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Development of an Electronic Media Kit (Smart Home) Based on Green Technology

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ABSTRACT

This study aims to develop a smart home electronic media kit based on green technology, using solar energy as the primary power source and an Arduino Uno as the system controller. The main problem identified is the difficulty students face in understanding technical and abstract electronic concepts in the Form 5 Invention (Reka Cipta) subject, which is exacerbated by a lack of interactive, practical teaching aids and a moderate level of green technology awareness among students. To address this, the media kit is designed to practically demonstrate how green technology works—such as solar energy conversion—alongside smart home automation functions like automatic light and temperature control. The development of the kit was carried out systematically using the ADDIE instructional design model, involving Analysis, Design, Development, limited Implementation, and Evaluation phases. The results show that the automated system functions effectively based on environmental changes and possesses high usability for educational purposes. Ultimately, this kit not only increases students' interest and understanding of electronics but also serves as an interactive educational platform to foster sustainable practices and strengthen STEM education in alignment with the Industrial Revolution 4.0.

1. Introduction

The rapid development of information and communication technology (ICT) during the Industrial Revolution 4.0 (IR 4.0) has brought significant changes to modern residential management and education. A smart home utilizes automation technology and the Internet of Things (IoT) to systematically control electrical appliances, improving both comfort and safety [5]. Furthermore, integrating smart homes with Green Technology—which employs eco-friendly innovations and renewable sources like solar energy—plays a crucial role in reducing environmental impacts such as carbon emissions and supporting long-term sustainability [19,20].

In the context of 21st-century education, particularly in the Form 5 Invention (Reka Cipta) subject, integrating these modern technologies is essential. However, students often face difficulties

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mastering electronic topics due to teaching approaches that heavily rely on abstract theory and lack interactive, hands-on activities [14]. This shortage of practical teaching aids often leads to a lack of student interest and motivation [1]. Additionally, while students generally possess a high theoretical knowledge of green technology and renewable energy, their actual practice and application of these concepts in daily life remain at a moderate level [11,21].

Despite government initiatives like the Green Technology Master Plan 2017–2030 (Ministry of Energy, Green Technology and Water Malaysia, 2017) and the National Green Technology Policy (Public Service Department Malaysia, 2024), the integration of green technology into practical educational materials remains insufficient. Applying concepts like Green Building and smart homes in education is critical, as it directly supports the United Nations' Sustainable Development Goals (SDGs), specifically SDG 4 (Quality Education), SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

To address these educational and environmental challenges, developing a solar-powered smart home electronic media kit using an Arduino Uno controller provides an innovative solution. By combining physical components, programming modules, and hands-on activities, this kit serves as an interactive IoT-based trainer [13] that demonstrates the practical workings of green technology and automation. This approach not only makes learning more contextual and enjoyable but also aims to increase students' digital literacy, interest in electronics, and active awareness of sustainable environmental practices through STEM-based methods [6,16,29].

2. Literature Review

2.1 IoT, Smart Homes, and Interactive Media in Education

The implementation of Internet of Things (IoT) in educational institutions provides a strong technological foundation for modern learning environments. Establishing IoT-vocational learning centers offers significant benefits for exploring emerging technologies, directly supporting Technical and Vocational Education and Training (TVET) initiatives [32].

In the classroom, combining IoT devices with gamification successfully increases students' energy awareness and their interaction with the learning materials [24]. Furthermore, large-scale IoT-based interventions in schools have demonstrated that exposing students to smart home kits and energy management systems encourages them to adopt sustainable habits in their daily lives [25]. Interactive learning media significantly impacts education; for instance, the use of interactive simulation applications like Tinkercad has been shown to notably improve students' mastery and interest in abstract electronic topics [31].

Similarly, interactive learning applications such as the Smart Sel app have increased students' understanding of complex scientific concepts by up to 96%, proving the high efficacy of technology-assisted teaching [30]. Additionally, interactive learning media has been found to exert a direct positive influence on improving students' academic performance.

2.2 Solar Energy and Green Technology Education

Teaching renewable energy through hands-on, project-based learning is highly effective for engineering and technology students [20]. In the Malaysian context, secondary school students currently possess only a moderate understanding of solar energy and photovoltaic (PV) technology, and they often struggle to link theoretical concepts to real-world applications [27]. To address this educational gap, studies emphasize that Malaysian teachers urgently require more practical teaching modules and kits to teach solar energy concepts effectively [26].

2.3 Theoretical Framework: Constructivism

The development of the smart home kit is grounded in the constructivist theories founded by Jean Piaget and Lev Vygotsky, which assert that students actively construct their own knowledge through direct experience and social interaction. Constructivist learning environments that allow students to manipulate concrete objects—such as electronic teaching kits—are essential for bridging the Zone of Proximal Development (ZPD) (DiCamillo, 2020). Furthermore, these environments boost intrinsic motivation, increase confidence in real-world problem-solving, and enhance students' competence in complex STEM and technological design tasks.

3. Methodology

This study employed a qualitative research design, focusing on the in-depth exploration of the product's development and its initial usability evaluation. The study utilized purposive sampling to select three secondary school teachers who specifically teach the Form 5 Invention (Reka Cipta) and Technology subjects. This approach ensured that the data collected was reflective, critical, and highly relevant to the targeted curriculum.

The ADDIE Instructional Design Model The development of the smart home kit was systematically carried out using the five interactive phases of the ADDIE Model, a widely adapted framework for creating effective educational media [2,4,17].

3.1 Analysis Phase

The initial stage involved a literature review and an analysis of the Form 5 Invention (Reka Cipta) syllabus to identify relevant electronic and green technology topics. Informal discussions confirmed that students struggled with abstract electronic theories and that there was a critical need for an interactive, hands-on teaching aid [23].

3.2 Design Phase

This phase focused on planning the kit's physical structure, educational supporting materials, and drafting research instruments. The system's architecture was designed using an Input-Process-Output (IPO) framework [7]. Input components include a DHT11 sensor (temperature and humidity), an LDR (light intensity), a water sensor, and an RC522 RFID reader. Processing is handled by the Arduino Uno using conditional logic. Output actuators include an I2C LCD screen, automated LED lighting, window and door servos, and a buzzer. Figure 1 shows the schematic design of the kit.

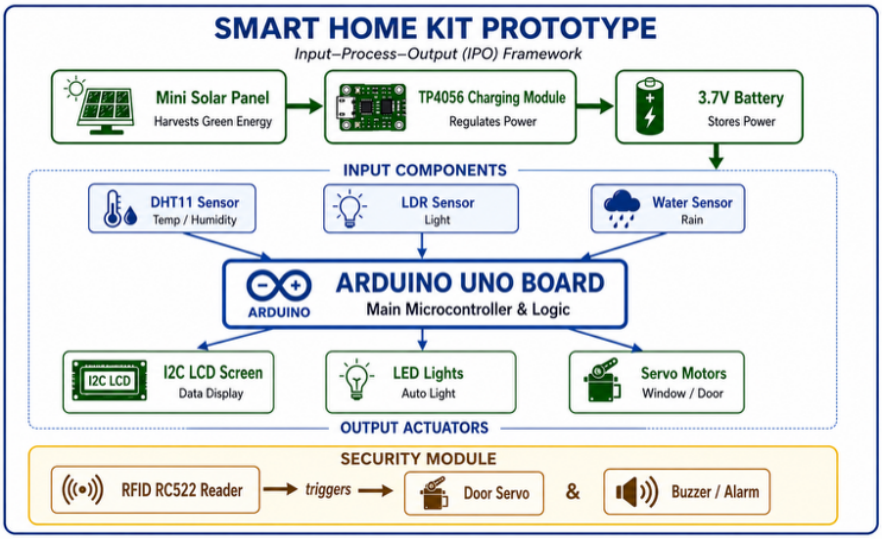

Fig. 1. Electronic media kit (Smart Home) schematic design

3.3 Development Phase

The physical prototype was assembled integrating actual electronic components, such as a mini solar panel for green energy sourcing, sensors, and the Arduino microcontroller. Specific programming logic was applied; for instance, the water sensor was coded to automatically close the window servo upon detecting rain. Before user evaluation, the researcher conducted initial technical testing to ensure hardware stability. Figure 2 shows the propose working model that has been developed based on the design that has been validated.

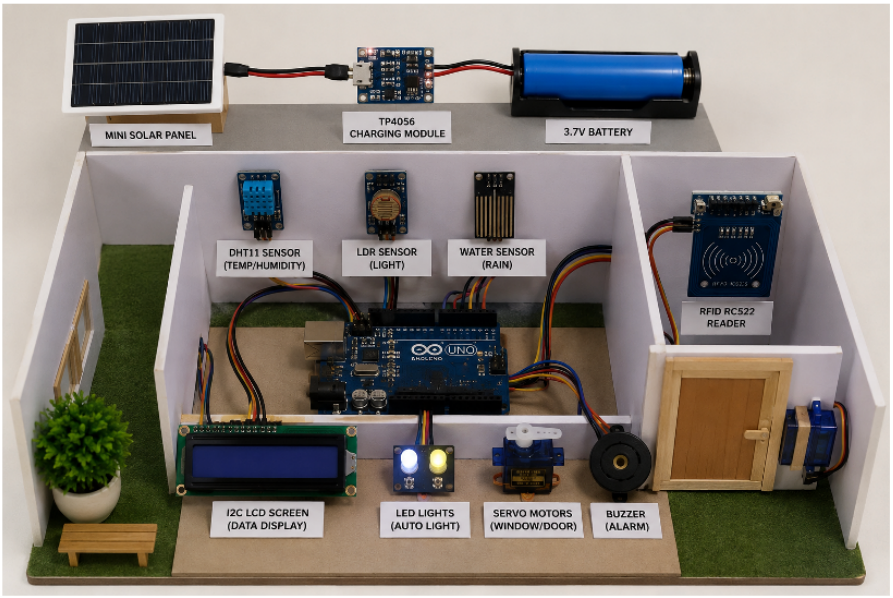

Fig. 2. Propose working model for the electronic media kit

3.4 Implementation Phase

The implementation was conducted in a highly controlled scope. Rather than a full-scale classroom intervention, the kit was introduced to the selected teachers via video demonstrations

showing exactly how the kit operates. The teachers observed its functionality and suitability within a classroom context.

3.5 Evaluation and Data Analysis

Evaluation was conducted through semi-structured interviews with the three participating teachers to gather in-depth feedback on the kit's usability and strengths. The qualitative data from the transcripts was processed using Thematic Analysis (familiarization, initial coding, searching for themes, reviewing themes, defining themes, and reporting) to provide a comprehensive understanding of the kit's potential for real-world teaching.

4. Findings and Discussion

Based on the thematic analysis of the semi-structured interview transcripts from the three participating teachers (Informants 1, 2, and 3), the evaluation of the solar-powered smart home kit yielded several critical insights into its usability, pedagogical value, and areas for refinement. The findings are categorized into five main themes:

4.1 Constraints in Teaching Electronic and Green Technology Topics

All informants strongly agreed that the primary constraint in teaching electronic topics is the severe lack of practical, interactive teaching aids [1]. Because the content is highly abstract, students struggle to visualize real-world applications of the theories they learn, forcing teachers to rely heavily on their own creativity. Furthermore, teachers highlighted logistical challenges, including limited teaching time, inadequate laboratory facilities, and a constant risk of losing small, delicate electronic components when students handle them during lessons. Frequent electricity outages in certain regions also make alternative power sources essential.

4.2 Needs and Justification for Kit Development

To address these constraints, the teachers expressed strong consensus on the necessity of a green technology-based smart home kit. They emphasized that such a kit transitions the classroom from a teacher-centered, theoretical environment to a student-centered, experiential one. By integrating solar energy, the kit allows students to directly observe real-time environmental parameters (such as temperature and light intensity) and witness the system's automatic responses, heavily supporting contextual project-based learning [12,18].

4.3 Suggested Features, Functions, and Modular Design

An effective kit must include specific features to maximize its educational value, such as various sensors, an automatic control system, a green energy source, and a real-time data display. Crucially, teachers warned against overcrowding a single kit board with too many sensors, which can confuse students and increase the risk of damage. Instead, a modular concept was highly recommended. Separating kits according to specific functions enables focused learning and group rotations, supporting a more structured approach to green building literacy [8]. Clear labels for each component (e.g., diodes, resistors) were also requested to aid parts identification.

4.4 Impact on Students' Understanding and Interest

The informants agreed that the kit has a profound impact on capturing students' attention. The element of "visible change"-such as an LED lighting up or a servo motor moving immediately after a sensor is triggered-is the primary factor that makes learning meaningful. Seeing the direct physical result of an electronic input aligns perfectly with 21st-century experiential learning.

4.5 Potential to Improve Higher-Order Thinking Skills (HOTS)

Beyond basic understanding, the kit serves as a catalyst for developing Higher-Order Thinking Skills (HOTS) [3]. The teachers noted that by interacting with the kit, students are pushed to engage in problem-solving, decision-making, and designing custom solutions. It provides students with a foundational reference that they can adapt and apply to produce higher-quality, automated coursework projects.

4.6 Suggestions for Future Improvement

To ensure optimal classroom use, teachers provided practical recommendations:

- Educational Support Materials: The physical kit must be accompanied by a comprehensive learning module, structured worksheets, staged experimental guides, and a user manual.
- Anti-Tampering/Safety System: Given the risk of students losing or damaging small parts, adding an alarm or buzzer system was suggested. If a component is unplugged improperly, the kit would emit a warning sound to help teachers easily monitor the classroom.
- Backup Components: Providing 2 to 3 sets of extra components is essential to ensure lessons continue smoothly if parts are misplaced

5. Conclusion and Recommendations

5.1 Summary of the Project's Impact

Overall, the development of the solar-powered smart home electronic media kit using the ADDIE model successfully achieved its objectives. The kit proves that integrating automation and renewable energy into an interactive teaching aid can significantly enhance the teaching and learning of abstract electronic and green technology concepts, particularly for Form 5 Invention (Reka Cipta) students.

5.2 Educational and Policy Implications

The project bridges a critical gap between the curriculum's demand for 21st-century skills and the practical realities of the classroom. It serves as a powerful medium for STEM integration, combining science, technology, engineering, and mathematics into a cohesive project [6,29]. Furthermore, the development of this green technology-based kit aligns directly with national initiatives, such as the National Environmental Policy (Department of Environment Malaysia, n.d.) and the Green Technology Master Plan 2017–2030 (Ministry of Energy, Green Technology and Water Malaysia, 2017)

5.3 Limitations of the Current Study

While initial evaluation was successful, the study was restricted to qualitative usability and content validation through semi-structured interviews with a small sample of three teachers. The study did not conduct a full-scale classroom intervention or utilize a quantitative pre-test and post-test design to statistically measure direct impact on student achievement.

5.4 Recommendations for Future Research

To maximize the potential of this kit, future research should:

- Involve quantitative experimental studies with control and treatment groups to measure actual academic impact.
- Expand testing across a wider, more diverse sample of schools and student demographics.
- Develop complete instructional modules, including daily lesson plans and project-based assessment rubrics.
- Integrate digital IoT platforms, such as real-time data dashboards, allowing students to visualize sensor data dynamically.
- Conduct longitudinal behavioral studies to evaluate whether exposure to this kit positively influences students' sustainable habits over time [15].

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