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Integrating Inquiry and Creative Activities through the Exploratory Spherical Power Plant Application

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This study investigated the educational impact of integrating a 360-degree power plant exploration application with creative production activities in elementary education. Sixth-grade students engaged in inquiry-based learning using the improved version of the application, followed by group work to design eco-friendly power generation systems. A four-point Likert scale survey and analysis of open-ended responses revealed that the application was easy to use, enhanced students' understanding of energy systems, and fostered active learning. Creative tasks further supported deeper knowledge construction, collaboration, and environmental awareness. The results suggest that combining VR-based exploratory learning with hands-on creative activities can effectively promote learner engagement and interdisciplinary understanding in sustainability and energy education.

Keywords: VR , Maker Education, Environmental Education , Inquiry-Based Learning

Introduction

In recent years, the imperative for education that contributes to the construction of a sustainable society has intensified in response to global-scale issues such as climate change and the depletion of energy resources. Goal 7 of the Sustainable Development Goals (SDGs), as proposed by the United Nations (2015)—"Ensure access to affordable, reliable, sustainable and modern energy for all"—emphasizes the promotion of renewable energy and the enhancement of energy efficiency as key global directives. In response to these societal transformations, Jorgenson et al. (2019) emphasized the crucial role of environmental education (EE) in facilitating the transition from fossil fuels to renewable energy sources. Hu and Yang (2024) comprehensively reviewed the empirical research in energy education, underscoring the importance of developing age-appropriate curricula and emphasizing that active public engagement and incorporation of hands-on learning opportunities are instrumental in fostering both conceptual understanding and behavioral change among learners. As a concrete example of experiential learning, Yeadon and Quinn (2021) demonstrated that practical activities involving Stirling engines are effective instructional strategies that enhance learners' comprehension of thermodynamic principles while bridging theoretical knowledge with real-world applications. Such hands-on approaches have also been shown to foster students' motivation by rendering abstract scientific concepts more accessible and tangible. Likewise, Chien et al. (2021) confirmed that classroom implementation of dye-sensitized solar cells (DSSCs) not only improved students' experimental competencies but also positively influenced their attitudes toward sustainability.

In Japan, educational policies such as those found in the Course of Study guidelines by the Ministry of Education, Culture, Sports, Science and Technology (2017a, 2017b) have integrated topics related to renewable energy and its efficient utilization into the science and social studies curricula, thereby promoting learning opportunities focused on sustainable energy. However, Irmak et al. (2023) have highlighted a paucity of empirical studies on school-based programs that encourage energy-saving behaviors, particularly in the context of elementary and secondary education. Similarly, Rohmatulloh et al.'s (2022) systematic review indicated that many existing energy literacy programs tend to prioritize factual knowledge transmission, with limited emphasis on affective and behavioral dimensions that are essential for promoting long-term attitude and behavior change. Considering the conceptual complexity of topics such as climate change and energy transitions, identifying and implementing effective pedagogical approaches tailored to the developmental stages of younger learners remains an urgent priority.

Virtual Reality (VR) has emerged as a powerful pedagogical tool for facilitating the understanding of abstract scientific concepts. Cooper et al. (2024) highlighted how VR's advanced visual and interactive affordances can foster deep learning by enabling students to conceptualize phenomena such as particle behavior and electromagnetic fields. VR technology can simulate real-world scenarios that are difficult to recreate in traditional classroom settings, thereby offering students immersive experiential learning opportunities (Radianti et al., 2020). Allcoat and von Mühlenen (2018) reported that VR-based instruction elicited high levels of learner engagement, motivation, and subjective satisfaction. Additionally, immersive environments enhanced behavioral engagement by stimulating students' interest and willingness to participate actively in learning tasks.

Nevertheless, implementing head-mounted display (HMD)-based immersive VR in school contexts has revealed several challenges. These include instructional difficulties for younger students (Fransson et al., 2020), technological malfunctions, costs associated with deployment and maintenance, and user discomfort such as VR-induced motion sickness (Jensen & Konradsen, 2018). In the context of these constraints, non-immersive VR platforms, such as those delivered via desktop computers or tablets, are gaining traction, as they offer comparable educational outcomes at significantly lower costs (Lavoie et al., 2025).

In Japan, the nationwide deployment of one-to-one tablet devices in schools has facilitated the development of VR learning applications suited to such platforms. For example, Shoji et al. (2022) developed a VR field trip module for earth science education that enables students to explore virtual terrains. Tashiro et al. (2021) introduced the "360-degree power plant exploration application," which supports learning by enabling students to navigate seamlessly between spherical images of power generation facilities and accompanying textual information. These studies have shown that even without the use of head-mounted displays (HMDs), 360-degree panoramic images can partially replicate learners' viewpoint movements and sense of immersion, and they have reported the effectiveness of such materials in providing experiential learning opportunities. In addition, as these materials enhance learners' interest and motivation and encourage an inquiry-based attitude, they are considered particularly effective for learning about locations that are difficult to access or facilities that are hard to visit in person. Furthermore, with thoughtful lesson planning, these tools have the potential to enhance higher-order thinking skills, such as collaboration and critical analysis. Tashiro et al. (2021) evaluated a 360-degree power plant exploration application in the context of environmental education, demonstrated that it was easy for learners to operate, and provided opportunities for experiential environmental learning. However, their study only yielded preliminary data regarding the application's usefulness and areas for improvement and highlighted the need for further investigation into its effective implementation and educational impact in environmental education.

On the other hand, in the context of addressing social issuessuch as environmental education, where no clear answers exist and learners must engage with abstract and complex problems, creative activities have gained attention as an effective educational approach. Aulakh et al. (2024) identified that engaging in creative tasks enhances children's cognitive capacities, including creativity, memory, and problem-solving, while also supporting the development of critical thinking, adaptability, and expressive abilities. Similarly, Papagiannis and Pallaris (2024) reported significant improvements in critical thinking, collaboration, communication, and creativity among university students participating in makerspace workshops. Rouse and Rouse (2022), through a systematic review, concluded that makerspaces in PreK–12 settings positively impact students' creative, analytical, and cooperative abilities. Moreover, as an example of creative activities in environmental education, Ariza and Olatunde-Aiyedun (2023) described a university–industry collaboration wherein students designed and built solar- and wind-powered electric vehicles, leading to nuanced understanding of sustainable energy systems and related technical competencies. Similarly, Chen and Lin (2021) documented that constructing wind and hydroelectric energy models fostered students' creativity, technical proficiency, and environmental consciousness. However, to make creative learning more effective, a cyclical process between inquiry and creation is essential (Kolodner, 2002), yet effective support for both inquiry-based and creative learning activities in environmental education has not been sufficiently explored. The aforementioned 360-degree power plant exploration application developed by Tashiro et al. (2021) was designed for use in inquiry-based activities related to various methods of power generation. To understand abstract concepts such as power generation methods, it is assumed that connecting prior knowledge and engaging in collaborative learning through dialogic activities with peers are effective. Therefore, this study focused on creative activities as a means of designing effective learning in combination with inquiry activities using this application.

Based on previous research, several key issues have emerged: the lack of practical examples of environmental education in primary and secondary schools; the fact that although Tashiro et al. (2021) demonstrated the usability of the 360-degree power plant exploration application through interface evaluation, they only provided foundational data and did not examine its educational effectiveness in practical settings; and the fact that while the application is expected to serve as an experiential alternative to real-world power plant visits, effective instructional strategies for integrating inquiry-based and creative learning have not been fully explored. In response to these challenges, this study posed the following research question: How do inquiry-based and creative learning activities using the 360-degree power plant exploration application enhance students' learning motivation, interest in environmental issues, and creative thinking in the context of environmental education at the elementary and secondary levels? This study builds on the work of Tashiro et al. (2021) and aims to clarify how the experiential use of the application as a substitute for physical power plant visits combined with inquiry-based and creative learning activities influences learners' motivation, environmental awareness, and creative thinking.

Overview and Improvements of the Educational Application

Figure 1 presents an overview of the Exploratory Spherical Power Plant Application. This application is an enhanced version of a prototype 360-degree power plant exploration application originally developed by Tashiro et al. (2021). The improvements were implemented to address the limitations identified in the previous study and to tailor the application for educational use in upper elementary school settings. The application was developed using Unity—an integrated development environment for game and interactive content, and was built in the WebGL format. The spherical panoramic images and documents related to power generation utilized in the application were provided by the Regional Coexistence Headquarters of Kyushu Electric Power Co., Inc. The application features information on power plants across the Kyushu region and comprises immersive 360-degree scenes designed to simulate plant visits, as well as 2D scenes for presenting instructional content related to energy generation. The application integrates virtual environments with supplemental materials and videos. The underlying aim is to facilitate investigative learning based on the reciprocal relationship between experiential immersion and cognitive understanding, thereby enhancing learners' engagement with the subject matter.

In the prototype version developed by Tashiro et al. (2021), information on each type of power generation system was provided; but specific data, such as electricity output, were absent. This limited the opportunities for data comparison among power plants. To resolve this issue, a display icon presenting basic metrics, such as, generation capacity, was added to the upper-right part of the main screen. Additionally, detailed explanation of equipment output (in watts) and site area was included on the overview page of each power plant.

Figure 1.
Overview of the Exploratory Spherical Power Plant Application

Tashiro et al. (2021) also highlighted the need for linguistic modifications to accommodate the cognitive development of elementary school learners. In response, the wording throughout the application was revised to match the target learners' developmental level. This included the introduction of furigana (phonetic guides) for kanji characters not included in the elementary curriculum, and the simplification of complex terms and technical jargon. The prototype's extensive content risked overwhelming younger users and obscuring essential focus areas. To address this issue, "task discovery support icons" were introduced into the 360-degree scenes of each power plant to scaffold learners' inquiry and guide their attention. When the "?" icon is tapped within a scene, a prompt panel appears with questions designed to stimulate reflection, such as, "What kind of location is suitable for constructing this power plant?" or "How many days' worth of electricity does 200 kW provide for a single household?"

Another improvement involved enhancing the image quality of the 360-degree scenes. Tashiro et al. (2021) previously indicated that low-resolution output reduced the visual clarity of the scenes. To rectify this issue, the original image data were replaced with higher-resolution versions during development, which significantly improved the visual fidelity of the 360-degree content.

Implementation of Inquiry-Based Learning and Creative Activities Using the Educational Application

Overview of the Implementation

Table 1 outlines Structure of the Unit and Flow of the Present Lesson Implementation. This study utilized an improved version of the educational application to conduct an instructional practice with 29 sixth-grade students in Nagasaki Prefecture, as part of the science unit "Use of Electricity" (Dainippon Tosho, 6th grade). This unit is closely related to the theme of this study, which involves topics such as renewable energy and selection of power generation methods. Therefore, we determined that it would be appropriate to use the improved version of the application, designed for upper elementary grades and above, as an educational tool for energy learning and selected sixth-grade students as the target group. In addition, the sixth-grade curriculum includes topics related to energy and the environment, such as "building a sustainable society" in social studies and "efficient use of resources" in home economics. For this reason, it was expected that the students would be able to engage in the creative activities conducted in this practice from an interdisciplinary perspective. The unit comprises 10 lessons organized around the overarching goal of "Let's Create an Eco-Friendly Town." The implementation took place during Lessons 5 and 6 of

Table1.
Structure of the Unit and Flow of the Present Lesson Implementation

The Science Unit "Use of Electricity" (10 Lessons) Overarching Goal "Let's Create an Eco-Friendly Town"	
Lessons	**Key Learning Content**
1	Develop a learning plan to explore how electricity is utilized in daily life
2	Investigate the processes of electricity generation and energy storage
3	Examine how electricity consumption varies across appliances or devices
4	Investigate the transformation of various energy sources into usable electricity in daily life
Designing a Sustainable Town Through Energy Conservation	
5	**Main Activities in This Lesson** Review and Goal Setting (10 minutes) "Let's Think of New Eco-Friendly Power Generation Methods" Inquiry Activity Using the Exploratory Spherical Power Plant Application (30 minutes) • Each student was assigned one type of power plant and conducted independent research using the application, recording their findings on a worksheet • Students then formed groups of 4–5 members to share and discuss their findings
6	Creative Production: Designing an Eco-Friendly Power Plant (40 minutes) • Students worked in groups of 2–3 to design and create their own models of eco-friendly power plants using prepared materials • During the production phase, they were allowed to freely use both the application and the internet for additional research Presentation and Sharing (10 minutes) Post-Activity Survey
7	Understanding how electricity is transformed and used in daily life
8	Engaging in programming-based learning activities
9	Exchanging opinions with peers from the perspective of energy conservation
10	Assembling and verifying code according to specific functional objectives

the 10-lesson unit. Prior to this intervention, students had explored various aspects of electricity usage in everyday life, including power generation, storage, and utilization. The objective of this instructional practice was to enable students to design a suitable power generation system for their envisioned eco-friendly town based on inquiry and creative production using the application.

Initially, students reviewed the content from the previous lesson and confirmed the objectives of the current session. As an introduction, the teacher presented issues related to environmental degradation caused by conventional power plants. Additionally, the overarching task of "Let's Think of a New Eco-Friendly Power Generation Method" was introduced. To approach this task, each student used the application to investigate the characteristics and operational aspects of a designated power plant. Findings were documented on worksheets and shared in small groups of four to five students.

Subsequently, students formed groups of two to three and engaged in creative activities under the theme of "eco-friendly power plants," using materials such as paper, pens, building blocks, tape, straws, and pipe cleaners. Students were also allowed to freely consult the application and internet resources during this activity. Upon completing their models or designs, each group presented their work to the entire class.

Evaluation Methodology

In this study, a four-point Likert-scale questionnaire was administered to 29 sixth-grade elementary school students to evaluate the effectiveness of the inquiry-based and creative activities conducted using the developed application. The questionnaire consisted of 23 items, which were set based on the following three perspectives: "Regarding the Application" (8 items), "Creative Activities" (10 items), and "Learning Outcomes in the Practice" (5 items). These questionnaire items were selected through discussion between the two authors based on the items used by Tashiro et al. (2021) as well as prior studies on the development and implementation of VR teaching materials published in the "Japan Journal of Educational Technology" and the "Journal of Science Education in Japan." Each item was rated using a four-point scale: "Strongly agree," "Agree," "Disagree," and "Strongly disagree." For analysis, responses were grouped into affirmative (Strongly agree and Agree) and negative (Disagree and Strongly disagree) categories. Statistical analysis was conducted using Fisher's exact test.

In addition, the students were asked to freely describe their impressions of the lesson in response to the following prompt: "Please write your thoughts about today's class." These responses were categorized and labeled by the two authors according to their content. Furthermore, the process of exchanging opinions during group work and students' creative activities were recorded as video data. These recordings, along with photos of the students' final products and the content of their presentations during the sharing session held at the end of the lesson, were used as reference materials to identify and classify the characteristics of the works submitted by all 12 groups. This study analyzed the application's interface and usability based on responses to the 8-item section of the questionnaire and students' free-form comments. Furthermore, the overall educational effectiveness of the practice was assessed by examining the results of the 15 items related to creative activities and learning outcomes, the qualitative content of student reflections, and the characteristics of the created artifacts.

Results and Discussion

Regarding the Educational Application

Table 2 summarizes the results of the four-point Likert scale survey. Valid responses were obtained from 28 out of 29 participants. The following section focuses on the analysis of eight items "Regarding the Application." First, for the item "The application was easy to use," a statistically significant number of learners responded affirmatively. As shown in Table 3, in the open-ended comments, one student stated while evaluating the usability of the application, "The application was very easy to use." During the implementation, although basic operational instructions were provided at the outset, the majority of learners were able to navigate the application independently, without requiring further guidance. These findings suggest that the application's user interface was sufficiently intuitive for sixth-grade elementary school students.

Next, for the three items: "Using this application for learning was fun," "Using this application encouraged active learning," and "I would like to continue learning with this application," the results similarly indicated a significant proportion of positive responses. As shown in Table 3, two learners remarked, "It was fun to use the application to research," indicating the application contributed to the enjoyment of the learning process and possibly facilitated enhanced learner engagement.

Table 2.
Analysis Results of the Four-Point Likert Scale

Questionnaire Items	Affirmative Responces		Negative Responces		Results Fisher's Exact Test
	Strongly Agree	Agree	Disagree	Strongly Disagree	
Regarding the Application (8 Items)					
The application was easy to use	21	6	1	0	**
Using this application for learning was fun	22	5	1	0	**
Using this application encouraged active learning	23	4	1	0	**
I would like to continue learning with this application	17	10	1	0	**
Using this application made me feel like I was visiting a power plant	21	7	0	0	**
Using this application helped me consider the advantages of each power generation method	15	12	1	0	**
Using this application helped me consider the disadvantages of each power generation method	10	15	3	0	**
This application was useful for designing an eco-friendly power plant	22	5	1	0	**
Creative Activities (10 Items)					
Building an eco-friendly power plant was enjoyable	27	1	0	0	**
I actively engaged in building an eco-friendly power plant	22	3	3	0	**
I would like to engage in more eco-friendly power plant creation	26	2	0	0	**
Through building an eco-friendly power plant, I deepened my understanding of how electricity is generated	24	4	0	0	**
Through building an eco-friendly power plant, I deepened my understanding of how electricity is transmitted	17	9	2	0	**
Through building an eco-friendly power plant, I deepened my understanding of how electricity is used	22	5	1	0	**
I conducted active research for creating an eco-friendly power plant	18	6	4	0	**
I discovered new insights through the activity	12	13	2	1	**
I gained new knowledge through the activity	22	4	2	0	**
I reflected on eco-friendly practices in my daily life through creating an eco-friendly power plant	17	9	2	0	**
Learning Outcomes in the Practice (5 Items)					
I have become more aware of electricity in my surroundings	15	10	3	0	**
I want to learn more about electricity around me	19	6	3	0	**
I have become more aware of eco-friendly practices in my surroundings	18	7	2	1	**
I want to learn more about eco-friendly practices around me	20	6	2	0	**
The knowledge I learned at school was useful	14	13	1	0	**

** : $p < .01$

Regarding the item "Using this application made me feel like I was visiting a power plant," positive responses were again significantly more frequent. Three comments referenced the immersive design of the application, such as "It was amazing to be able to enter the power plant using the application." These responses suggest that the application's 360-degree panoramic scenes effectively provided a virtual experience akin to an actual site visit.

Furthermore, the items "Using this application helped me consider the advantages of each power generation method" and "Using this application helped me consider the disadvantages of each power generation method" also received significantly more affirmative responses. In practice, learners were each assigned a different power plant and tasked with conducting individual research using the application, followed by group discussions. This instructional approach likely encouraged learners to examine power generation from multiple viewpoints. However, no free-response comments explicitly mentioned the advantages or disadvantages of specific power generation methods. While the application contains extensive data on power output and safety measures, it lacks consolidated explanations outlining the relative merits and demerits of each method. Thus, developing supplemental resources that effectively summarize such comparative information should be considered a future improvement in application design.

Finally, the item "This application was useful for designing an eco-friendly power plant" also garnered significantly more positive responses. In the open-ended responses, three students expressed that the application enhanced their

Table 3.
Open-Ended Responses Regarding Participants' Impressions

Category	Number of Items	Open-Ended Comments
Regarding the Application		
Design of the Application	3	• It was amazing to be able to enter the power plant using the application
Enhanced Understanding	3	• It was easy to understand because I used the application
Enjoyment	2	• It was fun to use the application to research
Usability of the Application	1	• The application was very easy to use
Creative Activities and Learning Outcomes in the Practice		
Enhanced Understanding	10	**Electricity and Power Generation (6)** • I thought about the amount of electricity generated using the application and the power plant • I learned for the first time that generating electricity is difficult **Invironmental Practices (2)** • It was fun to learn about things I hadn't really considered before, like the difference between incandescent and LED bulbs **Creative Activities (1)** • I was able to materialize and explain what I was thinking in my head, which gave me clarity **Collaborative Learning (1)** • Listening to others' opinions made me think more deeply, such as 'That's a good idea' or 'This might be the better approach,' and it was really enjoyable **Critical Awareness of Power Generation (1)** • I thought it would be good if we could reduce thermal power generation, even just a little
Enjoyment	9	• It was very fun to think of new eco-friendly power generation methods • It was fun to express ideas using blocks
Increased Interest and Motivation	5	• Through this lesson, I want to learn more about electricity and eco-friendly energy • I want to study more about eco-friendly practices and realize the eco-friendly town I imagined • I want to start saving electricity and water based on what I learned in this class
Difficulty of the Creative Task	3	• I understood how electricity is generated and made a plan first, but I was unsure what source of energy to use
Sense of Accomplishment	3	• I thought it would be difficult to create an eco-friendly town, but I was glad I could design it by devising simple power generation methods
Build upon Their Existing Academic Knowledge	2	• We used wind, hydro, and solar power, which we had studied before, to recreate a power plant using blocks • It was fun, and I want to connect this to what we learned about energy conservation in home economics
Increased Motivation for Future Creative Activities	2	• I want to think of additional power generation methods beyond those I came up with this time

understanding, with comments such as, "It was easy to understand because I used the application." During the lessons, a few student groups were observed referring to the application while working on their eco-friendly power plant designs. This suggests that both the application's functionality and the information provided may have contributed to learners' comprehension and supported their creative activities. However, a few groups did not utilize the application at all during the creative phase, indicating a need to revise the instructional design to ensure that the application is more effectively integrated into students' creative work.

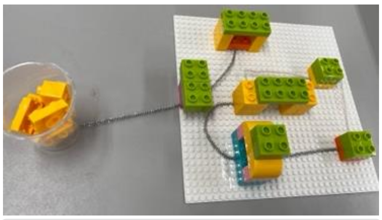
Creative Activities and Learning Outcomes in the Practice

This section discusses the results related to the 10 items on "Creative Activities" and the 5 items on "Learning Outcomes in the Practice", from the four-point Likert scale questionnaire. Regarding the items "Building an eco-friendly power plant was enjoyable" and "I actively engaged in building an eco-friendly power plant," a significantly higher number of affirmative responses were observed. As shown in Table 3, nine participants mentioned the enjoyment of creative activities in their free-text responses, including statements such as "It was very fun to think of new eco-friendly power generation methods" and "It was fun to express ideas using blocks." Additionally, three comments referred to a "sense of accomplishment," such as "I thought it would be difficult to create an eco-friendly town, but I was glad I could design it by devising simple power generation methods." These findings suggest that assigning a task such as "thinking of eco-friendly power generation methods" and designing the activity using blocks contributed to the learners' enjoyment and sense of achievement. A significantly higher number of affirmative responses was also observed for the item "I would like to engage in more eco-friendly power plant creation." Free-text responses included two remarks indicating increased motivation for future creative activities, such as "I want to think of additional power generation methods beyond those I came up with this time." These responses suggest that the activity encouraged learners to pursue new ideas beyond the scope of the current practice, thereby promoting expansive and developmental learning.

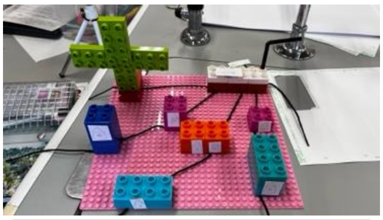
Moreover, significantly more positive responses were recorded for the following three items: "Through building an eco-friendly power plant, I deepened my understanding of how electricity is generated," "...how electricity is transmitted," and "...how electricity is used." Free comments provided further insight, with learners stating that "I was able to materialize and explain what I was thinking in my head, which gave me clarity," and "Listening to others' opinions made me think more deeply, such as 'That's a good idea' or 'This might be the better approach,' and it was really enjoyable." These comments indicate that the activity contributed to a nuanced understanding of electricity generation through both individual expression and collaborative learning. Conversely, three comments addressed the difficulty of the creative task, such as "I understood how electricity is generated and made a plan first, but I was unsure what source of energy to use." This highlights that, although learners acquired foundational knowledge using the application or online resources, a few of them found it challenging to generate and express new ideas. To support these learners, scaffolding strategies, such as step-by-step questioning—for example, "What type of energy do you want to use?" or "How can that energy be converted into electricity?"—may be beneficial during creative activities.

Regarding the items "I conducted active research for creating an eco-friendly power plant," "I discovered new insights through the activity," and "I gained new knowledge through the activity," significantly more affirmative responses were reported. Free-text responses included six comments indicating nuanced understanding, such as "I thought about the amount of electricity generated using the application and the power plant," and "I learned for the first time that generating electricity is difficult." These suggest that learners acquired more concrete understanding about electricity generation and its scale. Moreover, Figure 2 presents a selection of student-created models, categorized and excerpted from all 12 groups. Student-created models included applications of energy generation methods featured in the application, such as "placing solar panels on rooftops" (Figure 2a), "windmill-powered houses" (Figure 2b), and "hydropower", as well as original ideas beyond the application's scope, such as "wave power generation" (Figure 2c) and "hand-crank generators". This implies that learners also utilized the internet for additional research during the creative process. Notably, one creation labeled "Pikachu power generation" (Figure 2d) may initially appear to be a fictional and imaginative concept, but it could also be interpreted as inspired by real-life "bioelectricity," such as electricity produced by electric eels or rays. This example suggests that learners' creative ideas can connect with established scientific knowledge. However, as previously noted, a few students became deeply engaged in the creative activity and may have ignored the opportunities to fully utilize the application or external resources for research. To support meaningful learning during such creative processes, it may be helpful for teachers to offer gentle prompts and flexible guidance to encourage students to explore information more thoroughly and enhance their understanding.

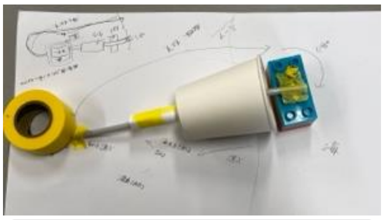
Figure 2.
Examples of Student-Created Models



(a)Placing Solar Panels on Rooftops

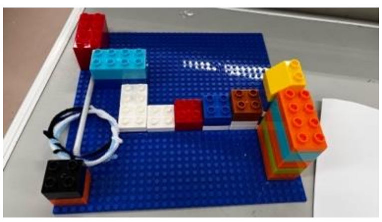


(b)Windmill-Powered Houses

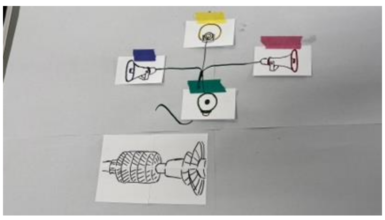


(c)Wave Power Generation

(d)Pikachu Power Generation



(e)Hydropower Generation Using Bathwater



(f)Sound Power Using Speakers to Collect Daily Noise

Affirmative responses were also significantly higher for the item "I reflected on eco-friendly practices in my daily life through creating an eco-friendly power plant." In the free-response section, two comments indicated nuanced awareness of environmental practices, such as "It was fun to learn about things I hadn't really considered before, like the difference between incandescent and LED bulbs." Student creations included innovative ideas such as "hydropower generation using bathwater" (Figure 2e), "sound power using speakers to collect daily noise" (Figure 2f), "swing motion-based power generation," "power generation from cars," and "power generation from bullet trains." These examples demonstrate an awareness of and focus on unused energy sources in everyday life, suggesting that learners were able to link the content of the lesson to their daily experiences.

In all four items: "I have become more aware of electricity in my surroundings," "I want to learn more about electricity around me," "I have become more aware of eco-friendly practices in my surroundings," and "I want to learn more about eco-friendly practices around me," there were significantly more affirmative responses. Five free-text responses indicated increased interest and motivation, including statements such as "Through this lesson, I want to learn more about electricity and eco-friendly energy," "I want to study more about eco-friendly practices and realize the eco-friendly town I imagined," and "I want to start saving electricity and water based on what I learned in this class." These suggest that the lesson enhanced learners' engagement and curiosity regarding electricity and sustainability. Furthermore, as previously mentioned, several projects were inspired by learners' real-life experiences, indicating that awareness and interest in sustainable practices in everyday life had increased. One particularly notable example was the idea of "switching between hydropower and solar power depending on the weather," which demonstrates learners' ability to understand the characteristics of different power generation methods and propose sustainable solutions that adapt to environmental conditions. This implies that learners were able to compare and integrate various power generation methods.

Additionally, one student expressed a critical awareness of power generation by stating, "I thought it would be good if we could reduce thermal power generation, even just a little." As demonstrated in this practice, engaging in discussions on the advantages and disadvantages of various power generation methods may serve as an opportunity to raise students' awareness of social issues, such as energy mix. This potential suggests that further exploration of such instructional approaches is warranted. Finally, there were significantly more affirmative responses to the item "The knowledge I learned at school was useful." Two responses in the free-text section mentioned connections to prior knowledge, including "We used wind, hydro, and solar power, which we had studied before, to recreate a power plant using blocks," and "It was fun, and I want to connect this to what we learned about energy conservation in home economics." These statements suggest that learners were able to build upon their existing academic knowledge and engage in interdisciplinary learning experiences.

Conclusion

This study builds upon the work of Tashiro et al. (2021) and aims to clarify how experiential use of the 360-degree power plant exploration application, as a substitute for physical power plant visits in the sixth-grade science unit on electricity combined with inquiry-based and creative learning activities influences students' motivation, environmental awareness, and creative thinking. The application, originally developed by Tashiro et al. (2021) and improved for use in this study, enabled learners to virtually explore various types of power generation facilities while interacting with related technical data. The two-part lesson design included both inquiry-based learning and hands-on creation of eco-friendly power plant models. Through this approach, the study attempted to foster students' understanding of complex energy systems, while simultaneously promoting creativity, collaboration, and environmental awareness.

The results of a four-point Likert scale questionnaire and the analysis of free-response comments indicated that learners found the application intuitive and engaging, with a significant number reporting increased enjoyment, motivation, and understanding. The 360-degree scenes effectively simulated on-site learning, affording students a sense of immersion and realism that promtoed their connection to the subject matter. Moreover, the structured task of minutely exploring one power plant and sharing findings within a group facilitated peer learning, helping students compare different energy sources from multiple perspectives.

The creative activities, which followed the exploratory phase, provided opportunities for learners to synthesize and apply their knowledge through model construction. Students expressed positive emotional responses, including enjoyment and a sense of accomplishment, and the creations demonstrated a wide range of ideas—from conventional renewable sources to imaginative and even biologically inspired systems. These outcomes suggest that pairing VR-based inquiry with open-ended design activities can effectively stimulate higher-order thinking skills and support interdisciplinary learning in science, technology, and environmental education.

Nonetheless, the findings also revealed that a few learners became so engrossed in the creative task that they did not fully leverage the application or conduct further research. This underscores the need for instructional scaffolding that flexibly supports learners' research processes without constraining their creativity. Future curriculum design should incorporate explicit prompts, guidance, or phased questioning strategies to encourage thoughtful integration of information throughout creative activities. Furthermore, it is expected that using questionnaire items with well-established validity as an evaluation method would yield more reliable results.

In sum, this study illustrates the pedagogical potential of combining immersive virtual experiences with maker-style learning in primary education. It highlights how such integration can enhance not only conceptual understanding and learner motivation but also foster engagement with real-world energy issues. Future research should examine ways to sustain these educational gains over time and expand such approaches across broader contexts and age groups.

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