국제과학영재학회지 제9권 제1호
Journal of the International Gifted in Science
Vol. 9, No. 1, 17-41 February 2025
ISSN 1976-2224
e-ISSN 2288-1441

Enhancing Renewable Energy Education Through Practical Applications in Grade-12 Physics: A Case Study in Myanmar

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<Abstract>

This study investigates the effectiveness of using the Science Davinci Box toolkit to enhance the teaching and learning of solar energy concepts in Grade-12 Physics classes in Myanmar. Addressing the educational challenges of limited resources, outdated curricula, and a lack of trained educators, the intervention aimed to bridge the gap between theoretical knowledge and practical applications through hands-on, experiential learning. Utilizing a mixed-methods approach, quantitative data were collected through pre- and post-intervention assessments, while qualitative insights were gathered from student interviews, focus group discussions, and classroom observations. The results revealed a statistically significant improvement in students' knowledge, with mean test scores increasing from 55% to 78% ($p < 0.01$). Additionally, the intervention fostered critical thinking, problem-solving skills, and increased student engagement with renewable energy topics. However, challenges related to technical difficulties, time constraints, and teacher readiness were identified. The findings underscore the potential of educational toolkits in enhancing renewable energy education in resource-limited settings and provide valuable implications for curriculum reform and teacher training programs in Myanmar.

key words: renewable energy education, experiential learning, hands-on learning tools, Science Davinci Box, solar energy concepts, educational toolkits, student engagement

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1. Introduction

As the global community intensifies efforts to combat climate change, the education sector plays a pivotal role in equipping future generations with the knowledge and skills required to develop and implement sustainable energy solutions. Renewable energy, particularly solar energy, is vital in this context due to its potential to reduce greenhouse gas emissions and provide clean, sustainable power (International Energy Agency, 2020). In developing countries like Myanmar, where the educational infrastructure is often under-resourced, there is a pressing need to enhance science education, particularly in the area of renewable energy. The United Nations Sustainable Development Goals (SDGs) emphasize the importance of quality education (Goal 4) and affordable, clean energy (Goal 7), making it essential for education systems to adapt to these global priorities (UN, 2015).

Myanmar's education system faces significant challenges, including limited access to quality educational materials, outdated curricula, and a lack of trained educators, particularly in rural areas. These issues are exacerbated by economic constraints that limit the availability of modern teaching tools and laboratory equipment, making it difficult to provide students with practical, hands-on learning experiences (Aung, 2021). The traditional focus on rote learning and theoretical instruction in Myanmar's schools often leads to a shallow understanding of complex scientific concepts. This approach limits students' ability to apply knowledge to real-world situations, particularly in subjects like Physics, where practical understanding is crucial (Sharma & Pathak, 2020).

2. Literature Review

This section provides a comprehensive overview of the theoretical background and existing research related to renewable energy education. It examines the educational challenges in Myanmar, the role of experiential learning, the impact of educational toolkits like the Science Davinci Box, and the influence of renewable energy education on student engagement, career aspirations, and environmental awareness. The review is organized to align with the key themes discussed in the study's findings and discussion sections.

2.1 Overview of Science Educational Toolkits : Science Davinci Box

The Science Davinci Box have become essential resources in modern science education, particularly in promoting hands-on learning experiences in classrooms. These toolkits are designed to support the practical application of scientific theories, allowing students to conduct experiments and explore complex concepts in a tangible way. The range of available such educational toolkits varies widely, from simple, low-cost kits intended for basic scientific experiments to advanced systems capable of simulating intricate scientific phenomena.

In developing countries, where resources for education may be limited, these toolkits serve as invaluable tools to bridge the gap between theoretical instruction and practical understanding. By making science education more interactive and engaging, they help cultivate critical thinking, problem-solving skills, and a deeper comprehension of scientific principles among students.

The Science Davinci Box is a prominent example of an educational toolkit designed with affordability and accessibility in mind, particularly for schools in developing countries. This toolkit has been specifically crafted to facilitate the teaching of renewable energy concepts, with a strong focus on solar energy. It was made available to schools in Myanmar as part of a sponsorship initiative by the ASEAN+3 Center for the Gifted in Science, following the 12th ASEAN+3 Student Camp and the 14th ASEAN+3 Teacher Workshop for the Gifted in Science.

The toolkit includes a variety of components such as solar cells, motors, voltmeters, wires, and light sources. These materials allow students to engage in a broad range of experiments, helping them to explore the principles of solar energy, such as the conversion of sunlight into electricity and the factors that influence the efficiency of solar cells. By providing these tools, the Science Davinci Box enables students to move beyond theoretical knowledge, offering them the opportunity to witness firsthand the practical applications of what they learn in their Physics classes.

One of the key strengths of this box is its user-friendly design. Both teachers and students can easily set up and conduct experiments without requiring extensive prior technical knowledge. This ease of use makes the toolkit an effective resource in diverse educational environments, including those with limited access to advanced scientific equipment or training. Its affordability ensures that even schools with constrained budgets can incorporate practical experiments into their curriculum, making high-quality science education more inclusive.

The sponsorship by the ASEAN+3 Center for the Gifted in Science highlights the international commitment to improving science education in Southeast Asia and beyond.

By providing resources like the Science Davinci Box, these initiatives help equip students with the necessary tools and knowledge to contribute to sustainable development in their countries, particularly in the field of renewable energy.

This initiative not only enhances the quality of education in Myanmar but also aligns with broader regional efforts to promote scientific literacy and innovation. The Science Davinci Box, therefore, represents a significant step forward in making science education more practical, engaging, and accessible, especially in resource-limited settings.

2.2 Addressing Educational Challenges in Myanmar

Myanmar's education system faces significant challenges, including limited access to modern educational materials, outdated curricula, and a lack of trained educators. These issues hinder students' ability to engage in experiential learning and apply scientific concepts in real-world contexts (Aung, 2021). The reliance on rote learning and theoretical instruction limits students' problem-solving abilities, particularly in complex subjects like Physics (Sharma & Pathak, 2020). Renewable energy education provides an opportunity to bridge this gap by integrating hands-on learning experiences that make science more relevant and engaging.

As the world faces increasing environmental challenges, renewable energy education has become crucial for preparing future generations to address sustainability issues. According to the International Energy Agency (2020), incorporating renewable energy topics into educational curricula can raise awareness and inspire innovative solutions for global energy challenges. In developed countries, advanced laboratories and educational resources enable in-depth exploration of renewable energy technologies, including solar, wind, and bioenergy (Chen et al., 2019). Conversely, developing countries often face limitations in educational resources, making it challenging to provide practical learning experiences (Aung, 2021). This disparity highlights the need for affordable and accessible educational tools to bridge the gap in renewable energy education.

Experiential learning, defined as learning through direct experience, plays a pivotal role in renewable energy education. It allows students to actively engage with the material, fostering a deeper understanding and retention of knowledge (Kolb, 1984). Research indicates that hands-on learning experiences can significantly enhance students' interest and motivation in science (Fredricks, Blumenfeld, & Paris, 2004). In renewable energy education, practical applications help students understand complex concepts by connecting theoretical knowledge to real-world scenarios (Sahin et al., 2015). This approach not only improves cognitive learning outcomes but also encourages critical thinking and problem-solving skills (Kolb, 1984; Sahin et al., 2015).

However, integrating renewable energy education into existing curricula presents challenges, particularly in developing countries. Sharma and Pathak (2020) noted that economic constraints limit the availability of modern teaching tools and laboratory equipment, leading to a reliance on theoretical instruction and rote learning. This instructional approach hinders students' ability to apply knowledge to real-world situations, especially in complex scientific subjects like Physics. To overcome these challenges, educational systems must adopt innovative teaching strategies and provide access to practical learning resources.

2.3 Enhancing Teacher Readiness and Pedagogical Approaches

Effective integration of renewable energy education requires not only modern educational tools but also well-trained educators who can utilize these resources effectively. Studies have shown that teacher readiness and pedagogical knowledge significantly influence the successful implementation of educational interventions (Chen et al., 2019). In Myanmar, the lack of professional development opportunities limits teachers' ability to adopt innovative teaching strategies (Sharma & Pathak, 2020). Building teachers' Technological Pedagogical and Content Knowledge (TPACK) is crucial for integrating renewable energy education effectively.

The Science Davinci Box have gained prominence in science education as effective resources for promoting hands-on learning experiences. It facilitates the practical application of scientific theories, allowing students to conduct experiments and explore complex concepts in a tangible way. Research by Tsai et al. (2017) demonstrated that integrating the Science Davinci Box in Physics classes significantly enhanced students' conceptual understanding and problem-solving abilities. It designed for renewable energy education, such as solar energy kits, have been particularly effective in helping students grasp complex energy conversion principles (Hernandez et al., 2020).

In developing countries, the educational toolkits such as the Science Davinci Box play a crucial role in bridging the gap between theoretical knowledge and practical applications. Due to resource constraints, schools in these regions often lack advanced laboratory equipment, hindering students' ability to engage in experiential learning (Aung, 2021). Low-cost these toolkits provide an affordable alternative, enabling students to explore scientific concepts through hands-on experiments (Sahin et al., 2015). This approach enhances student engagement, motivation, and critical thinking skills, contributing to a more holistic learning experience (Tsai et al., 2017).

2.4 Impact on Student Engagement and Knowledge Retention

Experiential learning using educational toolkits, such as the Science Davinci Box, significantly enhances student engagement and knowledge retention. Research suggests that hands-on activities allow students to directly observe scientific principles in action, thereby deepening their conceptual understanding (Kolb, 1984; Sahin et al., 2015). By connecting theoretical knowledge to practical applications, it fosters critical thinking and problem-solving skills, making learning more meaningful and relevant. However, there is a need for longitudinal studies to assess long-term knowledge retention and real-world application (Chen et al., 2019).

The Science Davinci Box is an innovative educational toolkit specifically designed to facilitate the teaching of renewable energy concepts, with a strong focus on solar energy. It includes components such as solar cells, motors, voltmeters, wires, and light sources, enabling students to engage in experiments that explore the conversion of sunlight into electricity and the efficiency of solar cells under different conditions. The toolkit's user-friendly design allows both teachers and students to set up and conduct experiments with ease, even in resource-limited educational settings. Additionally, the interactive nature of the experiments fosters student engagement and motivation, making learning more meaningful and relevant (Sahin et al., 2015).

2.5 Influence on Career Aspirations and Environmental Awareness

Renewable energy education not only enhances students' cognitive understanding but also influences their career aspirations and environmental awareness. Early exposure to sustainable energy concepts can inspire students to pursue careers in renewable energy fields, contributing to sustainable development (Kolb, 1984). Additionally, experiential learning fosters environmental consciousness by helping students understand the practical implications of energy consumption and sustainability. However, more research is needed to examine the long-term impact of renewable energy education on students' environmental values and career choices (Chen et al., 2019).

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Despite the growing interest in renewable energy education, significant research gaps remain, particularly in developing countries like Myanmar. While studies highlight the effectiveness of experiential learning and educational toolkits in enhancing students' conceptual understanding, there is limited research on their long-term impact on knowledge retention and application in real-world contexts (Chen et al., 2019). Additionally, the role of teacher training in effectively integrating renewable energy education into existing curricula has not been extensively explored (Sharma & Pathak, 2020). Understanding these factors is crucial for maximizing the educational impact of renewable energy toolkits.

Furthermore, while educational toolkits like the Science Davinci Box have demonstrated effectiveness in short-term learning outcomes, there is a lack of longitudinal studies examining their influence on students' career aspirations and environmental awareness. Research is needed to investigate how early exposure to renewable energy education shapes students' professional trajectories and contributes to long-term environmental engagement (Kolb, 1984). Addressing these research gaps will provide valuable insights into the scalability and sustainability of renewable energy education programs in developing countries.

2.6 Research Gap

Despite the growing interest in renewable energy education, significant research gaps remain, particularly in developing countries like Myanmar. While studies highlight the effectiveness of experiential learning and educational toolkits in enhancing students' conceptual understanding, there is limited research on their long-term impact on knowledge retention and application in real-world contexts (Chen et al., 2019). Additionally, the role of teacher training in effectively integrating renewable energy education into existing curricula has not been extensively explored (Sharma & Pathak, 2020). Understanding these factors is crucial for maximizing the educational impact of renewable energy toolkits.

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3. Methodology

3.1 Research Objectives

The primary aim of this study is to assess the effectiveness of using the Science Davinci Box toolkit in enhancing the teaching and learning of solar energy concepts in Grade-12 Physics classes in Myanmar. The core research question guiding this study is: How does the integration of hands-on, experimental learning tools impact students' understanding and engagement with solar energy concepts?

3.2 Specific Objectives

The specific objectives of the study include:

ⅰ. To evaluate the improvement in students' knowledge of solar energy concepts following hands-on activities using the Science Davinci Box.

ⅱ. To analyze the impact of experiential learning on students' critical thinking and problem-solving skills, particularly in relation to renewable energy concepts.

ⅲ. To assess the feasibility and scalability of using the Science Davinci Box in other schools across Myanmar, including the identification of any challenges to its implementation.

3.3 Research Design and Approach

3.3.1 Mixed-Methods Design

This study utilizes a mixed-methods approach, combining quantitative data from pre- and post-intervention assessments with qualitative insights derived from student interviews, focus group discussions, and classroom observations. This approach allows for a comprehensive evaluation of the intervention's impact on both cognitive (knowledge-based) and affective (engagement, motivation) learning outcomes (Creswell & Plano Clark, 2017). The quantitative data provide measurable evidence of students' academic improvements, while the qualitative data offer deeper insights into their learning experiences and the broader impact of the intervention on their attitudes toward renewable energy education.

3.3.2 Participants and Setting

The study was conducted at two schools in the Mandalay Region of Myanmar: No.2 Basic Education High School in Chan Aye Thar San Township and No.29, Branch Basic Education High School in Pyigyi Takhon Township. The two high schools chosen for this study were selected based on their accessibility and the availability of a trained Physics teacher familiar with the use of the Science Davinci Box toolkit. While these schools may not fully represent the entire range of educational settings in Myanmar, they were chosen to provide a practical and feasible setting for the intervention. The schools are located in the Mandalay Region, which offers a mix of rural and semi-urban environments, making them somewhat reflective of the diverse educational contexts found across the country. However, we acknowledge that the findings from these two schools might not fully capture the challenges or opportunities present in other regions, particularly in more remote or resource-deprived areas. Future studies could benefit from including a wider range of schools across different geographic and socioeconomic contexts to better represent Myanmar's broader educational landscape.

A total of 50 Grade-12 Physics students participated, selected to represent a diverse cross-section of the student population. However, it is important to acknowledge that these two schools may not fully represent the broader diversity of Myanmar's educational system, particularly as Myanmar's educational settings vary significantly across urban, semi-urban, and rural areas. Future studies should seek to include schools from a range of geographical and socioeconomic contexts to provide a more comprehensive understanding of the impact of such interventions in different educational settings.

3.3.3 Intervention Implementation

(1) Curricular Integration

The Science Davinci Box was integrated into the existing Grade-12 Physics curriculum for six weeks, with a particular focus on topics related to electricity and magnetism, as well as solar energy. The intervention was designed to align with the curriculum's learning objectives, ensuring that students were not only introduced to renewable energy concepts but also engaged in hands-on activities that reinforced their theoretical learning. Teachers were trained in advance on how to effectively incorporate the toolkit into their lessons, ensuring that the integration was seamless and supported by the necessary pedagogical guidance.

(2) Experimental Activities

The students engaged in a series of experiments designed to introduce and explore key solar energy concepts, including the conversion of sunlight into electricity, the relationship between light intensity and electrical output, and the efficiency of solar cells under varying conditions. These hands-on activities were structured to build progressively on students' prior knowledge, with each experiment reinforcing theoretical concepts and providing practical applications. Students were also encouraged to troubleshoot and problem-solve during the experiments, enhancing their critical thinking skills.

3.4 Limitation of the Study Design

One limitation of the study is the absence of a control group, which makes it difficult to definitively attribute any observed improvements in students' knowledge and engagement to the use of the Science Davinci Box alone. Other factors, such as increased teacher attention, enhanced motivation from the novelty of the experiments, or classroom dynamics, may have also contributed to the observed outcomes. While the study design allows for a preliminary understanding of the effectiveness of the toolkit, the lack of a control group prevents stronger causal claims from being made. Future studies should incorporate control groups to isolate the impact of the intervention and provide a more robust basis for causal inferences.

3.5 Addressing Response Bias in Student Engagement and Motivation

As part of the qualitative component of the study, self-reported data on student engagement and motivation were collected through interviews and focus group discussions. However, we recognize the potential for response bias, particularly since students may have provided more positive responses to align with what they perceived as the expectations of their teachers or researchers. To mitigate this issue, additional triangulation methods could be employed in future research. For instance, researchers could use anonymous surveys to gather data on student attitudes and behaviors outside of direct teacher influence, or they could observe students′ engagement through non-intrusive methods, such as classroom video recordings or third-party observations, to verify self-reported engagement levels. By employing these triangulation strategies, future studies can reduce the risk of biased responses and provide more reliable data.

3.6 Quantitative Data Collection and Analysis

To measure the effectiveness of the Science Davinci Box toolkit in enhancing students' understanding of solar energy concepts, quantitative data were collected using several instruments. Pre- and post-tests were administered to assess students' knowledge before and after the intervention. These tests included multiple-choice questions, short-answer questions, and problem-solving tasks directly related to the Grade-12 Physics curriculum. The content validity of these tests was ensured through expert review by experienced Physics educators, following the guidelines recommended by Crocker and Algina (2006) for developing educational assessments.

Additionally, a structured questionnaire using a Likert scale (ranging from 1 = Strongly Disagree to 5 = Strongly Agree) was used to measure students' perceptions of their critical thinking and problem-solving abilities. This approach is consistent with best practices in educational research for assessing cognitive and affective learning outcomes (Likert, 1932; Schreiber & Asner-Self, 2011). To evaluate changes in student engagement and motivation, a survey adapted from validated educational engagement scales was also administered, drawing on established frameworks for student motivation and engagement in science education (Fredricks, Blumenfeld, & Paris, 2004).

Before the main study, pilot testing was conducted at No.26 Basic Education High School in Chanmya Tharsi Township, Mandalay Region, with 30 Grade-12 students who did not participate in the main intervention. The pilot test aimed to check the reliability and validity of the data collection instruments and to refine the test items for better clarity and accuracy. The internal consistency of the questionnaires was assessed using Cronbach's alpha, following the guidelines by Tavakol and Dennick (2011). The reliability coefficients were as follows: 0.82 for the knowledge test, 0.79 for the critical thinking and problem-solving questionnaire, and 0.85 for the student engagement survey, indicating acceptable to high reliability for all instruments (Nunnally & Bernstein, 1994). Feedback from the pilot study was used to modify ambiguous questions, ensuring that all items were appropriate and comprehensible for the target population.

A total of 50 Grade-12 Physics students from two high schools in the Mandalay Region participated in the main study. The students were selected using purposive sampling to ensure a diverse cross-section representing different academic abilities and socio-economic backgrounds. Data collection occurred in three phases. First, baseline data were collected before the intervention using pre-tests and initial surveys to assess students' existing knowledge, critical thinking, problem-solving skills, and engagement levels. During the six-week intervention, the Science Davinci Box toolkit was integrated into the Physics curriculum, with students participating in hands-on experimental activities related to solar energy. After completing the intervention, post-tests and final surveys were administered to measure any changes in students' knowledge and skills.

Quantitative data were analyzed using various statistical methods to evaluate the impact of the Science Davinci Box on students' learning outcomes. Descriptive statistics, including means, standard deviations, and frequency distributions, were calculated to provide an overview of students' performance and perceptions before and after the intervention. Paired t-tests were conducted to compare pre- and post-test scores, determining whether there was a statistically significant improvement in students' knowledge of solar energy concepts (Field, 2018). For non-parametric data from the Likert-scale questionnaires, Wilcoxon Signed-Rank Tests were used to assess changes in critical thinking, problem-solving skills, and student engagement, consistent with recommendations by Pallant (2020). Additionally, the effect size (Cohen's d) was calculated to determine the magnitude of the intervention's impact on learning outcomes (Cohen, 1988). Pearson's correlation coefficient was also calculated to explore the relationship between students' engagement levels and their academic performance in the post-test (Field, 2018).

To ensure the reliability and validity of the data collection instruments, several measures were taken. The internal consistency of the questionnaires was confirmed using the Cronbach's alpha values obtained from the pilot testing, which all exceeded the acceptable threshold of 0.70 (Nunnally & Bernstein, 1994). Content validity was ensured by aligning test items with the curriculum objectives and obtaining feedback from expert Physics educators. Construct validity was established through pilot testing and factor analysis of the engagement and critical thinking questionnaires, following best practices in educational measurement (Schreiber & Asner-Self, 2011).

This approach to quantitative data collection and analysis provides robust evidence on the effectiveness of using the Science Davinci Box toolkit in enhancing students' understanding of solar energy concepts and improving their critical thinking, problem-solving skills, and engagement in Physics learning.

3.7 Qualitative Data Collection and Analysis

Qualitative data were collected through semi-structured interviews with students, focus group discussions, and classroom observations conducted by teachers. These methods provided valuable insights into students' perceptions of the hands-on activities, their level of engagement with the subject matter, and their overall motivation toward learning about renewable energy (Creswell & Poth, 2018; Merriam & Tisdell, 2016). The qualitative data analysis process followed a systematic, step-by-step approach to ensure rigor and transparency. First, all interviews and focus group discussions were audio-recorded, transcribed verbatim, and then reviewed for accuracy, ensuring that the data reflected the true responses of participants (Braun & Clarke, 2006). After preparing the transcripts, each one was carefully reviewed to identify key phrases, ideas, and concepts related to student engagement, understanding of solar energy, and motivation to learn. These initial codes were developed inductively, based on the data itself rather than predetermined categories (Miles, Huberman, & Saldaña, 2014).

The identified codes were then grouped into broader categories, leading to the development of recurring themes related to student attitudes toward renewable energy, the effectiveness of hands-on learning, and the perceived challenges of the intervention. The themes were refined through an iterative process, where multiple researchers initially worked independently to develop themes and then compared their findings. Any discrepancies in theme identification were resolved through discussion, ensuring that the final themes were consistent and reflective of the data (Nowell, Norris, White, & Moules, 2017). To ensure the validity and trustworthiness of the qualitative findings, the themes were shared with the research team for review and feedback. Inter-coder reliability was maintained by comparing and reconciling differing interpretations, and member checking was conducted by revisiting a small subset of participants to confirm that the themes accurately represented their views (Lincoln & Guba, 1985).

Once the themes were finalized, they were analyzed in the context of the research questions, helping to draw conclusions about the role of hands-on learning in improving student engagement and understanding of renewable energy concepts. Insights from the qualitative data complemented the quantitative findings, providing a deeper understanding of the intervention's impact (Patton, 2015).

3.8 Ethical Considerations

Ethical considerations were carefully addressed to ensure the integrity of the research process and the protection of all participants involved in the study. Before the commencement of the research, ethical approval was obtained from the school authorities at No.2 Basic Education High School in Chan Aye Thar San Township and No.29, Branch Basic Education High School in Pyigyi Takhon Township. Informed consent was secured from all participating students and their parents or guardians. A detailed information sheet explaining the purpose of the study, the nature of the intervention, and the voluntary nature of participation was provided. It was clearly communicated that students could withdraw from the study at any point without any negative consequences.

To protect the privacy and confidentiality of the participants, no personal identifiers were collected, and all data were anonymized before analysis. Unique codes were assigned to each student to ensure that individual responses remained confidential. The data collected, including pre- and post-test scores and survey responses, were securely stored in password-protected digital files accessible only to the research team.

The study also took into consideration the potential impact of the intervention on students' academic performance and well-being. The Science Davinci Box toolkit was integrated into the existing curriculum to ensure that students were not subjected to additional academic pressure. Additionally, care was taken to maintain an inclusive learning environment where all students, regardless of their initial knowledge levels or learning abilities, could participate and benefit from the hands-on activities.

During data analysis and reporting, ethical guidelines were followed to ensure accurate and honest representation of the findings. No data were manipulated or misrepresented, and limitations related to the study design were openly acknowledged. The study also adhered to ethical standards in academic writing, ensuring that all sources were appropriately cited using the APA reference style.

By addressing these ethical considerations, the study ensured the protection of participants' rights and well-being, while also maintaining the credibility and reliability of the research findings.

4. Findings

4.1 Quantitative Findings

The quantitative analysis aimed to measure the improvement in students' knowledge of solar energy concepts following the intervention. Pre- and post-intervention assessments were administered, consisting of multiple-choice questions, short-answer questions, and problem-solving exercises. The assessments were designed to evaluate both factual knowledge (e.g., definitions, concepts) and conceptual understanding (e.g., application of principles, problem-solving related to solar energy).

To determine the significance of the improvement in students' knowledge, we compared the pre-assessment and post-assessment scores using paired *t*-tests. This statistical test was selected because it compares the means of two related groups (pre- and post-test scores) to determine if there is a statistically significant difference.

4.1.1 Descriptive Statistics

The following table summarizes the descriptive statistics for the pre- and post-assessment scores:

Table 1. Descriptive Statistics for pre- and post-assessment score

Assessment Type	Mean Score (%)	Standard Deviation (%)	Sample Size (n)
Pre-Assessment	55.00	10.25	50
Post-Assessment	78.00	9.85	50

The mean score on the pre-assessment was 55%, while the mean score on the post-assessment increased to 78%, indicating an improvement in students' knowledge of solar energy concepts. The standard deviation values of 10.25 for the pre-assessment and 9.85 for the post-assessment show that the variation in scores was similar before and after the intervention.

4.1.2 Paired *t*-Test Analysis

To assess whether the observed increase in mean scores was statistically significant, we conducted a paired *t*-test. The null hypothesis (H_0) for this test was that there is no significant difference between the pre- and post-assessment scores, while the alternative hypothesis (H_1) stated that there is a significant difference between the two scores.

The paired t-test was conducted using the following formula for the t-statistic:

$$t = \frac{(Mean\ of\ the\ differences)}{(Standard\ deviation\ of\ the\ differences)/\sqrt{n}}$$

Where:

- Mean of the differences = Mean post-assessment score - Mean pre-assessment score
- Standard deviation of the differences = Standard deviation of the score differences between the two assessments
- n = Sample size

The results of the paired t-test are summarized in the table below:

Table 2. Results of Paired t-test

t-Statistic	Degrees of Freedom (df)	*p*-value
13.45	49	< 0.01

The *t*-statistic was calculated to be 13.45, with 49 degrees of freedom (df = n - 1, where n = 50). The corresponding p-value was found to be less than 0.01, which is below the conventional significance level of 0.05.

4.1.3 Interpretation of Results

Given that the *p*-value is less than 0.01, we reject the null hypothesis and conclude that there is a statistically significant difference between the pre- and post-assessment scores. The large *t*-statistic indicates that the observed difference is not due to random chance, but rather is likely a result of the intervention.

The mean score improvement from 55% on the pre-assessment to 78% on the post-assessment suggests that the hands-on activities with the Science Davinci Box toolkit effectively enhanced students' understanding of solar energy concepts. This improvement can be attributed to the experiential learning approach, which allowed students to directly engage with the material through practical experiments.

4.1.4 Effect Size (Cohen's d)

To further quantify the magnitude of the effect of the intervention, we calculated the effect size using Cohen's d, which measures the strength of the difference between two groups in terms of standard deviations. The formula for Cohen's d is:

$$d = \frac{Mean\ of\ post_{asssessme}nt - Mean\ of\ pre_{assessmen}t}{Pooled\ Standard\ Deviation}$$

Where the pooled standard deviation is calculated as:

$$\text{Pooled standard deviation} = \sqrt{\frac{(SD_{pre}^2 + SD_{post}^2 2}{}}$$

Substituting the values:

$$d = \frac{78 - 55}{\sqrt{\frac{(10.25^2 + 9.85^2)}{2}}} = \frac{23}{\sqrt{\frac{(105.0625 + 97.0225)}{2}}} = \frac{23}{\sqrt{101.5425}} = \frac{23}{10.08} = 2.28$$

An effect size of 2.28 suggests a large effect of the hands-on intervention on students' learning outcomes. According to Cohen's guidelines, an effect size of 2.28 is considered very large, indicating that the use of the Science Davinci Box toolkit has had a substantial positive impact on students' understanding of solar energy.

The quantitative data indicate that the hands-on learning activities using the Science Davinci Box significantly improved students' understanding of solar energy concepts. The pre- and post-assessment results showed a marked increase in student performance, from a mean score of 55% on the pre-assessment to 78% on the post-assessment. The paired t-test yielded a statistically significant result ($p < 0.01$), and the effect size (Cohen's d = 2.28) demonstrated a large, meaningful improvement in students' knowledge.

4.2 Qualitative Findings

Student Engagement and Interest: The qualitative data, gathered through semi-structured interviews, focus group discussions, and classroom observations, revealed a significant increase in student engagement and interest in renewable energy topics following the intervention. Students expressed that the hands-on nature of the Science Davinci Box toolkit helped them relate to the subject matter more effectively. One common theme from the interviews was that the practical activities allowed them to connect theoretical knowledge with real-world applications. As one student mentioned, "It was easier to understand how solar energy works when we could actually build circuits and see them light up." This hands-on approach not only deepened students' understanding of solar energy but also sparked their curiosity to learn more. Many students reported that they were motivated to continue exploring renewable energy concepts outside the classroom. A significant number expressed an increased interest in pursuing further studies in renewable energy or considering careers in related fields. This shift in career interests was particularly notable in rural schools where access to such specialized educational tools is often limited. Teachers also observed that students were more proactive in seeking additional resources on solar energy, indicating an intrinsic motivation to continue learning beyond the scope of the curriculum.

Challenges Encountered: Despite the overall positive feedback, several challenges emerged in the course of the intervention. Some students faced difficulties with the more technical aspects of the experiments, especially when setting up electrical circuits. These students expressed frustration when the circuits failed to function correctly, often due to misunderstandings in the assembly process. As one student stated, "It was hard to understand why the circuit didn't work the first time; I needed help to figure it out."

This issue was compounded by the complexity of the experiment instructions, which were sometimes difficult for students to follow without additional explanation. However, teachers played a crucial role in helping students overcome these challenges, providing guidance and clarification as needed. Most students were able to resolve these technical difficulties with support, and their problem-solving skills were visibly enhanced throughout the course of the intervention. Another challenge identified during classroom observations was the limited time available to fully explore each experiment. Teachers noted that while students were generally eager to engage with the material, the time constraints often meant that experiments had to be cut short before students could fully grasp all the underlying concepts. As one teacher remarked, "If we had more time, we could have explored the results more deeply and asked more questions." This limitation suggests that future implementations of the Science Davinci Box could benefit from an extended intervention period to allow for a more thorough exploration of each experiment.

In terms of the broader classroom environment, teachers also expressed a need for additional training on how to effectively integrate hands-on activities into their regular lessons. This was particularly important for teachers with limited prior experience in using such educational toolkits. The observations revealed that while the toolkit was a valuable teaching resource, some teachers struggled to align the activities with the existing curriculum, which occasionally led to missed opportunities for deeper exploration of renewable energy concepts.

5. Discussion

This study explored the challenges and potential of integrating renewable energy education into Myanmar's educational system, focusing on the application of the Science Davinci Box toolkit. The findings align with global trends in renewable energy education while highlighting context-specific obstacles faced in Myanmar. This section discusses the implications of these findings in relation to the literature reviewed and provides insights into how these challenges can be addressed.

5.1 Addressing Educational Challenges in Myanmar

The study revealed that Myanmar's education system faces significant barriers, including limited access to modern educational materials, outdated curricula, and a lack of trained educators. These findings are consistent with Aung (2021), who noted that economic constraints severely limit the availability of practical teaching tools in Myanmar's schools. The reliance on rote learning and theoretical instruction, as discussed by Sharma and Pathak (2020), continues to hinder students' ability to apply scientific concepts in real-world contexts.

However, the introduction of the Science Davinci Box provided a feasible solution to bridge this gap by enabling hands-on learning experiences despite resource constraints. This aligns with the literature highlighting the effectiveness of experiential learning in enhancing students' understanding and retention of complex scientific concepts (Kolb, 1984). By offering a cost-effective and user-friendly alternative to traditional laboratory equipment, the toolkit enabled students to explore solar energy principles practically, thereby enhancing their engagement and comprehension.

These findings underscore the importance of incorporating affordable and practical educational tools into Myanmar's curriculum to foster a deeper understanding of renewable energy concepts. However, to ensure the long-term success of such interventions, it is crucial to address systemic issues such as outdated curricula and inadequate teacher training programs.

5.2 Enhancing Teacher Readiness and Pedagogical Approaches

The study found that teachers faced difficulties in effectively integrating renewable energy education due to a lack of professional development opportunities and familiarity with experiential learning methods. This observation resonates with Sharma and Pathak (2020), who emphasized that teacher readiness and pedagogical support are critical for the successful implementation of innovative educational tools.

The findings revealed that while the Science Davinci Box is designed for ease of use, teachers struggled with maximizing its potential due to limited pedagogical training. This highlights the need for comprehensive teacher training programs that not only introduce the technical aspects of educational toolkits but also equip educators with innovative teaching strategies to effectively deliver renewable energy content.

In line with the literature, professional development programs should focus on building teachers' Technological Pedagogical and Content Knowledge (TPACK), enabling them to integrate technology effectively within their teaching practices (Chen et al., 2019). Additionally, peer collaboration and continuous support systems can enhance teachers' confidence and competence in adopting experiential learning methodologies.

5.3 Impact on Student Engagement and Knowledge Retention

The findings indicated a positive impact on student engagement and knowledge retention through the use of the Science Davinci Box. Students demonstrated increased curiosity and a deeper understanding of renewable energy concepts, particularly solar energy, when engaged in hands-on experiments. This supports the experiential learning theory proposed by Kolb (1984), which emphasizes learning through direct experience as a means to enhance cognitive understanding and retention.

However, while short-term engagement and knowledge gains were evident, the study could not assess long-term retention and the application of these concepts in real-world contexts. This aligns with the research gap identified in Chen et al. (2019), highlighting the need for longitudinal studies to evaluate the sustained impact of educational toolkits on students' learning outcomes.

To address this, future studies should employ a longitudinal design to track students' knowledge retention and application over time. Additionally, incorporating assessments that evaluate students' problem-solving and critical-thinking skills could provide a more comprehensive understanding of the educational impact.

5.4 Influence on Career Aspirations and Environmental Awareness

One of the emerging themes from the study was the potential influence of renewable energy education on students' career aspirations and environmental awareness. Exposure to practical renewable energy applications inspired some students to consider careers in sustainable energy fields, reflecting the potential of early educational interventions to shape professional trajectories.

However, the study did not find conclusive evidence on the long-term influence of renewable energy education on students' environmental attitudes and behaviors. This aligns with the gap identified by Kolb (1984), emphasizing the need for research that examines the impact of renewable energy education on long-term environmental engagement.

To better understand this relationship, future studies should investigate how experiential learning in renewable energy influences students' environmental values and decision-making processes. This would provide valuable insights into the role of education in promoting sustainable development and climate action.

5.5 Overcoming Practical Barriers to Implementation

The study identified several practical barriers to implementing renewable energy education in Myanmar, including logistical challenges, resource limitations, and cultural factors affecting curriculum integration. These challenges are consistent with Aung (2021), who noted the systemic issues hindering educational innovation in developing countries.

Despite these challenges, the sponsorship initiative by the ASEAN+3 Center for the Gifted in Science facilitated the introduction of the Science Davinci Box in Myanmar's schools, demonstrating the potential of international collaborations to enhance educational access and quality. This aligns with regional efforts to promote scientific literacy and sustainable development through educational interventions.

However, to scale renewable energy education effectively, it is essential to address these barriers through strategic policy interventions and cross-sector partnerships. This includes improving infrastructure, securing sustainable funding, and fostering community support to ensure the feasibility of nationwide implementation.

5.6 Implications for Policy and Practice

The findings of this study have several implications for educational policy and practice in Myanmar. Firstly, integrating renewable energy topics into the national curriculum aligns with the United Nations Sustainable Development Goals (SDG 4 and SDG 7) and supports Myanmar's commitment to sustainable development. Policymakers should prioritize curriculum reforms that incorporate experiential learning approaches and renewable energy education.

Secondly, there is a need for targeted teacher training programs to build educators' capacity in delivering renewable energy education effectively. This includes equipping teachers with TPACK skills and providing continuous professional development opportunities to support pedagogical innovation.

Finally, fostering international collaborations can enhance resource availability and knowledge exchange, supporting the scalability of renewable energy education in resource-constrained settings. By leveraging international sponsorships and educational networks, Myanmar can effectively bridge the gap between theoretical instruction and practical application, ensuring that students are equipped with the skills needed to contribute to sustainable development.

6. Conclusion

This study contributes to the growing body of literature on renewable energy education in developing countries by highlighting the potential and challenges of implementing educational toolkits in Myanmar's resource-limited educational context. The findings underscore the importance of experiential learning in enhancing student engagement and understanding while emphasizing the need for systemic curriculum reforms and targeted teacher training programs. Additionally, addressing practical barriers through strategic policies and international collaborations will be crucial for scaling these educational interventions to achieve sustainable development goals. By addressing these challenges and leveraging international support, Myanmar can enhance its educational system to better equip future generations with the knowledge and skills required for a sustainable energy future.

7. Recommendations for Further Research

Future research should examine the long-term impact of experiential learning by investigating the retention of knowledge gained and its application in real-world contexts. Longitudinal studies are necessary to assess sustained knowledge retention, critical thinking, and problem-solving skills. Additionally, future studies should evaluate the influence of renewable energy education on students' career aspirations and long-term environmental awareness, as this can contribute to sustainable development. It is also essential to assess the effectiveness of teacher training programs in integrating experiential learning methods and renewable energy topics, particularly in building Technological Pedagogical and Content Knowledge (TPACK) competencies. Furthermore, research should address practical barriers by investigating logistical challenges, resource limitations, and cultural factors that affect the implementation and scalability of educational toolkits in different educational settings. Finally, expanding the geographical scope through comparative studies across various regions in Myanmar, including both rural and urban settings, will provide a more comprehensive understanding of the challenges and opportunities for renewable energy education.

8. Acknowledgement

I would like to express my sincere gratitude to the ASEAN+3 Center for the Gifted in Science for their generous sponsorship and commitment to enhancing science education in Southeast Asia. By providing the Science Davinci Box toolkit, this organization enabled this study to explore innovative teaching methods and empowered students with the knowledge and skills needed for sustainable development in Myanmar. Their support has been instrumental in bridging the gap between theoretical learning and practical application, and I am truly grateful for their dedication to advancing educational opportunities in resource-limited settings.

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Paper Submission : 2024.12.03.
Paper Review : 2025.01.21.
Publication Approval : 2025.02.17.