educational Management*, *4*(1), 57–70.

McCarthy, A. M., Maor, D., McConney, A., & Cavanaugh, C. (2023). Digital transformation in education: Critical components for leaders of system change. *Social Sciences & Humanities Open*, *8*(1), 100479.

Musolin, M. H., Serour, R. O. H., Siregar, M., Hamid, S. A., Ismail, A., Huda, M., & Rohim, M. A. (2024). Developing Personalised Islamic Learning in Digital Age: Pedagogical and Technological Integration for Open Learning Resources (OLR). *International Congress on Information and Communication Technology*, 11–25.

Mustari, M., & Rahman, M. T. (2020). Transferring Technology in a Religious Based School (A Case in West Bandung). *International Conference on Agriculture, Social Sciences, Education, Technology and Health (ICASSETH 2019)*, 276–281.

Nsanzumuhire, S. U., & Groot, W. (2020). Context perspective on University-Industry Collaboration

processes: A systematic review of literature. *Journal of Cleaner Production*, *258*, 120861.

Rana, K., & Rana, K. (2020). ICT Integration in Teaching and Learning Activities in Higher Education: A Case Study of Nepal's Teacher Education. *Malaysian Online Journal of Educational Technology*, *8*(1), 36–47.

Ruslin, R., Mashuri, S., Rasak, M. S. A., Alhabsyi, F., & Syam, H. (2022). Semi-structured Interview: A methodological reflection on the development of a qualitative research instrument in educational studies. *IOSR Journal of Research & Method in Education (IOSR-JRME)*, *12*(1), 22–29.

Saniuk, S., Caganova, D., & Saniuk, A. (2023). Knowledge and skills of industrial employees and managerial staff for the industry 4.0 implementation. *Mobile Networks and Applications*, *28*(1), 220–230.

Santos, K. da S., Ribeiro, M. C., Queiroga, D. E. U. de, Silva, I. A. P. da, & Ferreira, S. M. S. (2020). The use of multiple triangulations as a validation strategy in a qualitative study. *Ciencia & Saude Coletiva*, *25*, 655–664.

Santosa, S., & Jazuli, M. F. (2022). The digital Madrasah as an idea of IT-Based Islamic education. *Nazhruna: Jurnal Pendidikan Islam*, *5*(2), 379–391.

Tlili, A., Zhang, J., Papamitsiou, Z., Manske, S., Huang, R., Kinshuk, & Hoppe, H. U. (2021). Towards utilising emerging technologies to address the challenges of using Open Educational Resources: a vision of the future. *Educational Technology Research and Development*, *69*, 515–532.

Tomazzoli, C., Scannapieco, S., & Cristani, M. (2023). Internet of things and artificial intelligence enable energy efficiency. *Journal of Ambient Intelligence and Humanized Computing*, *14*(5), 4933–4954.

Tran-Dang, H., Krommenacker, N., Charpentier, P., & Kim, D.-S. (2020). Toward the internet of things for physical internet: Perspectives and challenges. *IEEE Internet of Things Journal*, *7*(6), 4711–4736.

Tümen Akyildiz, S. (2020). College Students' Views on the Pandemic Distance Education: A Focus Group Discussion. *International Journal of Technology in Education and Science*, *4*(4), 322–334.

Yates, A., Starkey, L., Egerton, B., & Flueggen, F. (2021). High school students' experience of online learning during Covid-19: the influence of technology and pedagogy. *Technology, Pedagogy and Education*, *30*(1), 59–73.

Zaini, M., Barnoto, B., & Ashari, A. (2023). Improving Teacher Performance and Education Quality through Madrasah Principal Leadership. *Kharisma: Jurnal Administrasi Dan Manajemen Pendidikan*, *2*(2), 79–90.