IOT- BASED INNOVATION FOR ADULT EDUCATION AND SKILLS DEVELOPMENT

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Abstract

The development of digital technology, particularly the Internet of Things (IoT), has brought significant impacts across various fields, including education. IoT, as a network of interconnected smart devices, enables real-time data collection and analysis, making it highly potential to support adult education that emphasizes needs, experiences, and problem-solving. This study aims to analyze the utilization of IoT as an innovation in adult education and skills development by employing a qualitative descriptive method through a literature study. Data were collected from international journals, books, reports from international organizations, and case studies in Indonesia, and were analyzed using thematic analysis techniques. The findings indicate that IoT can support personalized learning, expand educational access for marginalized communities, strengthen industry-based skills, and improve the efficiency and sustainability of education. However, challenges include the digital divide, limited infrastructure, low digital literacy, as well as privacy and data security issues. Therefore, cross-sector collaboration is required to build an IoT-based education ecosystem that is inclusive, equitable, and sustainable. This study highlights that IoT has the potential to become a strategic innovation for improving the quality of non-formal education and adult skills development, provided there is sufficient support in terms of policies, infrastructure, and digital literacy.

Keywords: Internet of Things, adult education, skills development, digital literacy, innovation

1. INTRODUSTION

The advancement of digital technology has significantly impacted various aspects of human life, including education. One of the most important innovations is the Internet of Things (IoT), which refers to a network of physical devices connected through the internet that can automatically collect, exchange, and analyze data (Al-Fuqaha et al., 2015). Initially, this technology rapidly developed in sectors such as industry, transportation, and healthcare. However, in the last decade, it has begun to enter the field of education due to its potential to create more efficient and data-driven learning systems (Khan et al., 2021).

In the context of adult education, IoT is highly relevant because it aligns with the characteristics of adult learning that emphasize needs, experiences, and problem-solving. Knowles' (2015) theory of andragogy suggests that adults learn more effectively when the learning materials are directly related to their real-life experiences, are practical in nature, and acknowledge prior knowledge. The application of IoT enables this process, for instance, through smart devices that can adapt materials to the specific needs of learners (UNESCO, 2023).

In Indonesia, challenges in adult education remain complex. Limited access to educational facilities, low levels of digital literacy, and unequal infrastructure between urban and rural areas present significant issues (Ridwan, 2021). Digital literacy programs and initiatives such as the Digital Village in several provinces represent initial steps that demonstrate how technology can help reduce this gap. However, the implementation of IoT in non-formal education still requires sufficient policy support, resources, and training (OECD, 2022).

Furthermore, global demands for 21st-century skills increase the urgency of integrating IoT into adult education. UNESCO (2021) emphasizes that digital literacy, critical thinking, and adaptability are essential competencies to navigate the changing world of work. Therefore, IoT-based innovations not only enhance learning processes but also contribute to the development of skills relevant to industry needs.

Based on this background, this study aims to analyze how IoT can be utilized as an innovation in adult education and skills development. The discussion focuses on IoT's potential in personalized learning, expanding educational access, strengthening industry-based skills, enhancing efficiency, and addressing implementation challenges.

2. RESEARCH METHODOLOGY

This study employs a descriptive qualitative approach using library research. This method was chosen because it aligns with the research objective, namely to gain an in-depth understanding of the role of the Internet of Things (IoT) in adult education and skills development based on existing literature. According to Creswell (2018), a descriptive qualitative approach allows researchers to systematically describe social phenomena, portray actual conditions, and provide critical analysis of various relevant sources. Therefore, this method is considered appropriate to study educational and technological issues that are dynamic and contextual.

2.1. Data Sources

The data in this study were obtained from diverse and credible literature to ensure a comprehensive review. Sources included:

International academic journals retrieved from databases such as Scopus, IEEE Xplore, and Google Scholar. These articles were used to understand IoT fundamentals (Al-Fuqaha et al., 2015), its challenges (Khan et al., 2021), and applications in education.

Scholarly books discussing adult education theories and skills development. For instance, *The Adult Learner* by Knowles (2015), which emphasizes andragogy principles, and Suprijanto (2018), which elaborates on adult education practices in Indonesia.

Reports from international organizations such as UNESCO (2021, 2023) and OECD (2022), which highlight the importance of digital literacy, 21st-century skills, and technology integration in learning.

Local case studies in Indonesia, such as the Digital Village program in West Java (Ridwan, 2021), which illustrate how IoT is utilized in rural communities to enhance digital literacy and practical skills.

By combining global, regional, and local perspectives, this study provides a more comprehensive and contextual analysis.

2.2. Data Collection Techniques

Data collection was conducted systematically in several stages. First, the researcher employed specific keywords such as IoT in adult education, skills development IoT, digital literacy non-formal education, and IoT-based lifelong learning in searching academic databases. The search was carried out between February and August 2025 using academic search engines such as Google Scholar, Scopus, and IEEE Xplore.

Second, after collecting the literature, a screening process was conducted to select only relevant articles. Out of approximately 70 articles and reports identified, only 25 sources were selected based on quality, recency (2010–2024), and relevance to the research topic. Snyder (2019) emphasizes that literature selection based on quality and relevance is crucial to ensure accuracy and minimize bias in the findings.

Third, books and official reports from international organizations were added to complement the journal-based review. This was necessary since books and reports often provide broader theoretical frameworks and macro-level policy discussions, while journals focus more on empirical studies..

2.3. Data Analysis Techniques

Thematic analysis was applied to analyze the data. Braun and Clarke (2006) explain that thematic analysis is a technique for identifying, analyzing, and reporting patterns or themes within data. In this study, the steps included:

Data reduction: eliminating irrelevant information while gathering essential data for further analysis (Miles et al., 2014).

Categorization: grouping reduced data into main themes such as personalized learning, expanded access, industry-based skills development, educational efficiency, and challenges in IoT implementation.

Interpretation: relating categorized data to andragogy theory (Knowles, 2015), Indonesian adult education practices (Suprijanto, 2018), and UNESCO's digital literacy framework (2023).

This analysis enabled the researcher to explore connections between IoT concepts and adult education practices both globally and locally.

2.4. Data Validity

To ensure data validity, this study used source triangulation. This means that information from academic journals was compared with reports from international organizations and local case studies. Creswell & Poth (2017) argue that triangulation is important in qualitative research to increase credibility and minimize researcher subjectivity.

In addition, validity was maintained by ensuring that all sources were academically reputable, including peer-reviewed journals, official reports from international organizations, and books published by academic publishers.

2.5. Research Limitations

This study has several limitations. First, it only focuses on adult and non-formal education, without discussing IoT applications in formal education in detail. Second, it does not address the technical aspects of IoT device development, but rather its utilization in learning and skills development processes. Third, as a literature study, it does not involve empirical field data. Nevertheless, the findings provide valuable insights into the opportunities and challenges of IoT implementation in adult education.

3. RESULT AND DISCUSSION

3.1 Personalized Learning through IoT

IoT has the ability to support personalized learning tailored to the needs of each learner. Smart devices such as wearable technology, biometric sensors, and data-driven applications enable the collection of information on learning activities, learning styles, and individual progress. This information is then analyzed to adjust the content, methods, and pace of learning, making it more relevant to the learners' needs. In adult education, this approach is particularly important since each learner has diverse backgrounds, motivations, and learning experiences (Al-Fuqaha et al., 2015; Khan et al., 2021).

Personalization also aligns with the andragogical principles introduced by Knowles (2015), which suggest that adults learn more effectively when the learning process is directly connected to real-life experiences and actual needs. For instance, workers in the manufacturing sector can use IoT modules to train in specific technical skills, while farmers may benefit from soil moisture sensors to understand modern agricultural practices. IoT thus acts not only as a technological tool but also as a mediator that helps adult learners acquire knowledge contextually and practically (UNESCO, 2023). Furthermore, IoT-based learning systems enhance adult learners' motivation by providing immediate and accurate feedback. Learners facing difficulties can be quickly offered supplementary materials, while those progressing faster can be challenged with advanced tasks. This model has proven to improve self-confidence and learner autonomy, which are central objectives of adult education (Suprijanto, 2018; OECD, 2022).

3.2 Expanding Access to Education for Marginalized Communities

One of the key contributions of IoT is its potential to expand access to education for marginalized communities that were previously difficult to reach. In Indonesia, many rural areas still face challenges in terms of educational infrastructure and human resources. The Digital Village program in West Java has shown that digital technologies, including IoT, can be utilized to support digital literacy and enhance skills in rural communities (Ridwan, 2021). Through the use of soil and weather sensors, for example, farmers can learn smart agricultural practices that improve productivity without having to leave their villages.

IoT also enables more interactive distance learning. Learners in remote areas can utilize IoT-based applications to interact with facilitators located in other cities, reducing geographical barriers to

education. This approach is consistent with UNESCO's (2021) vision of inclusive education, which emphasizes that technology should serve as a tool to bridge educational disparities across regions. However, such access is highly dependent on digital infrastructure. Without stable and affordable internet connectivity, the application of IoT in education remains limited. OECD (2022) emphasizes that the digital divide is not only about access to devices but also the ability of communities to use these technologies effectively. Thus, strong policy support and community training programs are essential to ensure marginalized communities truly benefit from IoT for education.

Industry-Based Skills Development

IoT opens significant opportunities for developing skills aligned with modern industry needs. One prominent application is in vocational training, where IoT can simulate real working conditions through digital environments. In the automotive sector, for example, learners can study how modern vehicle sensors operate, while in agriculture, they can use IoT devices to manage automated irrigation and smart fertilization systems (Kim & Lee, 2020).

Beyond technical competencies, IoT also fosters the development of analytical skills. Learners are not only trained to operate devices but also to interpret and analyze the data generated. This supports the cultivation of critical thinking and problem-solving abilities, which are essential 21st-century competencies (UNESCO, 2023). At the global level, several advanced countries have integrated IoT into vocational and higher education training. OECD (2022) reports that European countries have implemented IoT-based learning in manufacturing, logistics, and factory automation sectors. These practices demonstrate that IoT is not only effective in enhancing training efficiency but also in preparing learners for the challenges of the Fourth Industrial Revolution.

Efficiency and Educational Sustainability

Beyond pedagogical benefits, IoT contributes to improving the efficiency of educational operations. For example, energy sensors in classrooms or training centers can help reduce electricity costs, while IoT-based attendance systems can minimize administrative burdens, allowing facilitators to focus more on the learning process (Khan et al., 2021).

From a sustainability perspective, IoT supports the concept of green education. By optimizing resource management, educational institutions can operate in more environmentally friendly ways. UNESCO (2023) highlights that technology should be leveraged to support sustainable development goals, including energy efficiency and carbon footprint reduction. For instance, digital devices can significantly reduce paper use, while automated IoT-based lighting systems can lower electricity consumption. Moreover, IoT can enhance the management of educational resources by enabling the collection of data to design curricula, monitor learner progress, and identify additional training needs. Thus, efficiency in this context relates not only to cost reduction but also to measurable learning effectiveness (OECD, 2022).

Challenges in Implementing IoT in Adult Education

Despite its significant potential, IoT implementation in adult education faces several critical challenges. First, the digital divide remains a major issue in many developing countries, including Indonesia. Not all communities have access to smart devices or stable internet networks, limiting the benefits of IoT to certain groups (Ridwan, 2021). Second, IoT devices are often costly, making it difficult for non-formal education institutions to adopt them widely (Al-Fuqaha et al., 2015).

In addition, adult learners' digital literacy levels remain relatively low. Many learners are unfamiliar with smart devices or IoT-based applications, which necessitates special training and mentoring programs. UNESCO (2021) stresses that digital literacy is a key prerequisite for communities to maximize technology use. Without this competency, IoT adoption risks widening educational inequalities. Another pressing issue involves privacy and data security. IoT systems collect massive amounts of data, including sensitive personal information. Without proper management, such data could be misused. Hence, clear regulations and robust security systems are required to protect learners' privacy (OECD, 2022). Overall, the success of IoT in adult education depends largely on the readiness of infrastructure, digital literacy, and regulatory frameworks.

4. CONCLUSION

Based on the findings, it can be concluded that the Internet of Things (IoT) holds great potential as a catalyst for transformation in adult education and skills development. IoT enables more personalized, flexible, and relevant learning for adult learners through real-time data collection and analysis (Al-Fuqaha et al., 2015; Khan et al., 2021). With personalization, each individual can learn at their own pace and according to their learning style, which aligns with the principles of andragogy that emphasize experience and real-life needs (Knowles, 2015).

Furthermore, IoT plays an essential role in expanding access to education for marginalized communities. This technology bridges the gap between urban and rural populations by providing distance learning through smart devices (Ridwan, 2021). This approach is consistent with UNESCO's (2021) vision of inclusive, equitable, and accessible education for all. Additionally, IoT strengthens industry-based skills development through practical training and simulations that closely replicate real-world work settings. Learners are able to master both technical and analytical skills, which are integral to 21st-century competencies (UNESCO, 2023; OECD, 2022).

From a sustainability perspective, IoT contributes to creating a more efficient and environmentally friendly education system. The use of energy sensors, automated attendance systems, and digital devices can reduce operational costs while supporting sustainable development goals (Khan et al., 2021; UNESCO, 2023). Thus, IoT not only enhances the quality of learning but also reinforces sustainability in non-formal education delivery.

However, this study also identifies several challenges in implementing IoT. Digital inequality, limited infrastructure, low levels of adult digital literacy, and data privacy and security issues remain significant barriers (Ridwan, 2021; OECD, 2022). Without proper strategies, IoT adoption risks widening educational disparities. Therefore, cross-sector collaboration among governments, educational institutions, the private sector, and communities is necessary to build an inclusive IoT-based educational ecosystem.

Overall, IoT has the potential to become a strategic innovation in improving the quality of adult education and skills development, provided it is supported by appropriate policies, enhanced digital literacy, and equitable infrastructure. Future research is recommended to gather empirical data through field studies in order to provide a more concrete picture of IoT implementation in non-formal education in Indonesia. In this way, IoT can truly contribute to achieving sustainable human development goals.

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