

Available online at

PISCES

Proceeding of Integrative Science Education Seminar

Beranda prosiding : <https://prosiding.iainponorogo.ac.id/index.php/pisces>

Article

ECO-CUBE: The Transparent Mini World of Life and Science

Rubi Makrifatul Istikhomah¹, Shella Sherlyna², Rahma Aulia Nur Hamidah³, Niken Ratna Dila⁴

^{1,2,3,4}UIN Kiai Ageng Muhammad Besari Ponorogo, Indonesia

Corresponding Address: rubimakrifatul@gmail.com

Article Info

5st AVES
Annual Virtual Conference of
Education and Science 2025

Keywords:

3D learning media;
ECO-CUBE;
Integrated science;
R&D.

ABSTRACT

Science learning in schools is generally still taught separately, causing students to experience difficulties in understanding the interrelation among scientific concepts as a whole. This condition calls for innovative learning media that can provide interactive and relevant learning experiences. One such innovation is ECO-CUBE (Transparent Educational Cube), a three-dimensional (3D) learning medium designed to integrate the concepts of biology, physics, and chemistry into a single, simple, engaging, and eco-friendly tool. ECO-CUBE consists of three interconnected sections. The first section illustrates a mini ecosystem to explain the relationship between living organisms and their environment (biology). The second section demonstrates the water cycle process (physics), while the third section shows pH testing of contaminated water to understand the impact of pollution on water quality (chemistry). This integration helps students comprehend natural phenomena comprehensively. This research employs the Research and Development (R&D) method using the 3D model by Thiagarajan, Semmel, and Semmel (1974), which includes the stages of define, design, and develop. Based on three validation sheets, ECO-CUBE obtained an average score of 4.62 with a percentage of 92.4%, categorized as highly feasible. These results indicate that ECO-CUBE is efficient and effective as an integrated science learning tool that promotes students' conceptual understanding, critical thinking, and environmental awareness.

© 2025 Rubi Makrifatul Istikhomah, Shella Sherlyna, Rahma Aulia Nur Hamidah, Niken Ratna Dila

INTRODUCTION

Natural Science (IPA) learning at the junior high school (SMP) level plays a crucial role in developing a scientific mindset and a comprehensive understanding of natural phenomena. However, in reality, the learning process in schools still tends to separate the fields of biology, physics, and chemistry, so students often view science as merely a collection of formulas and stand-alone memorization, rather than a connected system relevant to everyday life (Iswanto et al., 2024). The learning media used by teachers are often one-dimensional and do not support the integration of concepts across fields. This situation results in students experiencing difficulty understanding the interrelationships between concepts, reduces interest in learning, and hinders the ability to think scientifically as a whole.

In the context of 21st-century education, students are expected to develop critical thinking, collaborative thinking, creativity, and communication skills (the 4Cs). Effective learning must provide real-world experiences that foster scientific discovery through practical learning methods. Previous studies have shown that integrated science learning can significantly improve students' conceptual understanding and analytical thinking skills (Ilma et al., 2022). By implementing the integration of science, technology, engineering, and mathematics (STEM), students are able to connect theory with real-world phenomena and increase their awareness of the interconnectedness of sciences in understanding natural phenomena (Kusuma Ningtyas et al., 2024). Furthermore, project-based methods have been shown to be effective in increasing students' learning motivation and problem-solving skills (McKinney, 2023).

However, the implementation of integrated science learning is often hampered by a lack of laboratory facilities and learning media that support interdisciplinary practical activities. Engaging, interactive, and applicable media have been shown to have a positive impact on student learning interest and participation (Mirnawati et al., 2024). In this context, research on the development of mini-ecosystem media, both virtual and physical, shows significant potential in supporting students in understanding the concepts of interactions between living things, energy changes, and chemical processes occurring in the environment in a concrete and visual way (Arifin, 2024). However, most of these media are still focused on a single discipline, thus failing to present the integration of biology, physics, and chemistry in a single tool.

Based on this background, several problems can be formulated that form the basis of this research, namely:

1. Science instruction in schools is still delivered separately by subject, making it difficult for students to understand the interrelationships between science concepts as a whole.
2. The learning media used are usually one-dimensional and fail to integrate biological, physical, and chemical phenomena into a single tool.
3. Laboratory facilities in a number of schools are still minimal, making it difficult to implement integrated science practicals effectively.
4. Innovative, interactive, and affordable learning media are needed to demonstrate the relationships between science concepts and support 21st-century skills.

To address these issues, this research proposes a learning innovation called ECO-CUBE: Transparent Miniature of Life and Science. This learning tool, a transparent cube, combines biological, physical, and chemical phenomena into a single, interacting miniature system. The cube was designed to demonstrate the relationships between living organisms, the water cycle, and chemical reactions in a tangible way. With clear visual observations, students can grasp how the water cycle influences biological processes and how chemical reactions can affect ecosystem balance. The ECO-CUBE prototype was designed using a Research and Development (R&D) approach, encompassing needs analysis, product design, model creation, expert validation, and limited field trials. The tool also provides Student Worksheets (LKPD) and digital QR codes to direct students to experimental guides and reflect on learning outcomes.

The main novelty of ECO-CUBE lies in its ability to integrate three branches of science into one physical platform, enabling simultaneous observation and the interrelationship of phenomena. This innovation is unique compared to conventional learning media because it offers an integrated experimental experience that not only focuses on conceptual understanding but also strengthens science process skills and environmental literacy. Furthermore, its portable, affordable design and use of environmentally friendly materials make the ECO-CUBE suitable for use in a variety of schools, including those with limited lab facilities. By combining project-based learning principles, STEM integration, and digital technology, the ECO-CUBE is expected to increase students' learning motivation, scientific curiosity, and critical thinking skills in understanding science as the unity of life and the environment.

METHOD

This study employed the Research and Development (R&D) method, adopting the 3D model developed by Thiagarajan, Semmel, and Semmel (1974). This model consists of three core stages—Define, Design, and Develop—that serve as systematic steps for developing and validating educational products. The 3D model was chosen because of its simplicity, practicality, and suitability for classroom-based innovation. It enables researchers to not only create new instructional tools but also to evaluate their feasibility, validity, and effectiveness in improving student learning outcomes. According to (Sefriani et al., 2021), the R&D approach helps ensure that a product meets pedagogical needs, aligns with curriculum objectives, and can be immediately implemented in real educational contexts.

The research was carried out from August to October 2025 across three educational institutions—MTsN 1 Ponorogo, SMPN 2 Jetis Ponorogo, and SMPN 1 Dolopo Madiun. These schools were intentionally selected because they represent varying characteristics of student demographics, teaching practices, and laboratory facilities. This diversity allowed for more comprehensive evaluation of the ECO-CUBE's practicality and adaptability. The research subjects included three expert validators, all of whom were experienced science teachers actively involved in the development and implementation of innovative learning models at their respective schools.

The research process refers to a series of steps in a 3D model, outlined as follows.

a. Definition Stage (Name)

The first step aims to identify problems and needs in the development of learning media. An analysis was conducted of the state of science learning in schools, which showed that biology, physics, and chemistry were still taught individually. Teachers also identified a lack of learning media that could link science concepts contextually. Based on the needs analysis and curriculum review, it was determined that the media created must be integrative, engaging, user-friendly, and environmentally friendly.

b. Design Stage (Plan)

The second stage is the development of the initial product ECO-CUBE: Transparent Miniatures of Life and Science. The media is designed in the form of a three-segmented transparent cube, each representing the areas of biology (mini ecosystem), physics (water cycle), and chemistry (water pH testing). In this phase, a storyboard and functional diagram of the media were developed, showing the interrelationships between the processes in each compartment. The materials used were determined based on principles of efficiency, safety, and sustainability, such as clear glass or acrylic, glass glue, water, soil, small plants, and a natural pH indicator. The media was accompanied by a QR code linked to a digital Student Worksheet (LKPD), allowing students to access the experiment guide via their devices.

c. Development Stage (Development and Validation)

The third stage included the creation of an initial prototype, validity testing by experts, and product revisions until a final version was achieved that was ready for use. Validation was conducted by three assessors from different schools: Muh. Maksum, M.Pd. (MTsN 1 Ponorogo), Tri Ari Agustanti, S.Pd. (SMPN 2 Jetis Ponorogo), and Dita Eviana Nurachman, S.Pd. (SMPN 1 Dolopo). The assessment was conducted using a validation sheet that applied a 1–5 Likert scale to aspects of material suitability, accuracy, efficiency, safety, and aesthetics.

Validation results showed that ECO-CUBE achieved an average score of 4.62 with a percentage of 92.4%, which is classified as "Very Feasible." The media was deemed capable of visually demonstrating the relationships between science concepts, easy to operate, and relevant to the context of 21st-century learning. Based on these results, the product was categorized as valid, efficient, and effective for implementation in integrated science learning at the junior high school level.

These findings support research by (Arifin, 2024), which demonstrated that mini-ecosystem media can improve students' conceptual understanding of environmental phenomena, and by (Ilma et al., 2022), which revealed that STEM integration strengthens students' critical thinking and analytical skills. In addition, a study by (Erfariyah et al., 2024) showed that eco-education media designed through an R&D approach effectively increased ecological awareness and literacy among secondary school students. Therefore, the development of ECO-CUBE is considered successful in meeting the scientific, practical, and relevant standards of modern learning that enhance environmental awareness.

Research Flowchart

Needs and Challenges Analysis → Media Design (Storyboard & Materials) → Prototype Creation → Expert Validation → Product Revision → Final Product Ready for Trial.

The final research results show that using the R&D method with 3D models can produce innovative learning media that is not only theoretically sound but also practical and efficient for use in the context of integrated science learning in schools.

RESULT AND DISCUSSION

The results of this study were obtained through the development stages of the 3D model (Define, Design, Develop) adapted from Thiagarajan, Semmel, and Semmel (1974). This model was applied to produce and test the feasibility of the ECO-CUBE (Transparent Educational Cube) learning media, designed to support integrated science learning by combining biological, physical, and chemical concepts into a single, simple, interactive, and environmentally friendly device.

Define (Definition/Analysis)

The definition stage in this research aimed to comprehensively identify the needs, existing problems, and specific objectives of the development of innovative learning media. This stage served as the foundation for the overall Research and Development (R&D) process, ensuring that the product created would be relevant, functional, and aligned with curriculum expectations. Based on observations and in-depth interviews with science teachers at the junior high school level, it was found that the current implementation of science learning in schools still tends to separate the disciplines of biology, physics, and chemistry. Each field is taught independently with minimal integration between concepts, leading to a fragmented understanding of science phenomena among students. Consequently, learners often struggle to connect one scientific principle with another—for instance, linking the role of heat energy (physics) with water cycle processes (chemistry) or plant growth (biology).

This fragmented approach creates a learning experience that is theoretical and compartmentalized, which contrasts with the holistic nature of science itself. As Astiti et al. (2020) noted, science learning should be structured through an integrated approach that presents knowledge as an interconnected system rather than isolated facts. When students fail to perceive these connections, they are less able to apply scientific reasoning to solve real-world problems—one of the core competencies emphasized in the Merdeka Curriculum and 21st-century education frameworks.

Furthermore, classroom observations revealed that the problem is exacerbated by the limited availability of contextual and interactive learning media that can visually and concretely represent scientific relationships. Most learning activities still rely on textbooks and verbal explanations, which may not effectively bridge the gap between abstract theory and tangible experience. According to Nurrita (2018), learning media play a pivotal role as a bridge between abstract concepts and concrete reality, enabling students to visualize invisible processes and thereby increasing both comprehension and motivation. The absence of such media contributes to passive learning behavior and a decline in curiosity-driven exploration.

In response to these challenges, the development of the ECO-CUBE was conceptualized as a solution that integrates biology, physics, and chemistry into a single learning tool. The ECO-CUBE aims to provide a holistic and experiential learning environment, allowing students to directly observe natural interactions such as evaporation, condensation, and ecosystem balance within one system. This approach supports the interdisciplinary and project-based learning paradigm, which encourages inquiry, experimentation, and critical reflection.

Moreover, the increasing global emphasis on STEM (Science, Technology, Engineering, and Mathematics) and eco-literacy education further reinforces the urgency of such innovations. As noted by Syafruddin & Novianti (2023), 21st-century learning must not only equip students with conceptual knowledge but also foster the ability to apply scientific thinking in solving authentic, real-world issues. Therefore, the creation of the ECO-CUBE aligns with modern educational trends that advocate for integrated, contextual, and student-centered learning experiences. The definition stage thus provided a clear rationale and theoretical grounding for the subsequent phases of product design and development.

Design (Designing)

The design stage focused on developing the structure and visual appearance of the ECO-CUBE to achieve the objectives of integrated science learning. The design process considered aspects of functionality, aesthetics, safety, and ease of use so that the media could be applied effectively in classroom learning. According to Junaidi (2019), effective learning media must fulfill the criteria of functional effectiveness, time efficiency, and user safety within the learning environment.

The ECO-CUBE was designed in the form of a transparent cube measuring 40×20 cm, allowing students to observe scientific processes from various perspectives without needing to open the device. The cube consists of three interconnected compartments, representing different science disciplines that are conceptually and visually linked to one another. The first compartment illustrates a mini ecosystem, containing soil, plants, and small organisms such as worms or insects.



Figure 1. Mini Ecosystem

This section demonstrates the biological interaction between living organisms and their environment, including processes such as respiration, photosynthesis, and decomposition. Students can directly observe how plants grow in soil, how moisture supports life, and how

small organisms contribute to soil fertility, which builds an understanding of biological balance and energy flow.



Figure 2. Demonstrates the Water Cycle Process

The second compartment demonstrates the water cycle process, where water is heated using an LED lamp as a simulated heat source to show the stages of evaporation, condensation, and precipitation. The transparent wall enables students to see water vapor formation and condensation droplets, helping them relate it to real environmental phenomena such as rainfall. This section represents the physics aspect of ECO-CUBE, showing how energy transformation (from heat to vapor) occurs naturally and influences weather patterns and living systems.



Figure 3. Miniature Industrial City

The third compartment focuses on chemistry, particularly in observing water quality and acidity levels (pH). Two types of water samples are used: clean water and polluted water, the latter taken from industrial or household waste simulations. The polluted water sample, representing factory wastewater, typically contains chemical residues such as detergents, dyes, or metal ions that can lower or raise the pH value depending on the type of pollutant. For example, acid-containing waste may result in a pH of 4–5, while basic or alkaline waste might

reach pH 8–9, in contrast to normal clean water, which has a neutral pH around 7. Using acid-base indicators (litmus paper or universal indicator), students can observe the color changes corresponding to pH variations.

Each layer (skat) within the ECO-CUBE is not isolated, but rather interrelated, forming a complete conceptual flow of environmental balance. The first layer illustrates a mini ecosystem (biology) consisting of biotic components such as small plants, mosses, and soil organisms, as well as abiotic factors like water and soil. This miniature ecosystem demonstrates the interaction between living organisms and their environment. For the ecosystem to sustain life, it requires water as a vital element for photosynthesis, respiration, and growth.

The water that supports life in the first layer originates from the water cycle process (physics) demonstrated in the second layer. This layer visualizes evaporation, condensation, precipitation, and infiltration, explaining how water circulates naturally in the environment. The water cycle maintains the continuous availability of water essential for living organisms. Thus, the second layer bridges the understanding between energy transfer and phase changes that influence biological dynamics.

Meanwhile, the third layer represents the chemical aspect of real-world contexts, depicting an urban area with industrial activities. Industries produce wastewater that has a different pH level compared to the natural water in the second layer. By testing pH using a phenolphthalein (pp) indicator, students can observe differences in acidity between polluted and clean water. This variation has environmental implications: water with extreme pH (too acidic or too basic) can degrade soil and water quality, thereby threatening the survival of organisms represented in the first layer.

Hence, the interconnection among the three layers of ECO-CUBE demonstrates that a change in one environmental component inevitably affects others. The mini ecosystem in the first layer (biology) depends on the water balance maintained by the second layer (physics), which can be disrupted by chemical pollution from the third layer (chemistry). This model emphasizes the importance of interdisciplinary and systemic thinking in understanding natural phenomena and fostering environmental awareness among students.

Through this activity, students understand that pollutants significantly affect water quality and the sustainability of aquatic ecosystems. Acidic or basic water can disrupt the life of microorganisms and plants, reduce dissolved oxygen levels, and ultimately cause ecological imbalance. This aligns with Astiti et al. (2020), who emphasized that integrated science learning should connect real-life environmental issues with classroom learning to strengthen students' critical and environmental literacy.

The design of ECO-CUBE highlights the real interconnection among all three compartments. For instance, evaporation in the physics section contributes moisture to the biology compartment, supporting plant growth. Meanwhile, the chemical test results from the third compartment demonstrate how polluted water can negatively impact living organisms in the ecosystem. Thus, students can concretely see that each process in science—physical, chemical, or biological—affects the other, forming a complete ecological cycle.

Beyond conceptual integration, the ECO-CUBE design emphasizes visual appeal and interactivity to maintain student engagement. As stated by Sidiq and Syaripudin (2018), a clear, visually attractive display enhances students' focus and helps them comprehend abstract concepts through direct observation. Therefore, acrylic and glass materials were selected for their transparency, durability, and safety. A natural color scheme combined with soft LED lighting creates a realistic and calming learning atmosphere, simulating natural light conditions.

To enhance interactivity, ECO-CUBE is also equipped with a Quick Response (QR) code that connects to a digital student worksheet (LKPD) containing activity instructions, observation tables, and reflection questions. This digital integration supports students'

independent learning and aligns with Wulandari et al. (2023), who found that technology-based learning media increase student engagement and learning efficiency.

Overall, the design stage of ECO-CUBE embodies a combination of scientific accuracy, environmental awareness, and visual aesthetics. It serves as a concrete example of how integrated learning media can transform abstract science concepts into observable, real-world phenomena—encouraging both critical thinking and ecological responsibility among students.



Figure 4. ECO-CUBE as an Integrated Science Learning Media

Development

The development stage focused on creating the ECO-CUBE prototype and validating its quality through expert assessment to ensure the accuracy, functionality, and educational suitability of the media. The validation process involved three science education experts and school practitioners from MTsN 6 Ponorogo, SMPN 1 Dolopo, and SMPN 2 Jetis Ponorogo. At this stage, the prototype was tested for technical functionality, visual quality, and suitability for classroom use. Validators were given a rubric containing qualitative and quantitative indicators to assess each component of ECO-CUBE. The validation results showed that the media obtained an average score of 4.62 with a suitability percentage of 92.4%, which is classified as highly suitable.

Based on the validation results from three science teachers, the ECO-CUBE media: Multifunctional Educational Transparent Cube for Integrated Science Learning was declared suitable for use with several notes for improvement. The first validator, Atiek Noer Widiyanti, from MTsN 6 Ponorogo, assessed that this media falls into the category of “suitable for use/field testing without revision.” This media was evaluated as very good in terms of conceptual accuracy, durability, efficiency, and safety, with a dominant assessment score in the range of 4-5. The validators assessed that ECO-CUBE effectively displays a real mini-ecosystem that helps students understand the integration of biology, physics, and chemistry concepts visually. However, the validator suggested that each compartment be provided with an explanation of the material concepts so that students can more quickly understand the interrelationships between the parts.

The second validator, Dita Eviana Nurachman, from SMPN 1 Dolopo, also stated that this media is suitable for use with some revisions. She argued that ECO-CUBE has met the aspects of durability, safety, and curriculum accuracy, but still needs additional material explanations on each skat and adjustments to the soil media on the second skat that illustrates the physical process (condensation and water absorption). In addition, the difference between clean water and wastewater must be clearly stated so that the students' observations are more accurate.

In addition to the assessments from MTsN 6 Ponorogo and SMPN 1 Dolopo, the validator from SMPN 2 Jetis Ponorogo also rated the ECO-CUBE media as *very feasible* with an average score of 4.65 (93%). The teacher emphasized that the media is visually attractive, functionally

efficient, and contextually relevant for classroom use. The highest rating (5.0) was given for the aesthetic aspect, while the accuracy, safety, and durability aspects each received 4.6. This finding further confirms the consistency of positive evaluations across schools. Therefore, the three validators consistently rated ECO-CUBE as highly feasible, with average scores ranging from 4.6 to 4.7, confirming the reliability of the validation results.

Overall, both validators agreed that ECO-CUBE has great potential to deepen understanding of the concept of integrated science and can be used independently by junior high school students. These results reinforce the main research findings that this media received an average validation score of 4.62 (92.4%), which falls into the “highly feasible” category.

In addition to these validation results, this study is also supported by previous research by Riyana et al. (2023), which states that the application of interactive 3D media based on virtual reality can improve learning outcomes and understanding of science concepts, as students can observe objects from various angles. Three-dimensional media provides a more realistic learning experience for students compared to conventional learning methods that only use text or two-dimensional images.

Yuliandari et al. (2025) state that the use of innovative learning media in the independent curriculum can increase students' interest in learning and independence in exploring natural phenomena around them, so that contextually designed learning media enable students to not only passively receive knowledge but also actively develop understanding through inquiry and scientific exploration. This is in line with the principle of student-centered learning in the Merdeka curriculum, which emphasizes students' freedom and flexibility to learn according to their interests and learning styles.

By utilizing interactive media such as ECO-CUBE, students are encouraged to observe, identify variables, make hypotheses, and conclude the results of their observations independently. This process fosters higher order thinking skills, which are one of the main objectives in science learning. In the context of ECO-CUBE, similar skills are also developed because students not only observe the relationship between biological, physical, and chemical processes, but also relate the impact of these interactions to the overall balance of the ecosystem. Thus, ECO-CUBE media can be a concrete example of the application of integrated science learning that supports the achievement of 21st-century competencies.

These results indicate that ECO-CUBE meets the standards for learning media, both from a pedagogical and practical perspective.

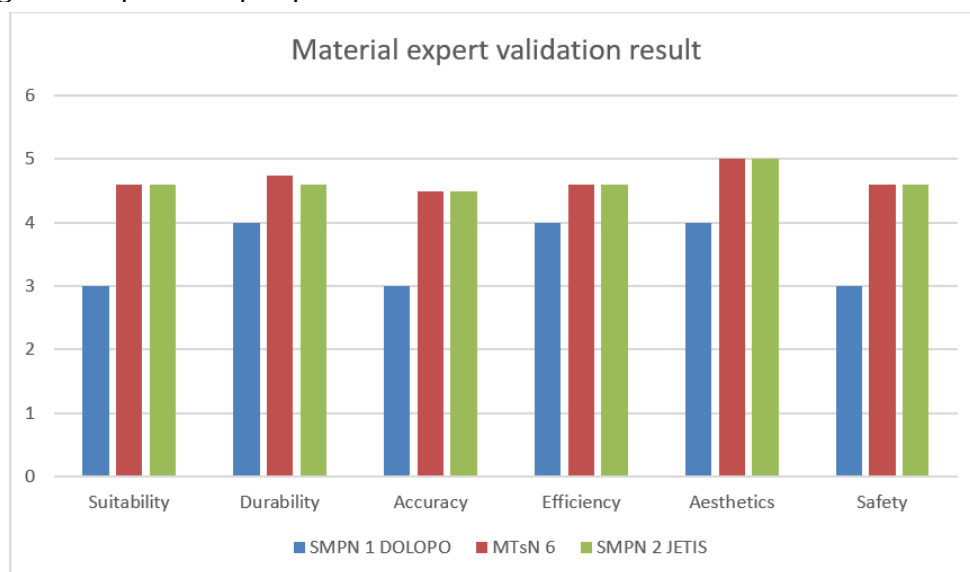


Figure 5. Material Expert Validation Result

The validation results show that ECO-CUBE is highly valued in terms of material relevance and aesthetic value. The validators noted that the integration of biological, physical, and chemical phenomena in a single cube produces a coherent visualization of natural processes, which is rarely achieved through conventional media. These findings support the ideas of Astiti et al. (2020).

In terms of conceptual accuracy, experts confirmed that each compartment of the ECO-CUBE accurately represents scientific principles. The biology section accurately depicts the interactions between living organisms and their environment, while the physics section effectively demonstrates the stages of the water cycle. The chemistry section, which focuses on testing the pH of clean and contaminated water, successfully provides an authentic context for discussing environmental pollution. This alignment between conceptual representation and real-world phenomena is consistent with Nurrita (2018).

The usability aspect also received a high score (90%), indicating that ECO-CUBE is user-friendly and can be easily operated by teachers and students without the need for complicated equipment. Teachers who participated in this review commented that this media can be used not only for classroom demonstrations but also for student experiments and group projects. This ease of operation is in line with Junaidi (2019).

Its durability and safety are also rated very highly, as the cube uses non-toxic acrylic and glass materials that are resistant to water, corrosion, and heat from LED light sources. These materials make ECO-CUBE safe for repeated use and suitable for various classroom conditions. As noted by Telaumbauna (2020), safety and sustainability are important aspects of any educational media, especially those used in experimental learning environments.

From an aesthetic perspective, the validators highlighted that the transparent cube design and LED lighting created an engaging learning experience. The natural color scheme enhanced visual appeal while maintaining clarity of observation. According to Sidiq and Syaripudin (2018), well-designed visual elements in learning media can significantly increase students' motivation and memory of scientific concepts. The combination of transparency, balance, and interactivity in ECO-CUBE successfully captures these principles.

Furthermore, the integration of Quick Response (QR) codes linked to digital Student Worksheets (LKPD) is an innovative step towards digital-based learning. This feature allows students to access experiment instructions, observation sheets, and reflective questions directly from their mobile devices. This technological integration supports independent learning and aligns with the 21st-century education paradigm that emphasizes digital literacy. This approach is in line with Wulandari et al. (2023), who found that incorporating digital devices into learning media increases student engagement, adaptability, and autonomy.

From an educational perspective, ECO-CUBE not only functions as a visual demonstration tool but also as a medium for developing scientific process skills, including observing, hypothesizing, experimenting, and analyzing. Students are encouraged to identify the relationships between phenomena occurring in each compartment, thereby promoting critical thinking and system understanding. This integrated observation process reflects the inquiry-based learning approach recommended by Tanesib, Astiti, and Hali (2022), who argue that integrated science learning materials effectively improve students' analytical thinking and environmental awareness.

In summary, the results of the development and validation stages show that ECO-CUBE is a highly feasible and effective learning medium for integrated science learning. Its combination of technical reliability, conceptual integration, and visual appeal supports meaningful learning experiences and helps students develop a holistic scientific understanding. ECO-CUBE not only bridges the gap between abstract theory and its real-world application but also encourages students to explore environmental issues through an engaging, inquiry-based approach.

CONCLUSION

This study concludes that the development of ECO-CUBE (Transparent Educational Cube) represents an innovative and effective approach to improving the quality of science learning at the junior high school level. Through a structured Research and Development (R&D) process following the 3D model of Thiagarajan, Semmel, and Semmel (Define, Design, Develop), the product successfully integrates key concepts from biology, physics, and chemistry into a single interactive medium that is simple, contextual, and engaging.

The implementation of ECO-CUBE provides students with opportunities to observe natural phenomena such as mini-ecosystem interactions, the water cycle process, and variations in water pH through direct experimentation. These activities transform abstract scientific theories into tangible experiences that students can see, measure, and analyze. As a result, the media encourages the development of students' scientific inquiry, analytical thinking, and environmental reasoning—three essential skills in the 21st-century learning framework and the Merdeka Curriculum.

Furthermore, the results of expert validation indicate that ECO-CUBE is not only valid and feasible in terms of material accuracy, safety, and efficiency, but also aesthetically appealing and pedagogically relevant. Its transparent structure and three-compartment design help demonstrate the interconnectedness of natural processes, allowing students to understand how physical, chemical, and biological systems operate as an integrated whole. This supports the development of a systemic scientific mindset, where knowledge is viewed not as isolated facts but as interconnected concepts influencing one another.

The use of eco-friendly and locally available materials—such as glass, acrylic, soil, and natural indicators—also reflects the principle of sustainability and cost-effectiveness in educational innovation. This aligns with national and global goals for green education and Environmental, Social, and Governance (ESG) awareness, making the ECO-CUBE both scientifically and ethically relevant. In addition, the integration of digital features, including a QR code linked to a Student Worksheet (LKPD), supports technology-based learning and promotes students' independence and responsibility in data collection, observation, and reflection.

ECO-CUBE thus functions as a bridge between theory and practice, reinforcing the harmony between scientific understanding and environmental awareness. It enhances students' engagement, nurtures their curiosity, and fosters positive attitudes toward science and sustainability. The findings suggest that using integrative, interactive media such as ECO-CUBE can significantly improve learning motivation, conceptual comprehension, and ecological literacy among junior high school students.

For future research, it is recommended to further develop ECO-CUBE by incorporating digital sensors, real-time monitoring systems, and data visualization software. These technological enhancements could enable the automatic recording of environmental parameters such as temperature, humidity, and pH changes, thereby providing richer learning data for both teachers and students. Expanding the implementation of ECO-CUBE in project-based and community-based learning programs would also help evaluate its broader impact on scientific literacy, problem-solving skills, and students' awareness of environmental sustainability.

ACKNOWLEDGMENTS

The author would like to express sincere appreciation and gratitude to Kiai Ageng Muhammad Besari State Islamic University Ponorogo for providing academic facilities, scientific forums, and valuable guidance throughout the process of this research and manuscript preparation. The institutional support and encouragement have been instrumental in realizing this project successfully.

The author also extends heartfelt thanks to the expert validators, namely the science teachers from MTsN 1 Ponorogo, SMPN 2 Jetis Ponorogo, and SMPN 1 Dolopo Madiun, who actively participated in the validation process of the ECO-CUBE (Transparent Educational Cube) media. Their insightful suggestions, constructive feedback, and professional evaluations greatly contributed to improving the quality, clarity, and practicality of the developed learning media.

Special appreciation is also addressed to the ECO-CUBE development research team, whose cooperation, dedication, and creative collaboration have been essential throughout the design, testing, and writing stages of this project. The strong synergy and teamwork demonstrated during the process played a crucial role in achieving the optimal outcomes of this research.

Finally, the author sincerely thanks all individuals and parties who have provided moral support, motivation, and inspiration during the completion of this study. It is hoped that the results of this work will contribute meaningfully to the advancement of integrative, innovative, and environmentally sustainable science education in Indonesia.

REFERENCE

- Arifin, A. A. (2024). Development of Mini Virtual Aquatic Ecosystem Learning Media Assisted by Professional 3D Pageflip Software. *International Journal of Science Education and Science*, 1(2), 45–51. <https://doi.org/10.56566/ijses.v1i2.227>
- Astiti, K. A., Supu, A., Sukarjita, I. W., & Lantik, V. (2020). Pengembangan bahan ajar IPA terpadu tipe *connected* berbasis pembelajaran berdiferensiasi pada materi lapisan bumi kelas VII. *Jurnal Pendidikan dan Pembelajaran Sains Indonesia*, 2(1), 34–44. <https://doi.org/10.23887/jppsi.v2i1.28222>
- Erfariyah, A., Jaenudin, D., & Permana, I. (2024). Development of Conservation E-Books Based on Local Potential to Improve Eco-literacy of Junior High School Students. *International Journal of STEM Education for Sustainability*, 4(2), 267–292. <https://doi.org/10.53889/ijses.v4i2.443>
- Ilma, A. Z., Wilujeng, I., & Prasetyo, Z. K. (2022). *Literature Review of Science Learning Activities with Integrated STEM Education*. 2022, 8–14. <https://doi.org/10.11594/nstp.2022.2502>
- Ilma, N. (2022). STEM integration and students' critical thinking skills in science learning. *Jurnal Inovasi Pendidikan IPA*, 8(3), 179–189. <http://doi.org/10.15294/jipi.v8i3.37265>
- Iswanto, I. H., Wulandari, A. Y. R., Wahyuni, E. A., Sutarja, M. C., & Putera, D. B. R. A. (2024). Pengembangan Media Pembelajaran IPA Terpadu Tipe Webbed Berbasis Wix Tema Garam Madura. *INKUIRI: Jurnal Pendidikan IPA*, 13(2), 182. <https://doi.org/10.20961/inkuiri.v13i2.85388>
- Junaidi. (2019). *Media pembelajaran dalam perspektif pendidikan modern*. *Jurnal Ilmu Pendidikan Indonesia*, 7(2), 55–62. <https://doi.org/10.21831/jipi.v7i2.2019>
- Kusuma Ningtyas, P., Retno Widarti, H., Parlan, P., Rahayu, S., & Dasna, I. W. (2024). Enhancing Students' Abilities and Skills through Science Learning Integrated STEM : A Systematic Literature Review To cite this article : literature review . *International Journal of Education in Mathematics , Science , and Enhancing Students' Abilities*. *International Journal of Education in Mathematics, Science and Technology*, 12, 1161–1181.
- McKinney, L. (2023). Effectiveness of project-based learning in a junior high science classroom. *Interdisciplinary Journal of Environmental and Science Education*, 19(3), e2312. <https://doi.org/10.29333/ijese/13678>
- Mirawati, Takdir, & Irmayanti. (2024). The Influence of Interactive Learning Media on Students Interest in Learning in Mathematics Subjects at UPTD SMPN 7 Sinjai. *JTMT: Journal Tadris Matematika*, 5(2), 160–165. <https://doi.org/10.47435/jtmt.v5i2.3234>

- Nurrita, T. (2018). Pengembangan media pembelajaran untuk meningkatkan hasil belajar siswa. *Jurnal Misykat*, 3(1), 121–132. <https://doi.org/10.33511/misykat.v3n1.121>
- Riyana, C., Darmawan, D., & Sutopo, A. (2023). 3D Interactive Virtual Reality Media to Improve Learning Outcomes in Elementary Schools. *Jurnal Pendidikan Indonesia*, 12(2). <https://ejournal.undiksha.ac.id/index.php/JPI/article/download/58472/26554/180831>
- Sefriani, R., Radyuli, P., Nurhidayati, N., & Sepriana, R. (2021). Design and Development Based Learning Media Application Using Mobile App Inventor. *International Journal of Educational Development and Innovation*, 1(1), 45–53. <http://ojs.unm.ac.id/IJEDI/article/view/22162>
- Sidiq, E. I., & Syaripudin, R. C. (2018). Sumber belajar dan alat peraga sebagai media pembelajaran. *Jurnal Pendidikan Nonformal*, 3(2), 85–93. <https://doi.org/10.37905/jpnf.v3i2.649>
- Syafruddin, S., & Noviati, W. (2023). Modul elektronik IPA terpadu berbasis pendidikan karakter sebagai inovasi bahan ajar untuk SMP. *Jurnal Edukasi Sains dan Aplikasi Berbasis Inovasi*, 4(1), 15–25. <https://doi.org/10.55606/jesabi.v4i1.3345>
- Wulandari, A. P., Salsabila, A. A., Cahyani, K., Nurazizah, T. S., & Ulfiah, Z. (2023). The importance of learning media in the teaching and learning process. *Journal on Education*, 5(2), 3928–3936. <https://doi.org/10.31004/joe.v5i2.5047>
- Yuliandari, D., Juniartina, I., & Marlinda, N. (2025). Studi penerapan media pembelajaran IPA pada Kurikulum Merdeka serta dampaknya terhadap minat belajar siswa. *Jurnal Pendidikan dan Pembelajaran Sains Indonesia (JPPSI)*, 5(1). <https://ejournal.undiksha.ac.id/index.php/JPPSI/article/view/95002>