Journal of Blended and Technical Education

Vol 01 (1) 2024 p. 1-9

Corresponding author:
Dwi Erlin Effendi
Email:
dwierlineffendi@unisnu.ac.id

Received 2 July 2024;
Accepted 28 August 2024;
Published 28 August 2024

Conflict of interest statement:
Author(s) reported no conflict of interest

DOI: http://doi.org/10.70764/gdpu-jbte.2024.1(1)-01

ENHANCING THE ACCESSIBILITY OF TECHNICAL EDUCATION IN INDONESIA: THE ROLE OF CLOUD-BASED REMOTE LABORATORIES IN RURAL AND DISADVANTAGED AREAS

Dwi Erlin Effendi[1], Sebastián Sterzer[2]

[1]Universitas Islam Nahdlatul Ulama Jepara, Indonesia
[2]Université nationale de Lujan, Argentina

ABSTRACT

Objective: This study aims to explore the application of cloud-based remote laboratories in engineering education, particularly in addressing educational disparities in remote and underdeveloped areas of Indonesia.

Research Design & Methods: This research method uses a comprehensive literature review approach conducted in conjunction with the analysis of sample applications to assess the potential of cloud-based distance laboratories. This research focuses on accessibility, learning effectiveness, scalability, and cost efficiency, taking into account the role of government and collaboration between stakeholders.

Findings: The findings reveal that cloud-based remote laboratories can significantly enhance the technical quality of engineering education in Indonesia by overcoming geographic, temporal, and financial barriers. However, challenges such as limited internet access and high initial infrastructure costs remain key obstacles.

Implications & Recommendations: To ensure successful implementation, the study emphasizes the need for government investment in ICT infrastructure, fostering partnerships between the private sector and educational institutions, and developing strategic policies to mitigate implementation challenges.

Contribution & Value Added: This study contributes to the discourse on leveraging ICT to bridge educational gaps in developing countries. It highlights cloud-based remote laboratories as a transformative solution for advancing engineering education, promoting equity, and enhancing Indonesia's competitiveness in the global technology and industrial sectors.

Keywords: accessibility education, cloud-based remote laboratories, technical education

JEL codes: I21, I25, O33

Article type: research paper

INTRODUCTION

In the increasingly developing digital era, information and communication technology (ICT) is the main driver of transformation in various sectors, including education. One of the latest innovations in the field of engineering education is cloud-based remote laboratories. By offering innovative solutions that enable broad access and save costs to laboratory experiments, both for mechatronics and engineering education (Vitliemov et al., 2020). The Industrial Revolution 4.0 and advances in Internet of Things (IoT) technology have created new opportunities to face these challenges through the use of cloud-based remote laboratories. This technology allows students in remote locations to access virtual laboratories anytime and anywhere with an internet-connected device. By leveraging a cloud platform, the laboratory can offer a variety of experiments and

simulations relevant to today's industrial needs, which were previously difficult to do without a physical presence in a traditional laboratory (Nugraha et al., 2021; Chamunorwa et al., 2021).

These remote laboratories allow users from various locations to perform experiments that may not be available locally, thereby expanding educational opportunities and research applications (Mokhtar et al., 2014). In addition, they can improve the learning experience by providing computer-based interactive teaching materials and overcoming geographic, social and economic challenges, especially in areas with limited resources, such as Indonesia as a developing country (Diwakar et al., 2019). The need for effective distance learning solutions is increasingly urgent, and this laboratory is one answer to maintaining the quality of education amidst physical limitations.

Indonesia as an archipelagic country with more than 17,000 islands faces major challenges, especially in dealing with gaps in access to education, especially in technical education which requires adequate laboratory facilities. Many educational institutions in remote and less developed areas do not have sufficient resources to build and maintain adequate physical laboratories, resulting in students lagging behind in technical abilities and career opportunities compared to their peers in more developed urban areas (Nan Cenka & Hasibuan, 2013).

Cloud-based remote laboratories have the potential to overcome this problem without having to require a lot of costs but can also expand the reach of technical education to previously inaccessible areas by providing access to resources widely through digital devices. The application of this technology in Indonesia is expected to increase quality of engineering education and preparing a more competent workforce in the future (Pastor et al., 2013). However, there are challenges such as limited internet access in remote areas and the initial costs of developing cloud infrastructure and teacher training (Caminero et al., 2016). Other challenges include difficulties in collaborative learning in virtual environments, which requires the development of innovative solutions such as collaborative virtual computer lab (CVCL) environments (Hu et al., 2018). However, the transition to virtual spaces during the COVID-19 pandemic highlighted challenges in providing effective laboratory experiences and raised concerns about gaps in student achievement (Poo et al., 2023).

This research focuses on analysing the implementation of cloud-based remote laboratories in engineering education in Indonesia, with the aim of understanding the existing challenges and opportunities, as well as providing recommendations for improving the quality and accessibility of engineering education throughout the country. It is hoped that the successful application of this technology can reduce the education gap between urban and rural areas, as well as increase Indonesia's competitiveness in the fields of technology and industry in the future. Nonetheless, full realization of their potential requires addressing challenges related to collaboration, curriculum integration, and ensuring equitable access to quality learning experiences (Chen, 2023; Hu et al., 2018).

LITERATURE REVIEW

The literature on technology in education emphasizes the transformative impact of cloud solutions in remote and resource-constrained environments. The integrity of cloud-based remote labs into local education is based on several theoretical frameworks that emphasize the importance of accessibility, technology integration, and educational equity. The transition to Emergency Remote Teaching (ERT) highlights the need for educational solutions that can adapt and respond to various contexts, including in rural Indonesia (Cahyadi et al., 2021). Study by Martin-Someret and Verma, et al, highlights how cloud-based educational tools have the potential to increase student engagement and facilitate personalized learning experiences (Martín-Sómer et al., 2024; Verma et al., 2023).

One of the most significant frameworks for implementing cloud-based remote laboratories is the Technology Acceptance Model (TAM). This model was extended to assess factors influencing the acceptance and use of e-learning platforms, especially during the pandemic. In educational activities in Indonesia, factors such as perceived ease of use, perceived benefits, and ease of conditions are

very important in determining the effectiveness of technology integration (Sukendro et al., 2020). Implementing a cloud-based remote laboratory depends on the availability of reliable digital infrastructure, including internet connectivity, access to digital devices, and technical support. Research shows that lack of infrastructure is a major barrier to implementing distance learning solutions in rural areas (Aditya et al., 2022).

Cloud-based remote laboratories offer a flexible and cost-effective solution to bridge the educational gap in rural and disadvantaged areas. These laboratories enable students to conduct experiments and access technical education resources remotely, which is particularly beneficial in regions with limited physical infrastructure. The integration of mobile learning and cloud-based platforms has been shown to support equitable access to education by overcoming geographical barriers (Sulisworo et al., 2021). The successful implementation of cloud-based remote laboratories requires careful planning and consideration of local contexts.

The comparison between traditional technical education methods and cloud-based remote laboratories reveals important differences, particularly in learning quality. Traditional methods offer direct physical interactions that reinforce learning through hands-on experience. In contrast, cloud-based remote labs, while lacking physical interaction, deliver greater flexibility and can achieve comparable or even superior learning outcomes in certain situations. Cloud-based remote labs present a more adaptable, cost-effective, and inclusive alternative to traditional technical education. Despite a reduction in hands-on experience, this technology offers significant advantages in accessibility, cost savings, and scalability, making it an increasingly favored option in higher education.

The use of cloud-based laboratories supports the development of 21st-century skills such as critical thinking, creativity, and digital literacy, which are important for today's students. Cloud-based systems' flexibility and scalability enable personalized learning experiences and address the diverse needs of students in rural and disadvantaged areas (Bento Silva et al., 2020).

METHODS

The following are the research steps used to achieve the research objectives:

1. Literature Review

   This step aims to identify, collect, and analyze previous research on the use of cloud-based remote laboratories in the context of engineering education in rural and disadvantaged areas. A literature review includes identifying sources from relevant academic databases, filtering literature based on inclusion and exclusion criteria, in-depth analysis of the content of selected articles, and synthesizing findings to build a theoretical foundation for this research. The results of this literature review are expected to provide a significant contribution in understanding the role of cloud-based remote laboratories in improving the accessibility and quality of engineering education in Indonesia.

2. Deployment Examples

   This research uses an example deployment to provide a real illustration of the implementation of a cloud-based remote laboratory in rural and disadvantaged areas. in Indonesia. With strategically selected case studies, this research documents the application of processes, challenges, solutions, and the impact of this technology on the quality of engineering education in underserved areas. This research explores aspects such as geographical and socio-economic conditions, implementation processes, challenges faced, as well as the results and impacts of using this technology. The aim is to provide practical guidance for educational institutions in

Indonesia and contribute to the global literature on the use of educational technology to reduce educational disparities in remote areas.

3. Analyzes the Potential

   The aim of this analysis is to shine a light on the extent to which this technology can be applied effectively to overcome various challenges faced by educational institutions in areas lacking infrastructure and resources. By considering several things as the main focus in this analysis, including increasing accessibility, learning effectiveness, scalability and adaptability, cost efficiency, and reducing educational gaps. This research aims to provide nuance an understanding of the extent to which cloud solutions can do this address the unique challenges faced by remote schools in Indonesia

4. Benefit and Recommendation

   Apart from being based on a literature review, development examples, and potential analysis, this research uses the Benefit and Recommendation method to start the role of a cloud-based remote laboratory. This method aims to provide a comprehensive understanding of the benefits of cloud-based remote laboratories as well as provide practical recommendations to improve implementation and impact in Indonesia. This, of course, includes some information related to the positive impact on student learning, teacher effectiveness, and educational infrastructure globally. This research also makes recommendations to several parties such as policymakers, educators and other stakeholders. In addition, supporting suggestions that include successful implementation, considerations in facing challenges and changes, as well as strategies for overcoming these challenges also support providing actionable insights to help improve education in remote schools in Indonesia through the effective use of cloud solutions.

RESULT

Before digging deeper into the potential of cloud technology for remote schools in Indonesia. The following are examples of Cloud-Based Remote Laboratories tools and platforms that have been implemented in remote areas to support technology education, especially in situations where access to physical laboratories is limited. Table 1 shows that it allows students and researchers to carry out experiments and practice online without requiring direct access to a physical laboratory.

Table 1. The application of cloud technology

No.	Tools Cloud	Application in Remote School	Result
1.	Remote Laboratory Management Application Mebiyantara et al., (2021)	Using a mobile-based Restful Web Service method. Focuses on the use of tools such as oscilloscopes and remote signal generators with web technology.	To manage laboratory access efficiently, reduce energy consumption and minimize equipment investment costs. **Advantage :** a. Easy and Flexible Access: Accessible from anywhere with an internet connection, increasing productivity. b. Better Collaboration: Facilitates real-time team collaboration from multiple locations. c. Reduced Infrastructure Costs: Reduces hardware and maintenance costs as the cloud service provider manages it. d. Data Security: provides encryption and regular backups, protecting data from loss or theft. e. Scalability: Easily scales as needed without large investments in physical infrastructure. f. Automatic Updates: Software updates are performed automatically by the service provider.

No.	Tools Cloud	Application in Remote School	Result
			Disadvantages: a. Dependence on Internet Connection: The system depends on the quality of the internet connection, which can disrupt work if interrupted. b. Subscription Fee: Requires an ongoing subscription fee which may increase with usage. c. Data Security: Still at risk of security threats like hacking, even though it is safe. d. Lack of Direct Control: Users have limited control over the physical infrastructure. e. Compliance Issues: Potential compliance issues with regulations regarding storing data on third-party servers.
2.	IoT-Based Remote Laboratory for Microscope Practice Kustija & Jayanto (2022)	By utilizing the Internet of Things (IoT) to control and monitor laboratory equipment in real-time.	Students can carry out microscope practicum remotely via internet access. **Advantage :** a. Remote Access: Students and researchers can operate the microscope from anywhere without needing to be physically present. b. Time and Cost Efficiencies: Reduce travel requirements and costs, and increase accessibility. c. Optimal Use of Tools: Tools can be used interchangeably by multiple users, increasing efficiency. d. Improved Learning: IoT enables better data tracking and analysis, providing detailed feedback. e. Enhanced Collaboration: collaborate in real-time between users from different institutions or countries. f. Centralized Monitoring and Management: Laboratories can monitor and manage remotely, improving control quality **Disadvantages:** a. Implementation Costs: IoT and cloud infrastructure can be expensive to implement. b. Lack of Physical Touch: Users may miss out on the practical experience they usually get in person. c. Latency Issues: There is a possibility of delay in data transmission, which affects the user experience. d. Technical Complexity: Requires higher technical knowledge for use and maintenance
3.	Development of Web-Based Real-Time Remote Laboratory	This laboratory combines Human-Computer Interaction (HCI) with control and communication systems,	Increase access to quality education and reduce the gap between urban and rural schools.

No.	Tools Cloud	Application in Remote School	Result
	Mahmud et al., (2020)	utilizing Node-RED as a connecting platform to provide online access to laboratory facilities via a web interface.	**Advantage :** a. Global Accessibility: Users can access the laboratory in real-time from various locations. b. Interactive Learning: Users can interact directly with laboratory equipment via the web, enhancing the learning experience. c. Resource Efficiency: Laboratory equipment can be used interchangeably by multiple users, increasing efficiency. d. Low Operational Costs: Reduced physical infrastructure requirements lower operational costs. e. Easy Updates: Software updates and maintenance are done automatically. **Disadvantages:** a. Dependence on the Internet: Performance depends on the stability and speed of the internet connection. b. Latency Issues: Delays in data transmission can affect the quality of experiments. c. Initial Implementation Costs: Developing and implementing a cloud-based web system can be expensive. d. Lack of Practical Experience: Users may miss the hands-on experience of a physical laboratory. e. Technical Limitations: Not all experiments are accessible or well replicated over the web. f. Resistance to New Technology: Some users may be reluctant to switch to cloud-based systems.

DISCUSSION

Based on examples of implementing Cloud-Based Remote Laboratories tools and platforms in Table 1, the author summarizes several potential solutions for Cloud-Based Remote Laboratories which are presented in table 2. The form of educational development in Indonesia, especially in remote areas, is of particular concern to all parties. Cloud-Based Remote Laboratories is not only the responsibility of individuals and educational institutions, but the government also has an important role in designing and improving Accessibility of Technical Education in Indonesia. Governments can play a role in several key aspects that will help facilitate wider and more sustainable implementation of this technology.

In addition, it is important for the government to provide digital learning platforms that can be accessed by all groups, including students in remote areas with limited infrastructure. The government needs to continue developing information and communications technology (ICT) infrastructure throughout Indonesia, including rural and remote areas, to ensure more equitable accessibility. This is in line with the digital transformation initiative in Indonesia which aims to develop digital infrastructure and increase digital literacy in remote areas (Saputra et al., 2023).

Collaboration between government, the private sector and educational institutions is very important to improve the quality of technical education in remote areas. The government can collaborate with the private sector to provide training to teachers and other education personnel in

the use of cloud-based technology. This training will ensure that the technology is applied effectively in the learning process and can reach all levels of society. The combination of the right policies and infrastructure support can accelerate equitable access to technical education throughout Indonesia and improve the quality of human resources in the digital era.

Table 2. Analyzes the Potential

No.	Analyzes the Potential	Description
1.	Increasing accessibility	The potential that can be taken is that it can overcome geographical, time and cost barriers. This allows more individuals to get involved in increasing educational inclusion, and prepares students to face more global challenges.
2.	Learning effectiveness	As a solution, Learning effectiveness offers a more interactive, adaptive and flexible learning experience, increasing access to quality educational resources and reducing dependence on physical facilities. It also increases student engagement and allows for learning tailored to individual needs.
3.	Scalability and adaptability	To be an effective and sustainable solution to overcome educational challenges in remote areas by providing broad access to education based on the needs of educational institutions, and ensuring that they can adapt to changes that occur
4.	Cost efficiency	Cloud solutions offer the potential for significant cost efficiencies. By reducing the need for physical infrastructure, laboratory equipment, and operational costs, and leveraging scalability
5.	Reducing educational gaps	Cloud-based education enables access to e-learning, e-libraries, and e-laboratories from any device, expanding the reach of education in remote areas, and providing a laboratory experience that approaches a physical laboratory.

CONCLUSION

The implementation of Cloud-Based Remote Laboratories in remote schools across Indonesia presents significant potential to transform technical education by addressing key challenges such as accessibility, learning effectiveness, scalability, cost efficiency, and reducing educational gaps. By overcoming geographical, time, and financial barriers, these technologies facilitate greater educational inclusion, ensuring that students in remote and underdeveloped areas have access to quality educational resources. The government's role is critical in this transformation, particularly in developing the necessary ICT infrastructure and providing digital learning platforms accessible to all, including those in remote areas.

Moreover, collaboration between the government, private sector, and educational institutions is essential to ensure that cloud-based technologies are effectively integrated into the educational process. This collaboration includes providing training for educators and ensuring that policies support the equitable distribution of these resources. By embracing these initiatives, Indonesia can accelerate digital transformation, reduce educational gaps, and enhance the overall quality of human resources, preparing students to meet global challenges in the digital era.

REFERENCES

Aditya, B. R., Ferdiana, R., & Kusumawardani, S. S. (2022). Identifying and prioritizing barriers to digital transformation in higher education: a case study in Indonesia. *International Journal of Innovation Science*, 14(3/4), 445–460. https://doi.org/10.1108/IJIS-11-2020-0262

Bento Silva, J., Nardi Silva, I., & Meister Sommer Bilessimo, S. (2020). Technological Structure for Technology Integration in the Classroom, Inspired by the Maker Culture. *Journal of Information Technology Education: Research*, 19, 167–204. https://doi.org/10.28945/4532

Cahyadi, A., Hendryadi, Widyastuti, S., Mufidah, V. N., & Achmadi. (2021). Emergency remote teaching evaluation of the higher education in Indonesia. *Heliyon*, 7(8), e07788. https://doi.org/10.1016/j.heliyon.2021.e07788

Caminero, A. C., Ros, S., Hernández, R., Robles-Gómez, A., Tobarra, L., & Granjo, P. J. T. (2016). VirTUal remoTe labORatories Management System (TUTORES): Using Cloud Computing to Acquire University Practical Skills. *IEEE Transactions on Learning Technologies*, 9(2), 133–145. https://doi.org/10.1109/TLT.2015.2470683

Chamunorwa, T., Modran, H. A., Ursuțiu, D., Samoilă, C., & Hedeșiu, H. (2021). Reconfigurable Wireless Sensor Node Remote Laboratory Platform with Cloud Connectivity. *Sensors*, 21(19), 6405. https://doi.org/10.3390/s21196405

Chen, T. (2023). Advancing Technical Education and Fostering Soft Skills Development through Digital Learning. *Advances in Education, Humanities and Social Science Research*, 7(1), 91. https://doi.org/10.56028/aehssr.7.1.91.2023

Diwakar, S., Radhamani, R., Sujatha, G., Sasidharakurup, H., Shekhar, A., Achuthan, K., Nedungadi, P., Raman, R., & Nair, B. (2019). Usage and Diffusion of Biotechnology Virtual Labs for Enhancing University Education in India′s Urban and Rural Areas. *In Biotechnology* (pp. 1359–1379). IGI Global. https://doi.org/10.4018/978-1-5225-8903-7.ch056

Hu, X., Le, H., Bourgeois, A. G., & Pan, Y. (2018). Collaborative Learning in Cloud-based Virtual Computer Labs. *2018 IEEE Frontiers in Education Conference (FIE)*, 1–5. https://doi.org/10.1109/FIE.2018.8659018

Kustija, J., & Jayanto, N. D. (2022). IoT Implementation for Development of Remote Laboratory (Case Study on Microscope Practice). *REKA ELKOMIKA: Jurnal Pengabdian Kepada Masyarakat*, 3(1), 20–29. https://doi.org/10.26760/rekaelkomika.v3i1.20-29

Mahmud, F., Zubir, M. N. M., Ahmad, M. Y. Bin, Abdullah, Z. B., Kadri, N. A. Bin, Obaidellah, U. H. B., & Amin Faisal, T. (2020). Development of Web Based Real Time Remote Laboratory for Teaching and Learning. *IOP Conference Series: Materials Science and Engineering*, 854(1), 012025. https://doi.org/10.1088/1757-899X/854/1/012025

Martín-Sómer, M., Casado, C., & Gómez-Pozuelo, G. (2024). Utilising interactive applications as educational tools in higher education: Perspectives from teachers and students, and an analysis of academic outcomes. *Education for Chemical Engineers*, 46, 1–9. https://doi.org/10.1016/j.ece.2023.10.001

Mebiyantara, F., Faisol, A., & Ariwibisono, F. (2021). Remote Laboratory Management Application Development Using A Mobile-Based Restful Web Service Method. *JATI (Jurnal Mahasiswa Teknik Informatika)*, 5(1), 152–161. https://doi.org/10.36040/jati.v5i1.3223

Mokhtar, A., Mikhail, G. R., & Seong-Joo, C. (2014). A survey on remote laboratories for e-learning and remote experimentation. *Contemporary Engineering Sciences*, 7, 1617–1624. https://doi.org/10.12988/ces.2014.411218

Nan Cenka, B. A., & Hasibuan, Z. A. (2013). Enhancing educational services using cloud technology. *2013 International Conference of Information and Communication Technology (ICoICT)*, 155–160. https://doi.org/10.1109/ICoICT.2013.6574565

Nugraha, T. P., Pratama, R., Wahyudin, D., & Somantri, Y. (2021). Development of Integrated IoT Trainer (LRioT) for Practical Work in Electrical Engineering Education Program Amid Pandemic. *Proceedings of the 6th UPI International Conference on TVET 2020 (TVET 2020)*. https://doi.org/10.2991/assehr.k.210203.126

Pastor, R., Caminero, A. C., Sánchez, D., Hernández, R., Ros, S., Robles-Gómez, A., & Tobarra, L. (2013). Laboratories as a service (LaaS): Using cloud technologies in the field of education. *Journal of Universal Computer Science*, 19(14), 2112–2126. https://doi.org/10.3217/jucs-019-14-2112

Poo, M. C.-P., Lau, Y., & Chen, Q. (2023). Are Virtual Laboratories and Remote Laboratories Enhancing the Quality of Sustainability Education?. *Education Sciences*, 13(11), 1110. https://doi.org/10.3390/educsci13111110

Saputra, F. T., Indrabudi, T., Dirgahayu, D., Karman, & Mudjiyanto, B. (2023). Initiatives of the Indonesian Government for Digital Transformation in Rural Areas. *E3S Web of Conferences*, 444, 03001. https://doi.org/10.1051/e3sconf/202344403001

Sukendro, S., Habibi, A., Khaeruddin, K., Indrayana, B., Syahruddin, S., Makadada, F. A., & Hakim, H. (2020). Using an extended Technology Acceptance Model to understand students' use of e-learning during Covid-19: Indonesian sport science education context. *Heliyon*, 6(11), e05410. https://doi.org/10.1016/j.heliyon.2020.e05410

Sulisworo, D., Kusumaningtyas, D. A., Prasetyo, E., Fitriah, Fitrianawati, M., & Erviana, V. Y. (2021). The Mobile Learning Implementation for Physics Lesson in Indonesia: A Narrative Review. *Journal of Physics: Conference Series*, 1933(1), 012123. https://doi.org/10.1088/1742-6596/1933/1/012123

Verma, N., Getenet, D. S., Dann, D. C., & Shaik, T. (2023). Designing an artificial intelligence tool to understand student engagement based on teacher's behaviours and movements in video conferencing. *Computers and Education: Artificial Intelligence*, 5, 100187. https://doi.org/10.1016/j.caeai.2023.100187

Vitliemov, P., Bratanov, D., & Marinov, M. (2020). An Approach to Use Virtual and Remote Labs in Mechatronics Education Based on Cloud Services. *2020 7th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE)*, 1–4. https://doi.org/10.1109/EEAE49144.2020.9279072