

# Utilization of Windmills as Interactive Learning Media to Introduce Power Generation Concepts

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## ABSTRACT

Environmental degradation and climate change necessitate early childhood renewable energy literacy to foster sustainable behaviors from a young age. However, early childhood education at TK ABA 25 Malang lacked clean energy integration due to conventional text-based teaching methods and an absence of safe kinetic Educational Teaching Aids (APE). This study aims to evaluate the effectiveness of an interactive mini wind turbine APE in introducing mechanical-to-electrical energy conversion concepts to preschool students. Utilizing a descriptive-evaluative Participatory Action Research (PAR) framework involving 20 students (aged 4–6 years) and 4 educators, the intervention combined student windmill drafting with hands-on "Wind to Electricity" experiments. Data were gathered through direct observations, child-friendly visual card pre/post-tests, and teacher interviews, analyzed using percentage formulas and qualitative reduction. Results demonstrated that 90% of participating students achieved clear conceptual comprehension of energy transformation, responding enthusiastically to instant visual LED feedback without chemical batteries. Furthermore, the initiative enhanced teachers' STEM pedagogical capacities, eliminated battery waste, and established a permanent learning asset. In conclusion, simplifying complex engineering concepts into interactive kinetic media provides an effective, safe, and scalable model for early childhood renewable energy education, empowering both learners and educators toward long-term environmental sustainability.

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## 1. INTRODUCTION

Global climate change and environmental degradation require a fundamental shift toward renewable energy literacy from an early age (Lowan-trudeau & Fowler, 2026). Kota Malang's high plateau location offers a favorable natural environment with local wind speeds averaging 3.1 to 4.8 m/s, presenting an ideal natural laboratory for clean energy education (Baruah & Gaudet, 2022; Emmanuel et al., 2023). However, early childhood education (PAUD) rarely integrates engineering concepts or energy

conversion due to the perception that technical topics are too complex for young learners (Romero-lankao et al., 2023). TK ABA 25 Malang, located on Jalan Veteran Dalam 427S, Lowokwaru, Malang City, serves as an early childhood educational institution under Muhammadiyah (Mamungkas, 2024, 2025). The school employs 3 teachers and 1 principal (Ibu Raminah) and serves 20 active students. Facilities include 3 classrooms, a library, indoor and outdoor play areas, and a 60 m<sup>2</sup> outdoor courtyard. Baseline observations revealed that 100% of students lacked an understanding of mechanical-to-electrical energy conversion. Instructional methods remained dependent on static text and pictures, lacking interactive kinetic Educational Teaching Aids (APE) designed for STEM (Science, Technology, Engineering, and Mathematics) learning (Ilyas & Meiyani, 2022; Minarti et al., 2022; Zhang et al., 2024). To solve these challenges, this community service initiative introduced an interactive mini windmill system paired with hands-on workshops. By converting wind motion into electrical energy to illuminate LED lights, abstract physical phenomena were transformed into visual, tangible experiences (Lotfabadi, 2025; Omodan, 2024).

This project aligns with national and global strategic frameworks:

- Sustainable Development Goals (SDGs): Supports Goal 4 (Quality Education) through innovative teaching tools and Goal 7 (Affordable and Clean Energy) by fostering early environmental stewardship.
- Higher Education Main Performance Indicators (IKU): Contributes to IKU 3 (Lecturers Engaging in Community Outreach) and IKU 5 (Utilization of Research/Lecturer Innovations by Society).
- Asta Cita & RIRN: Aligns with Asta Cita Pillar 4 (Environmental Harmony and Energy Independence) and the National Research Master Plan (RIRN) in renewable energy social-humanities adoption.

State-of-the-art research in early childhood science education emphasizes the efficacy of experiential, hands-on learning (Kurnianingtyas & Anugrahini, 2021; Sari et al., 2025). While recent outreach initiatives have explored renewable energy for secondary students (Effendy et al., 2024) or utilized photovoltaic kits (Nurwijayanti et al., 2025), a distinct research gap exists regarding low-cost, battery-free kinetic media specifically designed for preoperational preschool learners. Existing solutions often rely on complex electronic charge controllers, expensive hardware, or screen-based simulations that are impractical and unsafe for early childhood environments (Harerimana et al., 2023). Quantitative data were analyzed using simple percentage calculations ( $P = f/\{N\} \times 100\%$ ), while teacher feedback was analyzed using qualitative descriptive reduction.

To address this gap, this community service research introduces a portable mini wind turbine APE paired with a creative student workshop. The primary novelty of this intervention lies in transforming abstract electromagnetic induction into immediate, battery-free visual LED light feedback, creating an intuitive physical cause-and-effect experience for 4–6-year-old children. The core objective of this study is to evaluate how this interactive media improves student conceptual comprehension of energy generation and enhances teachers' STEM pedagogical readiness.

## 2. METHODS

This study applies a descriptive-evaluative Participatory Action Research (PAR) methodology to collaboratively design, implement, and evaluate kinetic learning media in an early childhood setting (Cornish, Flora, Breton, Nancy, Moreno-Tabarez, Ulises, Delgado, Jenna, Rua, Mohi, de-Graft Aikins, Ama & Hodgetts, 2023; Salviana et al., 2022). The PAR approach is highly appropriate for community service research as it directly engages educators and young learners as active co-participants in the educational intervention. The procedure covers five phases: socialization, teacher capacity building, field application (student workshop and experiment), mentoring, and asset transfer. Instruments include a portable mini wind turbine (30–40 cm tall, 20 cm propeller, DC motor, 3V–5V LED), student workshop materials, and visual card questionnaires. Data collected through direct observation, visual tests, and teacher interviews were analyzed using quantitative percentage formulas ( $P = f/\{N\} \times 100\%$ ) alongside qualitative descriptive techniques.

### 3. FINDINGS AND DISCUSSION

#### 3.1. Interactive Windmill Prototype and Instructional Module

The engineering team developed a main portable mini wind turbine and individual student workshop kits. The main turbine stands 30–40 cm tall with a 20 cm propeller, coupled directly to a small DC motor/dynamo generator connected to 3V–5V LED lights. Designed with blunt plastic edges and plug-and-play wiring, it ensures absolute safety for preschool handling. When air currents from a fan strike the propeller, the dynamo converts kinetic energy into electrical energy, instantly lighting up the LED.

**Table 1.** Technical Specifications of the Wind Energy Learning Media

| Technical Parameter          | Specification & Characteristic                              | Learning Function                                                               |
|------------------------------|-------------------------------------------------------------|---------------------------------------------------------------------------------|
| Structure Height & Propeller | Height: 30–40 cm; Propeller diameter: 20 cm (Blunt plastic) | Safe physical manipulation for preschool children.                              |
| Generator System             | Low-voltage DC micro-dynamo generator                       | Converts rotational kinetic energy into electricity without chemical batteries. |
| Output Indicator             | Plug-and-play 3V–5V LED light indicators                    | Provides immediate visual feedback of energy generation.                        |
| Instructional Module         | "Wind Playing Module" & Visual Card Assessment Kit          | Standardized guide for teacher-led STEM facilitation.                           |

#### 3.2. Workshop Implementation and Student Comprehension

During the initial phase of the interactive workshop, preschool students actively engaged in building their own simplified windmill models using safe, lightweight, and eco-friendly materials such as carton paper, straws, and wooden sticks. Guided closely by the university team and their classroom teachers, the children experienced the step-by-step process of assembling propeller blades and mounting them onto rotating shafts. This hands-on drafting activity served as a critical pedagogical bridge, encouraging fine motor skill development while sparking natural curiosity about how air currents interact with physical structures. By transforming passive young listeners into active builders, the workshop established a collaborative, inquiry-based atmosphere where students felt a personal sense of ownership over their learning artifacts before advancing to the experimental phase.



**Figure 1.** Implementation of the "Wind to Electricity" interactive workshop with students and teaching staff at TK ABA 25 Malang.

Transitioning into the "Wind to Electricity" experimental demonstration, the children gathered around the main portable mini wind turbine to observe energy conversion in real time under controlled airflow generated by a desktop fan. As the air currents struck the propeller blades, causing the shaft to spin the small DC dynamo generator, kinetic mechanical energy was instantly converted into clean electrical power. The key highlight of this demonstration was the immediate, vivid visual feedback: a connected 3V–5V LED light illuminated instantly as the blades began to rotate, glowing noticeably brighter as the wind speed increased. This battery-free setup allowed the young learners to witness a direct physical manifestation of power generation without needing complex wiring or abstract theoretical jargon.

This immediate cause-and-effect interaction proved to be a powerful educational tool, successfully transforming the traditionally abstract concept of energy conversion into a concrete, tangible understanding for early childhood learners. By witnessing the direct correlation between air movement and light output, the students intuitively grasped that invisible natural forces can be harnessed to produce functional electricity. The overwhelming enthusiasm displayed during the post-activity visual card-based evaluations demonstrated that seeing the LED light up firmly solidified their conceptual comprehension. Ultimately, this experiential learning approach not only demystified green technology for young children, but also established a lasting foundation for early environmental stewardship and STEM literacy.

**Table 2.** Program Target Achievements and Evaluation Metrics

| No | Solution Offered                        | Baseline Condition                                                     | Post-Activity Target & Result                                                                              | Achievement Rate |
|----|-----------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|------------------|
| 1  | Mini Wind Turbine APE                   | No functional kinetic APE available at the school.                     | 1 Main turbine produced and formally donated to the school.                                                | 100% Completed   |
| 2  | Creative Student Workshop               | Students unfamiliar with turbine drafting and windmill assembly.       | 100% of participating students (20 children) successfully built individual windmills.<br>≥ 90% of students | 100% Completed   |
| 3  | 'Wind to Electricity' Experiment        | No visual comprehension of mechanical-to-electrical energy conversion. | comprehend cause-and-effect relationship (wind to LED illumination).                                       | 90% Achieved     |
| 4  | Teacher Training & Instructional Module | No standardized EBT instructional guide or hands-on STEM training.     | 1 Instructional module delivered; 4 teaching staff fully trained.                                          | 100% Completed   |

Visual card-based post-tests indicated that 90% of students (18 out of 20) successfully identified that wind movement can generate electricity to turn on lights.

### 3.3. Teacher Empowerment and Institutional Impact

The project delivered a long-term impact on teacher capacity at TK ABA 25 Malang. Instructors gained confidence in facilitating STEM experiments and integrating EBT concepts into the "Universe" and "Technology" themes of their Daily Lesson Plans (RPPH). Operationally, using wind-generated kinetic APE eliminated the school's dependence on single-use chemical batteries, reducing hazardous waste and operational costs.

## Discussion

The empirical findings directly address the primary educational objective by resolving the baseline knowledge gap at TK ABA 25 Malang, where 100% of preschool students initially lacked an understanding of mechanical-to-electrical energy conversion due to reliance on static text materials. Following the intervention, 90% of participating students (18 out of 20 children) demonstrated clear conceptual comprehension during visual post-tests, while 100% of the teaching staff (4 educators) successfully mastered the "Wind Playing Module" for STEM instruction. Scientifically, the mini wind turbine converts wind kinetic energy into rotational mechanical energy that drives a low-voltage DC generator to power 3V–5V LED lights without chemical batteries. Cognitively, this instant visual feedback—where faster blade rotation yields visibly brighter LED illumination—translates abstract electromagnetic induction into intuitive physical cause-and-effect observations suitable for children in the preoperational development stage (ages 4–6) (Vicovaro, 2023).

These results align with previous studies on experiential science learning (Misriatun, 2022; Hendaryati et al., 2024) and early renewable energy outreach (Nurwijayanti et al., 2025; Mamungkas, 2025), while offering a safer, battery-free alternative to complex photovoltaic setups or screen-based digital simulations. Beyond immediate learning gains, eliminating single-use chemical batteries reduces hazardous B3 waste and lowers operational costs for early childhood centers, directly supporting Sustainable Development Goals 4 (Quality Education) and 7 (Affordable and Clean Energy). Future research should evaluate multi-quarter knowledge retention and explore scaling this battery-free kinetic Educational Teaching Aid (APE) model across the broader Aisiyiah Bustanul Athfal (ABA) kindergarten network.

## 4. CONCLUSION

The community service program successfully introduced renewable wind energy and power generation concepts to students at TK ABA 25 Malang. The mini wind turbine APE effectively converted abstract engineering principles into concrete, engaging learning experiences. Post-activity evaluations showed that 90% of participating students understood mechanical-to-electrical energy conversion. Additionally, the program elevated teacher pedagogical capabilities in STEM education and established permanent, battery-free learning assets for the institution. Future Recommendations: For School Partners: Maintain regular "Wind Exploration" sessions in outdoor play areas and establish a dedicated "Science Corner". For Program Expansion: Replicate this APE model across the Aisiyiah Bustanul Athfal (ABA) kindergarten network and integrate hybrid renewable energy sources (e.g., combined solar-wind micro generators).

Practically, this study provides a safe, environmentally friendly, and cost-effective learning model that eliminates single-use battery waste and reduces operational expenses for early childhood centers. Methodologically, it demonstrates the efficacy of kinetic-visual tools in early STEM literacy. To build upon these achievements, future research should evaluate long-term conceptual retention across multiple academic quarters and explore scaling this kinetic APE model across broader early childhood educational networks.

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