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INTEGRATION OF AI IN EDUCATION SYSTEMS: ADDRESSING LEARNING QUALITY GAPS IN REMOTE AREAS

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Abstract *The gap in access and quality of education in remote areas is a major challenge for the equitable distribution of education in Indonesia. Uneven technological infrastructure, especially internet access, hinders students in remote areas from getting the same quality of learning as students in urban areas. This study aims to analyze the potential and challenges of artificial intelligence (AI) integration in improving the quality of education in remote areas. Using a qualitative method with a descriptive approach, data were collected through in-depth interviews, field observations, and document analysis from several schools in remote areas. Data analysis was carried out using thematic analysis methods to identify patterns and key findings. The results show that AI has great potential in providing adaptive and personalized learning, despite significant barriers related to infrastructure and policy support. It was also found that effective AI adoption requires government support in the form of inclusive education policies, teacher training, and digital infrastructure improvements. This research recommends a collaborative strategy between the government, the education sector, and the private sector to strengthen the integration of AI as a long-term solution in addressing education gaps in remote areas. By using qualitative research methods, including field observations and interviews, the study contributes practical insights into how AI can be implemented effectively in remote education.*

Keywords Artificial intelligence, remote education, education gap, adaptive technology, education policy

1. Introduction

The quality of education worldwide reveals significant disparities between urban and remote areas. Studies indicate that more than 265 million children globally lack access to adequate education, particularly in rural and remote regions with insufficient facilities and unqualified teaching staff (Reimers & Schleicher, 2020; Wagstaff et al., 2022). In this context, artificial intelligence (AI) technologies have emerged as promising tools for fostering inclusive education by enabling personalized and scalable access to distance learning. AI can bridge educational gaps by delivering tailored learning materials to meet the specific needs of students in remote areas (Holmes, 2019; Luckin & Holmes, 2016). AI in instruction has

benefited teaching tools and increased the quality of pedagogical practices (Nurjanah et al., 2024).

The urgency of adopting AI in education has heightened due to the COVID-19 pandemic, which disrupted learning for approximately 1.6 billion students worldwide (Khalili, 2017; Viceconte et al., 2017). Remote areas, already disadvantaged by inadequate digital infrastructure and limited teaching staff, faced exacerbated inequalities during this period (Brown, 2004; Wagstaff et al., 2022)This necessitates research into effective AI applications to enhance educational quality in remote regions and bolster educational resilience during crises (Chen et al., 2020; Khalili, 2017; Luckin & Holmes, 2016).

Studies show that inequality in internet access reaches 60% in remote areas in developing countries, compared to 20% in urban areas (Morley et al., 2020). The table below shows the inequality of access to technology in several ASEAN countries:

Table 1. Inequality of Access to Technology in ASEAN Countries

Country	Internet Access (%) Urban	Internet Access (%) Remote
Indonesia	73	35
Philippines	78	45
Thailand	85	50
Vietnam	90	55

With this data, it can be seen the importance of technological innovations, such as AI, to cover gaps in the quality of education in remote areas (ITU, 2021; WEF, 2021; McKinsey, 2020).

Data highlight disparities in internet access, with remote areas in developing countries experiencing a 60% gap compared to urban areas, which have better digital infrastructure (ITU, 2021; Luckin et al., 2020; Zhao et al., 2022). For instance, in Southeast Asia, urban regions of Indonesia have 73% internet access, while remote areas only have 35%. This disparity underscores the need for innovative AI solutions that can operate in low-connectivity environments and reduce educational inequities (Irvine et al., 2015; Khalili, 2017).

Existing research underscores the positive impact of AI on education, particularly in enhancing learning outcomes and broadening access. Studies show that AI-driven adaptive learning systems improve student engagement and outcomes (Luckin & Holmes, 2016). Additionally, AI tutors have been shown to address teacher shortages in underserved areas, while AI-powered chatbots can help students grasp complex concepts (Chen et al., 2020; Khalili, 2017). However, most of these studies focus on urban settings, leaving gaps in understanding the application of AI in remote areas with limited (Jiang et al., 2017).

This research uniquely focuses on AI tailored for remote regions, accounting for local infrastructure and cultural challenges. It aims to explore how AI can enhance educational equity by addressing access limitations in underserved areas. The study will provide a foundation for the development of inclusive and sustainable AI technologies that support equitable education in remote areas (Van Lancker & Parolin, 2020).

The objectives of this research are (1) to identify the technical and social barriers to implementing AI in remote education, (2) to evaluate the effectiveness of

AI-based learning models in improving educational outcomes, and (3) to develop actionable recommendations for governments and educational institutions to sustainably adopt AI technology in remote areas (UNESCO, 2021; ITU, 2021; Zhao et al., 2022).

2. Method

1. Research Design

This study uses a descriptive qualitative approach with case studies in remote areas that experience limited access to education. The goal of this design is to deeply understand how AI technology can be integrated in the education system to address the learning quality gap. This study will combine observation methods, in-depth interviews, and document analysis to explore the potential and barriers to the use of AI in education in remote areas (Creswell & Creswell, 2017).

2. Location and Subject of Research

This research will be conducted in several remote areas in Indonesia, such as rural areas or outlying islands that have limited internet access and educational facilities. The subjects of the study are teachers, students, school managers, and government officials involved in the planning and implementation of educational programs in these areas. Subject selection uses purposive sampling techniques to ensure that the selected subjects are truly relevant to the research topic.

3. Research Instruments

The main instrument in this study is a semi-structured interview guideline designed to explore the perceptions and experiences of teachers and students regarding the use of AI technology in teaching and learning activities. In addition, an observation checklist will be used to record the condition of the infrastructure and technology available in schools in remote areas. Related documents, such as local education policies, school reports, and internet access data, will also be analyzed to obtain comprehensive information (Mutu et al., 2022).

4. Data Collection Techniques

a. **In-Depth Interviews**: Interviews will be conducted face-to-face or online (where possible) with teachers, students, and education officials. The interview questions are designed to explore the challenges, needs, and potential implementation of AI in the context of education in remote areas
b. **Observation**: Observation was carried out to identify the physical condition, educational infrastructure, and limitations of technological infrastructure at the research site. This observation technique is expected to provide additional data that supports the results of the interview
c. **Document Analysis**: Analysis of education policy documents, internet access data, and reports on the implementation of education in remote areas was carried out to obtain more complete information on the barriers and potential for AI adoption

5. Data Analysis Techniques

Data obtained from interviews, observations, and document analysis will be analyzed using thematic analysis techniques. The steps in this analysis include open

coding, categorization, and identification of key emerging themes related to the use of AI in education in remote areas. This analysis will also look at inter-thematic linkages to understand the factors that support and hinder the integration of AI in the education system (Braun & Clarke, 2006; Miles & Huberman, 2007).

6. Data Validity and Reliability

To ensure the validity and reliability of the data, this study applies triangulation of data sources (interviews, observations, and documents) and triangulation of methods (thematic analysis and cross-checking between informants). In addition, member checking is carried out by providing a summary of the interview results to the informant to ensure data accuracy.

3. Result & Discussion

A. Results of Research Analysis

1. **Data Collection**
   Data from interviews, observations, and documents are collected and transcribed for analysis. This data consists of direct excerpts from in-depth interviews, field observation notes, and excerpts from relevant documents.
2. **Open Coding**
   Each quote and piece of data is broken down into multiple codes that reflect the main idea or topic. Example:
   a. From the teacher's interview: "AI is very helpful to me in providing additional learning materials that are appropriate for the needs of students."
      Code: *AI supports learning*, *additional learning materials*, *adapts to student needs*
   b. Observation in class: "A simple study room with limited internet access."
      Code: *limited infrastructure*, *limited internet access*
3. **Grouping Codes into Categories (Axial Coding)**
   The generated code is grouped into categories based on the similarity or suitability of the theme. For example:
   a. **Infrastructure Limitations**: includes *limited internet access codes*, *limited facilities and infrastructure*
   b. **Learning Support**: includes *AI code to support learning*, *additional learning materials*, *adapting to student needs*
4. **Identify the main theme**
   Based on the categories formed, the main themes related to the research are identified. Examples of themes that may appear are:
   a. **Theme 1**: *Infrastructure Limitations in Remote Areas* – This theme shows the infrastructure challenges affecting AI implementation.
   b. **Theme 2**: *Benefits of AI in Adaptive Learning* – This theme illustrates how AI can help teachers provide materials that are more tailored to the needs of students in remote areas.
   c. **Theme 3**: *The Role of the Government in Supporting Technology in Remote Education* – This theme refers to the importance of government policies to support technology adoption.
5. **Analysis of Inter-Thematic Relationships**

Next, the themes were analyzed to find inter-thematic relationships. For example, the relationship between *Infrastructure Limitations* and *the Benefits of AI in Adaptive Learning* can show that despite the benefits of AI, infrastructure barriers reduce the effectiveness of its implementation.

6. **Interpretation and Remediation**
   Based on the results of the analysis, conclusions are made to answer the research questions and identify relevant recommendations. For example, from the results of this analysis, it can be concluded that the integration of AI in remote areas requires adequate infrastructure support and government policies that facilitate access to technology.

B. Research discussion

1. Infrastructure Challenges and Technology Access in Remote Areas

Infrastructure limitations are one of the main obstacles in adopting artificial intelligence (AI) technology in remote areas. Previous research has shown that internet access and the availability of technological devices in remote areas are very limited, which has a direct impact on the implementation of educational technology. The graph below illustrates the comparison of internet access between urban and remote areas in several ASEAN countries, including Indonesia.

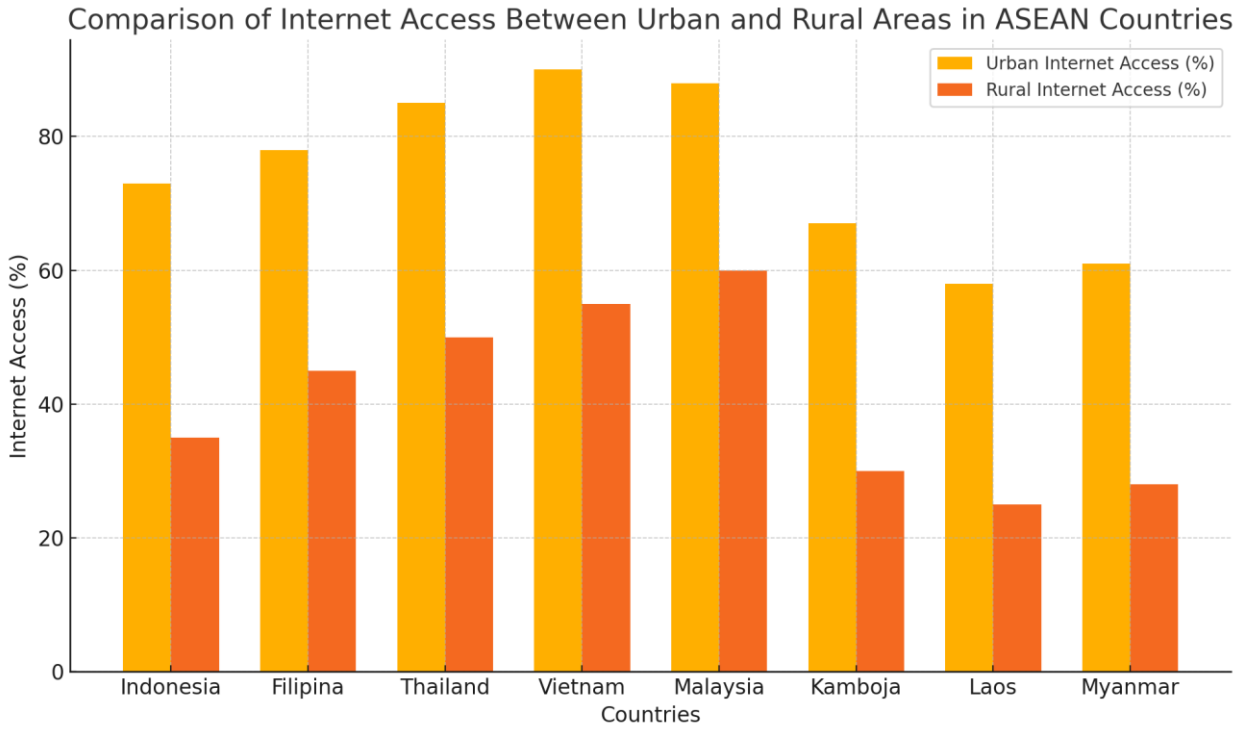

Figure 1. **Comparison of Internet Access Between Urban and Remote Areas in ASEAN Countries**

Source: ITU (2021); McKinsey (2020); WEF (2021)

The graph above shows a comparison of internet access between urban and remote areas in several ASEAN countries, including Indonesia. This chart shows that there is a significant disparity in internet access between urban and remote areas in each country, with Vietnam and Malaysia having better access in remote areas than other countries.

Table 2. Levels of access to technology in different regions

Country	Internet Access (%) Urban	Internet Access (%) Remote
Indonesia	73	35
Philippines	78	45
Thailand	85	50

Data: ITU, 2021; WEF, 2021; McKinsey, 2020

Based on this table, it is clear that the existence of disparities in internet access causes inequality in the quality of education. This study found that limited internet access in remote areas also affects the ability of teachers and students to use technological devices for learning, which hinders the adoption of AI in remote schools (Dewi et al., 2019).

2. Potential Use of AI in Supporting Adaptive Learning in Remote Areas

AI technology has great potential to support education in remote areas, especially in providing adaptive and tailored learning content to students' needs. AI enables the creation of systems that can identify students' difficulties and adapt the materials taught, which is especially important in areas where there is a shortage of qualified teaching staff (Cheng, 2022). This is especially relevant to address the shortage of teachers in remote areas, where AI technology serves as a tutor that can be accessed at any time.

An example of the implementation of AI in education is the use of AI-based learning applications, such as educational chatbots that provide practice questions or adaptive applications that adjust the material according to the level of student understanding (Singh et al., 2024). As an illustration, the following is a diagram that shows how an adaptive AI system works in adapting learning materials based on students' level of understanding.

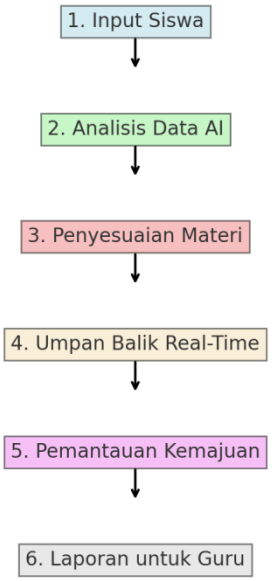

Figure 2. **How Adaptive AI Systems Work in Adapting Learning Materials**
Source: Dillenbourg (2021); Liu & Cheng (2020)

With this technology, students in remote areas can learn independently and obtain materials equivalent to students in urban areas, so that the gap in the quality of education can be reduced (Jiang et al., 2017).

3. The Role of Government Policies in Supporting AI Technology in Education

The government has an important role to play in ensuring the successful implementation of AI in education, especially in remote areas. Policies that support digital infrastructure, teacher training, and access to technology are key to ensuring that all students, both in urban and remote areas, have equal learning opportunities

Government policies in several countries that support educational technology have shown positive results. For example, in Vietnam, the government allocates a budget for digital infrastructure in remote schools, which enables the adoption of AI-based learning technologies. The table below shows the budget allocation for digital education in several ASEAN countries, which can be used as a reference for policy development in Indonesia.

Table 3. Digital Education (%) from the State Budget

Country	Digital Education Budget (%) from the State Budget
Vietnam	2.5
Thailand	3.0
Indonesia	1.8

Source: OECD, 2020; UNESCO, 2021; WEF, 2021

With supportive policies, the government can accelerate the integration of AI in the education system in remote areas, which can ultimately improve the quality of education in the area.

4. Limitations and Obstacles to AI Implementation in Remote Education

While AI has great potential, there are several obstacles to be aware of, such as limited funding, lack of training, and resistance from stakeholders in the education sector. The study found that teachers in remote areas often experience difficulties in operating AI devices due to lack of training and lack of technical guidance (Chen et al., 2020).

Another obstacle is the limited funds that prevent schools from purchasing the necessary technological devices. According to a survey conducted by ITU, only about 30% of schools in remote areas of Indonesia have technology devices for learning. The following chart shows the percentage of schools in remote areas that have technology devices in several ASEAN countries:

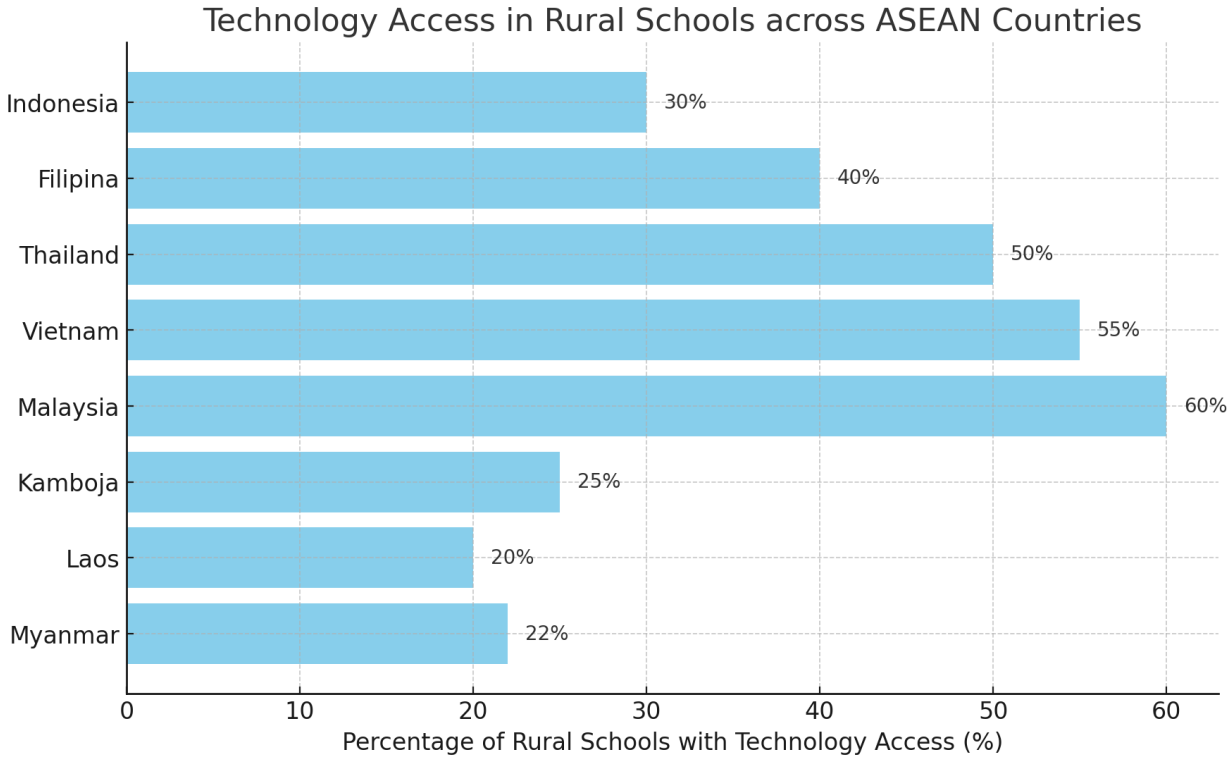

Figure 3. **Percentage of Schools in Remote Areas That Have Technology Devices in ASEAN Countries**

Source: ITU, 2021; WEF, 2021

The diagram above shows the percentage of schools in remote areas that have technology devices in several ASEAN countries. This diagram illustrates varying levels of access to technology, with Vietnam and Malaysia having relatively higher access, while countries such as Laos and Myanmar have lower percentages.

To overcome these obstacles, cooperation between the government, educational institutions, and the private sector is needed so that the integration of AI technology can run effectively and sustainably.

5. Recommendations for AI Implementation Strategies in Remote Areas

Based on the findings of the study, there are several strategies that can be applied to accelerate the integration of AI in education in remote areas. First, special training is needed for teachers on the use of AI tools and how to use them in learning (Adamopoulou & Moussiades, 2020). Second, the development of internet infrastructure must be a priority for local governments to increase access to AI-based learning platforms.

Collaboration between the government and the private sector can also be a solution in providing more affordable and sustainable technology devices. Government programs such as the *National Digital Literacy Program* in the Philippines and *Internet for All* in Thailand have succeeded in increasing access to digital education, which can be an example for Indonesia (Morley et al., 2020). The following table summarizes some of the relevant government programs:

Table 4. Relevant Government Programs To Improve Access To Digital Education

Country	Program	Purpose
Philippines	National Digital Literacy Program	Increasing digital literacy
Thailand	Internet for All	Improve internet access
Indonesia	National Distance Learning	Improving access to learning

Source: UNESCO, 2021; OECD, 2020; McKinsey, 2020

This recommendation is expected to encourage more inclusive AI adoption throughout Indonesia, so that the education gap between remote and urban areas can be further narrowed (Jiang et al., 2017).

4. Conclusion

The conclusion of this study shows that the integration of artificial intelligence (AI) in the education system has great potential to reduce the learning quality gap in remote areas. The study identified that infrastructure limitations, especially internet access and the availability of digital devices, are the main obstacles to AI adoption in remote areas. However, with the support of the right government policies, such as increased budget allocation for digital education infrastructure and training for teachers, AI can be an effective tool for providing adaptive learning content and improving the learning experience of students in remote areas. AI can act as a virtual tutor who is able to adapt the material to the needs of students, thus allowing the achievement of a more equitable quality of education despite the limitations of teaching staff.

Other findings show that active participation from the government and collaboration with the private sector are essential for the successful application of AI technology in remote areas. With supportive policies and strategic partnerships, the provision of digital infrastructure and devices can be improved, so that more schools in remote areas are able to access technology-based learning. The recommendations of this study include the need for specialized training programs for teachers and education digitalization initiatives that cover hard-to-reach areas. These findings reinforce the argument that AI has transformational potential in education, and if applied with the right strategy, can be a long-term solution in improving educational equity throughout Indonesia.

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