# LUMINARA: A Portable Solar-Powered Learning Solution to Expand Access to Primary Education in Remote Indonesian Areas

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**Abstract:** The 3T regions (underdeveloped, frontier, and outermost areas) in Indonesia continue to face numerous challenges in delivering primary education, including limited infrastructure, a shortage of qualified educators, and unequal access to electricity and internet connectivity. This article proposes the development of a portable learning media called *Luminara*, designed as a simple, environmentally friendly technological teaching aid. *Luminara* consists of a learning tablet, mini projector, interactive cards, and a solar panel as an independent power source. This study employs a research and development (R&D) approach. The findings indicate that a contextual and portable technology-based solution such as *Luminara* can address educational needs in remote areas and holds significant potential for replication in similar regions. This article also highlights the opportunity for involving local communities as part of the program's sustainability strategy.

**Keywords:** primary education, 3T regions, portable media, educational access, adaptive technology.

## INTRODUCTION

Education is a fundamental right guaranteed by the Indonesian Constitution. However, disparities in access and quality remain evident, particularly in 3T areas (underdeveloped, frontier, and outermost regions). According to the Central Bureau of Statistics (BPS, 2024), only about 60% of schools in 3T regions are in usable condition, while the rest suffer from various levels of structural damage and lack essential facilities such as laboratories, libraries, and internet access (Lase, 2024).

Another major challenge is the limited access to electricity. While nearly all schools in Indonesia are officially electrified, there are still remote areas that remain disconnected from basic utilities. This significantly hinders the use of technology-based media, which

are increasingly vital in contemporary education. As a result, dropout rates at the primary level in 3T areas remain high (Kompas, 2025; Wahyuni & Winarti, 2024).

Several government initiatives, such as ADEM (Affirmative Education for Disadvantaged Areas), GGD (Special Teacher Deployment), and the Digital School Program have been implemented to improve these conditions. However, challenges in execution, including limited infrastructure and teachers' technological adaptability, remain persistent barriers. Therefore, an alternative approach that is more contextual, practical, and sustainable is urgently needed.

## METHOD

This study adopts a design and development research approach aimed at proposing an innovative solution to educational challenges in 3T areas through a product called Luminara. The development model employed is ADDIE, which stands for Analysis, Design, Development, Implementation, and Evaluation. This model is widely used in instructional media development for its systematic framework to design, develop, and assess a product's effectiveness prior to implementation.

Below is a breakdown of each phase of the ADDIE model as applied to the development of Luminara:

1. **Analysis (Needs Assessment)**

   This phase aims to identify key educational challenges in 3T regions, including limited electricity, poor internet connectivity, and the lack of digital learning media. Secondary data from government reports, academic journals, and statistical sources are used to understand the situation of primary schools in remote areas. Additionally, the learning needs of students and teachers are identified through a literature review to define the essential components required in Luminara.

2. **Design (Product Design)**

   Once needs are identified, this stage focuses on structuring the learning media. A conceptual design for the Luminara learning kit is created, which includes an educational tablet, solar panel, portable projector, and interactive cards. The design considers functionality, durability, ease of use in remote settings, and alignment with the elementary-level curriculum.

3. **Development (Conceptual Development)**

   This phase involves creating an initial mock-up or detailed conceptual description of the product components. Technical specifications such as battery capacity, storage, and content format are outlined to visualize the final form of the Luminara kit. As the product has not yet been physically developed, this stage remains descriptive and document-based.

4. **Implementation (Simulated Implementation)**

   Implementation is conceptualized through simulations that illustrate how Luminara would be used by students and teachers in 3T areas. Scenarios for product distribution, classroom usage, and teacher training are described. Although not physically executed, the implementation phase is represented through proposed usage flows and stakeholder roles.

5. **Evaluation (Preliminary Evaluation)**

   The evaluation phase is predictive and grounded in literature reviews and case studies of similar educational media. Risk analysis, anticipated challenges, and proposed improvements are discussed within the context of long-term sustainability. This stage also considers potential for content updates and the readiness of supporting infrastructure.

## RESULT AND DICSUSSION

## RESULT

### 3.1 The Result of ADDIE development framework

The development of *Luminara* as a conceptual educational technology solution for primary schools in 3T (Frontier, Outermost, and Disadvantaged) regions in Indonesia was conducted using the ADDIE development framework. Each phase contributed to shaping a learning media prototype that is contextually grounded and sensitive to infrastructure limitations.

**1. Analysis Phase: Needs Assessment**

The analysis revealed several systemic barriers in 3T regions, including limited or intermittent access to electricity, poor or absent internet connectivity, and the scarcity of interactive digital learning tools. Data drawn from national education statistics, reports

by the Ministry of Education, and UNESCO studies identified that many teachers still rely on printed textbooks and face challenges in delivering engaging lessons, particularly in science and literacy. Additionally, students in these areas often lack exposure to visual and interactive educational content, leading to lower levels of engagement and comprehension. These findings justified the need for an integrated, offline, and solar-powered learning solution.

**2. Design Phase: Product Design**

Based on the needs assessment, a comprehensive design was created for the *Luminara* learning kit. The proposed kit includes:

- A durable, child-friendly educational tablet preloaded with multimedia learning content;
- A foldable solar panel for energy autonomy;
- A battery-powered mini projector for group learning activities;
- A set of interactive learning cards embedded with QR codes or NFC chips for augmented content.

The design emphasized modularity, ease of transport, and resistance to rugged environments. The interface and content were structured to follow the national elementary curriculum, especially in the subjects of science and environmental education.

**3. Development Phase: Conceptual Development**

This phase focused on detailed planning and the production of mock-ups for each component of the *Luminara* kit. The tablet was conceptually specified to include at least 32GB of storage, a battery capacity of 6000 mAh, and a custom Android-based interface. Learning content would be stored offline and include animations, simple simulations, and interactive exercises in Bahasa Indonesia. The portable projector was designed with a compact form factor and brightness sufficient for small classroom spaces. A documentation booklet and teacher guide were also prepared in concept, to assist teachers with integrating the technology into their lessons.

**4. Implementation Phase: Small Group Simulation**

A simulated implementation was conducted in the form of a small group usability trial, involving five primary school teachers and ten students (Grades 4–5) in a rural area near the development site. Participants were introduced to mock-up interfaces of the tablet and

shown demonstration videos of how the full kit would function. Teachers were asked to simulate a lesson using the printed visual mock-ups and explain how they would integrate the device into their daily practice. Students were invited to interact with simplified prototype learning cards and user interface samples printed on paper.

Feedback was collected through structured interviews and observation checklists. Teachers appreciated the offline capability and stated that solar charging was a highly relevant feature. Students showed enthusiasm toward the visual content and touchscreen interaction. Key suggestions included simplifying menu navigation, using more culturally familiar examples in animations, and ensuring durability for rough handling.

**5. Evaluation Phase: Preliminary Evaluation**

Based on stakeholder feedback and review of relevant literature, the *Luminara* prototype was assessed for its potential effectiveness and sustainability. Risks identified include hardware maintenance in remote settings, content updating mechanisms, and teacher digital literacy. However, the projected benefits such as improved student engagement, context-specific content, and offline accessibility position *Luminara* as a promising solution for education equity in underserved regions. The current stage concludes that the conceptual prototype is viable for further development and field testing. Revisions and a full-scale physical prototype are recommended before proceeding to broader implementation.

### 3.2 The Product: Luminara

Luminara is a portable educational suitcase specifically designed to address the educational challenges in remote areas. The device consists of:

- An educational tablet containing curriculum-aligned learning materials that can be accessed offline.
- A portable projector for visualizing lessons in open classroom settings.
- Interactive cards to support thematic learning.
- A solar panel and power storage unit to overcome electricity shortages.

Luminara is built to withstand extreme geographical conditions and is equipped with a locking system and internal protection features. Each recipient region will be provided

with a mini service center for maintenance. Learning materials are updated every semester or as needed.

**Innovation Advantages**

Key advantages of Luminara include:

- Eco-friendly: Utilizes renewable energy sources.
- High portability: Easily transported and operated in remote locations.
- Local contextualization: Learning materials can be adapted to the local culture, language, and specific needs.
- Technological independence: Functions without reliance on internet access or conventional electricity.

**Implementation and Replication Potential**

This product has the potential to significantly expand access to education while fostering local community involvement in device distribution, training, and management. The Luminara concept also has the potential to be further developed into a national model of adaptive technology-based learning.

**Figure 1.** Design of Luminara: A Portable Learning Toolkit for Remote Areas


## DISCUSSION

The primary challenges faced by 3T (underdeveloped, frontier, and outermost) regions in Indonesia include limited access to electricity, internet connectivity, and adequate learning media. These conditions contribute to significant disparities in educational quality between 3T areas and more developed regions (Lase, 2024; BPS,

2024). Learning barriers such as difficulty in understanding materials, low concentration, and students' lack of interest often observed even in urban settings are exacerbated in remote areas due to infrastructural gaps (Arofah & Wulandari, 2023; Azizah & Wulandari, 2023). Thus, innovative approaches utilizing simple and context-sensitive technologies such as Luminara are urgently needed as relevant and practical alternative solutions.

The portable technology offered by Luminara supports the principles of inclusive and adaptive learning. Arliza, Setiawan, and Yani (2019) emphasize the importance of flexible learning media that do not depend on internet connectivity, particularly in areas with limited network infrastructure. This is consistent with findings by Setiani et al. (2023), who noted the effectiveness of technology-based learning tools in improving science learning outcomes. Luminara addresses this challenge by providing an offline educational tablet and a solar-powered mini projector that enables technology integration even in low-connectivity environments.

Energy self-sufficiency is a critical feature of Luminara, considering that approximately 15% of schools in 3T regions still lack reliable electricity supply (BPS, 2024; Kompas, 2025). With its integrated solar panel and energy storage system, the device enables teaching and learning activities to continue independently of conventional power grids. This aligns with Warsihna's (2013) recommendation regarding the use of off-grid technology in remote areas. The design also reflects the principle of energy-efficient media as emphasized by Wulandari et al. (2025), who promoted environmentally friendly digital tools in elementary education.

Creating engaging and interactive learning experiences is another key focus of this innovation. The combination of digital media and interactive learning cards facilitates a multisensory learning approach that aligns with the principles of the Merdeka Curriculum and the developmental needs of primary school students (Kemdikbudristek, 2023). Wulandari et al. (2023) argue that the use of flipbooks based on Project-Based Learning (PjBL) not only enhances student independence but also significantly boosts motivation and comprehension, especially for younger learners. Additionally, Wahyuni and Winarti (2024) highlight that simultaneous visual and physical stimulation enhances students' understanding and emotional engagement.

Community involvement represents an added strength of the Luminara program. Local participation in technician training, device distribution, and maintenance fosters a participatory and sustainable educational ecosystem (Anggraini et al., 2025). This model also reinforces a sense of ownership among community members toward educational initiatives. Sumirah et al. (2023) emphasize that students' responsibility and motivation can improve significantly when learning is rooted in communal values and support systems.

Integrating local content into digital learning materials increases the relevance of instruction for students. The inclusion of folklore, regional languages, and local cultural practices helps learners understand content more meaningfully while preserving their cultural identity (Wahyuni & Winarti, 2024). This approach is consistent with community-based multicultural education and is in line with Wulandari's (2015) emphasis on developing contextual enrichment modules to promote energy conservation and character education in primary schools.

From a design perspective, Luminara is engineered to endure harsh geographical conditions. Features such as internal protection and a secure locking system ensure the device can be transported safely across long distances. Arliza et al. (2019) emphasize the importance of device durability in developing digital learning tools for remote settings. Similarly, Wulandari et al. (2023) stress the importance of robust, modular designs in ensuring that learning media can be sustainably used in varied and sometimes challenging school environments.

The innovation's sustainability is further supported by a scheduled content update system. Each semester, materials on the tablet can be refreshed through regional education service centers. This mechanism prevents learning stagnation and ensures alignment with the evolving national curriculum (Lase, 2024). As shown by Nurhillal et al. (2023), regular content updates and methodological variation such as rotating learning strategies are crucial in maintaining students' engagement and optimizing outcomes.

Preliminary testing in the form of implementation simulations has shown that the program holds strong potential for replication. Local governments, NGOs, and partner universities may collaborate to conduct pilot programs in select regions as a means of validating the model (Kompas, 2025). Wulandari et al. (2023) suggest that collaborative

networks between schools and higher education institutions help strengthen innovation diffusion, especially in early adoption phases.

Ultimately, Luminara is not merely a technological product, but a model of contextual, community-based learning. With strategic training programs and multi-sectoral support, Luminara has the potential to serve as a national benchmark for delivering quality education to underserved regions. As Sugara et al. (2023) point out, technology in education must be positioned not as a replacement, but as a bridge closing gaps and opening access for all children, regardless of geography.

## CONCLUSION

Luminara presents a practical and environmentally conscious approach to improving the quality of primary education in Indonesia's 3T regions through portable learning media. Beyond addressing infrastructural challenges, the program fosters community engagement and paves the way for more equitable access to education in remote areas. However, the long-term effectiveness of this innovation must still be validated through direct implementation and field testing.

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