Implementation of 5E Cycle-Based Learning Media Assisted by Scratch to Enhance Students' Physics Identity on Renewable Energy Topics

Lucky Adi Nugroho[1*], Riki Perdana[2], Febrina Siska Widyaningtyas[3]

[1] Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

[2] Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

[3] Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

Corresponding author e-mail: luckyadi.2023@student.uny.ac.id

Abstract

Students' persistently low achievement in physics highlights the need for instructional media that better align with learners' characteristics and learning needs, particularly in fostering a sense of identity within the discipline. This study aims to develop an interactive physics learning medium based on the 5E learning cycle model, assisted by a three-dimensional Scratch application, to strengthen students' physics identity on the topic of renewable energy. This research and development study employed the 4D model, comprising the define, design, develop, and disseminate stages. Data were collected through a validation questionnaire assessing content validity, construct validity, media quality, pedagogical suitability, and readability, with five pre-service physics teachers serving as expert validators. The results yielded an average validity score of 3.56, placing the medium in the highly valid category. These findings suggest that the developed Scratch-based learning medium is both feasible and effective for supporting conceptual understanding and cultivating students' physics identity through engaging, interactive learning experiences. This study contributes to the growing body of research on technology-assisted physics instruction and offers practical implications for designing media that connect content mastery with students' identity development in science learning.

Keywords: *Renewable Energy; Learning Media; Scratch; 5E Model; Physics Identity.*

1. INTRODUCTION

Students' physics learning outcomes across various levels of education in Indonesia continue to show low achievement, with average test scores frequently falling below the minimum mastery standard (Suhartini, 2023). This condition reflects a fundamental problem in the physics learning process (Fuadi et al., 2020), particularly for abstract topics such as renewable energy, which students consistently find difficult to understand (Chania et al., 2020). These findings underscore the need to reform instructional strategies in order to significantly improve students' conceptual understanding.

National and international survey data reinforce this picture of Indonesian students' low scientific literacy. The National Examination recorded that renewable energy material obtained the lowest score compared to other physics topics (Rahmayani, 2024). At the international level, the Programme for International Student Assessment (PISA) 2018 ranked Indonesia 71st out of 79 countries in scientific literacy, with an average score of 396—far below the OECD countries' average of 489 (OECD, 2019; Tohir, 2019). This gap underscores the urgency of improving the quality of physics instruction nationwide.

This low achievement largely stems from instructional methods that remain unresponsive to students' characteristics. Learning is still teacher-centered and fails to actively engage students (Permata Sari et al., 2022), while lectures and rote memorization, which continue to dominate classroom activities, leave students passive (Putri et al., 2020). Such approaches fail to cultivate critical and analytical thinking skills (Utami, 2020), while also diminishing learning motivation due to the monotonous classroom atmosphere.

Beyond instructional methods, several external factors further weaken students' physics learning outcomes. Limited laboratory facilities hinder experimental activities that should support conceptual understanding (Riskawati & Marisda, 2020), while teachers' minimal use of interactive media makes physical phenomena difficult to visualize (Marsa & Desnita, 2020). Instructional materials that are poorly connected to everyday life also make it difficult for students to relate theory to reality (Sujanem & Suwindra, 2023), weakening their ability to link physics concepts to real-world experience (Wulandari, 2021).

Various efforts have been made to address these issues through the development of learning media, ranging from interactive modules and multimedia to computer-based simulations designed to help students grasp abstract physics concepts (Agustina et al., 2023; Astuti et al., 2020). The use of such technology has been shown to increase student motivation and engagement in learning (Watin et al., 2023). This innovation has been further strengthened through the development of locally contextualized instructional materials, which help students connect content to everyday experience (Sae et al., 2021) and have proven effective in improving retention and conceptual understanding (Pratiwi et al., 2020), positioning technology-based contextual learning as a new direction in science education innovation.

Nevertheless, the learning media developed thus far have not fully met students' needs. Much of this media remains passive, merely delivering information without interaction, leaving students positioned as recipients rather than constructors of knowledge (Muliani et al., 2024; Rais et al., 2020). This lack of exploratory activity makes it difficult for students to grasp the relationships between physics concepts (Rizkita & Mufit, 2022), thereby reducing the overall effectiveness of such media in improving learning outcomes.

A further weakness lies in the aspects of personalization and visualization dynamics: most existing media fail to adapt to individual students' learning pace (Pulu et al., 2022), while the visualization of physics concepts remains limited and insufficiently dynamic (Rodiawati et al., 2023). This indicates that students require media capable of delivering active, contextual learning experiences, making the development of interactive media a promising solution for strengthening students' conceptual understanding..

2. METHOD

This study used the *Research and Development* (R&D) approach with the 4D model (*Define, Design, Develop, Disseminate*; Thiagarajan et al., 1974), chosen for its systematic framework and iterative validation process (Fadli et al., 2024; Nisa et al., 2025; Rahmah et al., 2024). In the Define stage, an analysis of the gap between students' conceptual understanding and curriculum demands on renewable energy (Zuhrie et al., 2020), together with an analysis of student characteristics and content, informed learning objectives integrating the 5E Learning Cycle to foster students' physics identity through exploratory and reflective activities, with Scratch designed as the interactive visualization medium. In the Design stage, an initial Scratch-based prototype was developed, incorporating content structure, interface layout, and interactive elements aligned with the 5E stages (Azzahra et al., 2023; Hermiyati et al., 2023; Kurniawan & Hadi, 2023). In the Develop stage, the prototype was validated by content and media experts and revised accordingly, then trialed at individual, small-group, and field scales to assess its effectiveness, practicality, and appeal (Yusuf, 2023). In the Disseminate stage, the validated medium was implemented in an actual classroom using the 5E Learning Cycle and distributed through a user guide and a digital version accessible via open platforms such as Google Drive and YouTube (Hariyanto et al., 2022; Hidayat & Syofyan, 2023; Putra et al., 2023).

The validation subjects consisted of five expert validators in physics content and instructional media, purposively selected based on their relevant expertise, who assessed the feasibility of the developed medium prior to classroom implementation. Data were collected using a validation questionnaire completed by the five expert validators, covering five aspects: content validity, construct

validity, media and display quality, pedagogical suitability, and language readability, as summarized in Table 1. Each indicator was rated on a four-point scale (Table 2). Data were analyzed quantitatively by calculating the mean score across validators for each aspect, and the overall average was converted into a qualitative validity category using the interval scale presented in Table 3.

Table 1. Validation Aspects and Indicators

Aspect	Indicators
Content Knowledge (CK)	Alignment of material with the curriculum; accuracy of physics concepts; depth and completeness of content; accuracy of scientific examples and illustrations
Pedagogical Knowledge (PK)	Accuracy of the learning model's stages/phases; active and reflective student engagement; appropriate integration of local cultural values relevant to physics concepts
Technological Knowledge (TK)	Ease of navigation and interactivity; quality of graphics, audio, and video; accessibility and compatibility across devices
TPACK Integration	Coherence between physics content, instructional strategy, and technology; relevance of technology use to pedagogical and content goals; meaningfulness of the learning experience
Aesthetics and Language	Text readability and clarity of language; visual appeal; consistency of layout and design

Table 2. Validator Rating Scale

Score	Category
1	Very Infeasible
2	Infeasible
3	Feasible
4	Very Feasible

Table 3. Validity Score Interval Categories

Average Score Range	Validity Category
$1.00 \leq x < 1.60$	Very invalid
$1.60 \leq x < 2.19$	Invalid
$2.19 \leq x < 2.79$	Fairly valid
$2.79 \leq x < 3.49$	Valid
$3.49 \leq x \leq 4.00$	Highly valid

3. RESULTS AND DISCUSSION

The results of this study on the development of a Scratch-assisted, 5E-based physics learning medium are presented according to the four stages of the 4D model.

3.1 Define Stage

The needs analysis revealed that physics instruction in schools remains dominated by conventional methods with limited use of interactive media, leaving students passive and struggling to understand abstract concepts—particularly energy and its transformations. Most students were unable to connect renewable energy principles to everyday phenomena, such as energy conversion in solar panels or wind turbines, indicating limited conceptual understanding and scientific thinking skills. The student characteristics analysis further showed low interest in physics, limited confidence in grasping concepts, and little perceived relevance of physics to students' identity as future science learners.

These findings established the need for a medium that functions not merely as a visual aid but as a tool to cultivate curiosity, active engagement, and a positive disposition toward physics. Accordingly,

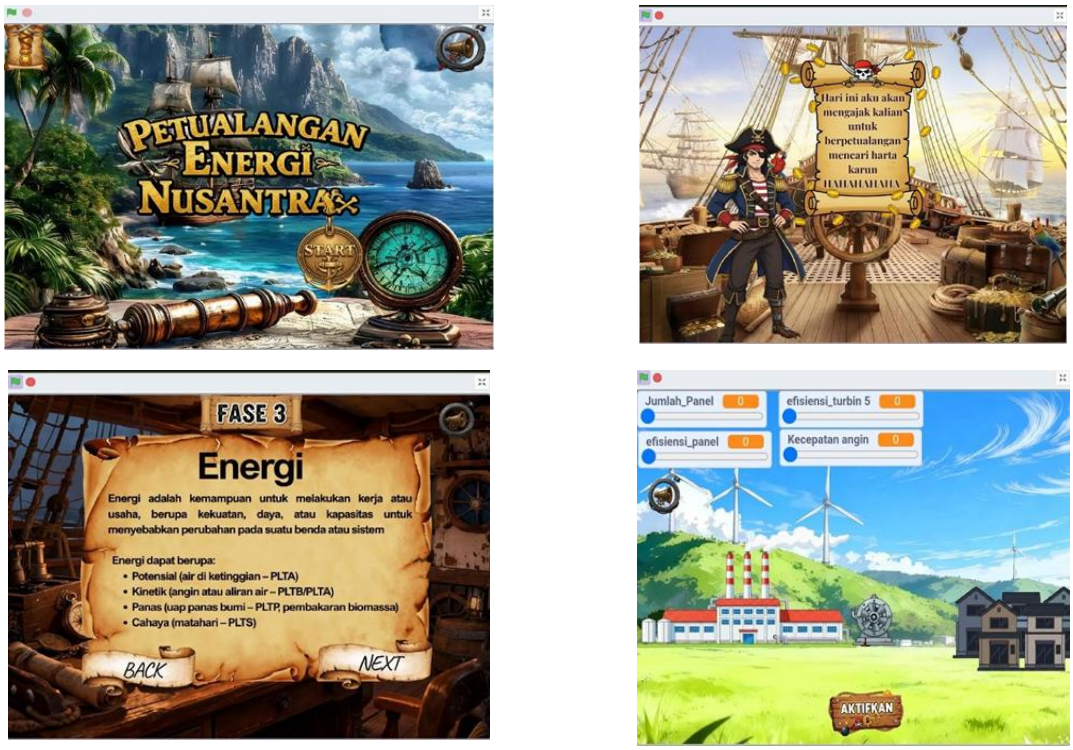
the learning medium was defined as an interactive Scratch-based product combining visual simulation and project-based activities within the 5E Learning Cycle framework (Engage, Explore, Explain, Elaborate, Evaluate), designed to help students explore renewable energy concepts progressively while strengthening their physics identity through authentic, meaningful learning experiences. Scratch was selected as the core platform because its dynamic visualization allows students to observe cause-and-effect relationships between physical variables—such as energy conversion in solar panels, wind turbines, or simple mechanical systems—without requiring direct laboratory experimentation, while its interactive, game-like features support exploration, observation, and reflection consistent with the 5E stages.

3.2 Design Stage

Building on the Define stage, the Design stage translated the identified needs into a structured initial product design through five sequential steps: (1) analyzing the syntax of the 5E Learning Cycle to establish a framework for the medium's activity flow and interactivity; (2) identifying a theme capable of visually and interactively representing renewable energy conversion processes; (3) refining the selected theme—a pirate-themed adventure in which students search for renewable energy sources across the Indonesian archipelago—to ensure both scientific accuracy and contextual appeal; (4) aligning each 5E phase with the corresponding simulation flow, where Engage introduces the renewable energy issue, Explore facilitates direct interaction with energy-conversion simulations, Explain consolidates the concepts observed during exploration, Elaborate prompts reflection and application to new real-life phenomena, and Evaluate measures conceptual understanding; and (5) translating the theme and syntax analysis into a storyboard, encompassing simulation visuals, energy-conversion animations, and interactive elements that support scientific exploration and reasoning.

This stage produced a comprehensive, structured storyboard functioning as both a visual guide and development roadmap, detailing the sequence of learning activities, interactive screen displays, narrative content for each 5E phase, and the intended student interaction flow (Figure 1). The resulting design prioritized renewable energy conversion and its real-life applications, aimed at strengthening both conceptual understanding and students' physics identity through active, reflective, and contextual learning experiences.

Figure 1. Initial Media Prototype



3.3 Develop Stage

The Develop stage realized the Design-stage storyboard into a functional Scratch-based product. The medium simulates renewable energy conversion processes—such as solar-to-electrical and wind-to-electrical energy—in an interactive format. Each 5E phase was embedded within the medium: Engage presents a triggering scenario involving the energy needs of a pirate ship; Explore facilitates conceptual exploration through simulations of geothermal, hydro, biomass, wind, and solar energy; Explain provides concept-based explanations grounded in the preceding simulations; Elaborate allows students to apply their understanding to new situations; and Evaluate offers reflective exercises to assess conceptual understanding.

During development, internal testing and iterative revisions were conducted to ensure the medium functioned properly and aligned with the intended instructional design. The resulting functional prototype was then validated by five pre-service physics teachers acting as expert validators, who assessed content validity, construct validity, media/display aspects, pedagogical aspects, and language readability using a four-point rating scale. Validation data were analyzed quantitatively by calculating the mean score for each aspect and the overall product score.

The validation results showed that the developed Scratch-assisted medium fell into the highly valid category, with an overall average score of 3.56. This result indicates that integrating the 5E Learning Cycle with the Scratch platform successfully produced a medium responsive to 21st-century learning needs. The 5E model encourages active student engagement across the Engage, Explore, Explain, Elaborate, and Evaluate phases, emphasizing a cycle of scientific thinking (Hariyanto et al., 2022), while Scratch provides a visual programming environment that supports direct experimentation, simulation, and conceptual exploration (Kurniawan & Hadi, 2023). Together, these two elements created constructive, interactive learning experiences that enabled a more holistic understanding of renewable energy concepts (Wahyuningtyas et al., 2021; Hermiyati et al., 2023), indicating that the developed medium is not only theoretically valid but also pedagogically relevant for improving the effectiveness of physics instruction.

The Scratch-assisted medium helped students build conceptual understanding through dynamic visualization of energy conversion processes, such as the transformation of wind energy into electrical energy. Its animation and simulation features allowed students to observe abstract phenomena as concrete, measurable events, thereby reducing common difficulties in grasping physics concepts (Marsa & Desnita, 2020). The medium positioned students as active constructors of knowledge through exploratory and reflective activities consistent with the 5E syntax (Agustina et al., 2023). Presenting renewable energy content within a local cultural context [— please verify: "Lisung-Halu" — which region/culture does this refer to?] further made learning more contextual and meaningful for students (Sae et al., 2021). This authentic learning experience contributed to strengthening critical thinking and scientific literacy—areas that have long been identified as weaknesses in Indonesian physics education (Effendi et al., 2023)—suggesting that the Scratch-based medium can serve as an effective bridge between theory and everyday reality.

Beyond conceptual understanding, the Scratch-assisted medium also appeared to strengthen students' physics identity. Students were encouraged to think like scientists through digital simulation and experimentation activities requiring observation, analysis, and reflection (Yusuf, 2023). The medium's interactivity created space for collaboration and independent experimentation, supporting the development of critical, creative, and collaborative thinking (Agustina & Okmarisa, 2023). Project-oriented activities embedded in each 5E phase further supported experiential learning that fosters confidence and a sense of ownership over physics as a meaningful field of study (Rizkita & Mufit, 2022), contributing to increased intrinsic motivation and science orientation in understanding renewable energy (Prastika et al., 2020). These findings suggest that Scratch-based media hold strategic potential for cultivating scientific character and sustainably strengthening students' physics identity.

These findings align with prior studies demonstrating the effectiveness of interactive visual technology integration in science learning (Muliani et al., 2024; Watin et al., 2023). Scratch was shown to accommodate diverse learning styles through flexible visualization and simulation-based interaction (Pulu et al., 2022), while the integration of the 5E Learning Cycle strengthened the medium's systematic

and reflective instructional structure, making inquiry-based teaching easier for teachers to facilitate (Waruwu, 2024). The high validity scores obtained for the pedagogical and technological aspects indicate that this medium is a viable alternative for physics instruction in the digital era—one that, in the context of renewable energy, may also foster students' environmental awareness and sense of social responsibility as future contributors to sustainable development.

4. CONCLUSION

The Scratch-based physics learning medium integrating the 5E Learning Cycle model was found to be highly valid, based on expert judgment, with an overall average validity score of 3.56. This result indicates that the developed medium satisfactorily met the criteria for content, construct, display, pedagogical, and readability aspects, and is capable of accommodating the characteristics of renewable energy—a topic that has traditionally been difficult for students due to its abstract nature and reliance on dynamic visual representation. The Scratch-assisted medium was shown to provide a more interactive and exploratory learning experience, with realistic simulations helping students connect theoretical concepts to real-world applications. Each phase of the 5E model, from Engage to Evaluate, played a critical role in fostering scientific, analytical, and reflective thinking, resulting in learning that is more contextual, meaningful, and engaging—ultimately supporting greater student involvement and motivation in physics.

Beyond enhancing conceptual understanding, this study suggests that the Scratch-based medium has the potential to strengthen students' physics identity through active engagement and project-based activities. The integration of visual technology with a constructivist model such as 5E appears to support the development of 21st-century skills, including computational thinking, collaboration, and creativity. Based on these findings, physics teachers are encouraged to adopt interactive media such as Scratch as an innovative alternative for teaching abstract topics, particularly renewable energy. Future research is recommended to test the medium's effectiveness on actual student learning outcomes and scientific attitudes through classroom implementation.

AI USAGE STATEMENT

No AI tools were used in the preparation of this manuscript.

REFERENCES

Agustina, M., Ariani, T., & Yolanda, Y. (2023). Pengembangan modul fisika berbasis CTL berbantuan aplikasi Canva untuk meningkatkan hasil belajar siswa. Jurnal Penelitian Pembelajaran Fisika, 14(2), 169–178. https://doi.org/10.26877/jp2f.v14i2.16909

Chania, D. M. P., Medriati, R., & Mayub, A. (2020). Pengembangan bahan ajar fisika melalui pendekatan STEM berorientasi HOTS pada materi usaha dan energi. Jurnal Kumparan Fisika, 3(2), 109–120. https://doi.org/10.33369/jkf.3.2.109-120

Effendi, E., Sinensis, A. R., & Firdaus, T. (2023). Peningkatan literasi sains mahasiswa pendidikan fisika melalui pembuatan LKPD berbasis sosio saintifik. JIPFRI (Jurnal Inovasi Pendidikan Fisika dan Riset Ilmiah), 7(1), 35–39. https://doi.org/10.30599/jipfri.v7i1.2222

Fuadi, M., Arsyad, M., Arafah, K., & Asriyadin. (2020). Pengaruh model learning cycle 5E terhadap motivasi belajar dan hasil belajar fisika peserta didik SMA Negeri 2 Woha Bima. Jurnal Pendidikan MIPA, 10(2), 116–121. https://doi.org/10.37630/jpm.v10i2.387

Hazari, Z., Sadler, P. M., Sonnert, G., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. Journal of Research in Science Teaching, 47(8), 978–1003. https://doi.org/10.1002/tea.20363

López, V., & Hernández, M. I. (2015). Scratch as a computational modelling tool for teaching physics. Physics Education, 50(3), 310–316. https://doi.org/10.1088/0031-9120/50/3/310

Organisation for Economic Co-operation and Development. (2019). PISA 2018 results (Volume I): What students know and can do. OECD Publishing. https://doi.org/10.1787/5f07c754-en

Permata Sari, I., Nanto, D., & Putri, A. A. (2022). Pengaruh hasil belajar pendidikan fisika siswa menggunakan teknik meta-analisis dengan model PBL (Problem Based Learning). Jurnal Mentari: Manajemen, Pendidikan dan Teknologi Informasi, 1(1), 20–28. https://doi.org/10.34306/mentari.v1i1.124

Rahmayani, F. (2024). Development of e-book integrated augmented reality based on STEM approaches to improve critical thinking and multiple representation skills in learning physics. International Journal of Information and Education Technology, 14(4), 632–641. https://doi.org/10.18178/ijiet.2024.14.4.2087

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). Instructional development for training teachers of exceptional children: A sourcebook. Indiana University, Center for Innovation in Teaching the Handicapped.

Tohir, M. (2019). Hasil PISA Indonesia tahun 2018 turun dibanding tahun 2015. https://doi.org/10.31219/osf.io/pcjvm

Wulandari, S. (2021). Studi literatur penggunaan PBL berbasis video untuk meningkatkan kemampuan pemecahan masalah. JPF (Jurnal Pendidikan Fisika) Universitas Islam Negeri Alauddin Makassar, 9(1), 7. https://doi.org/10.24252/jpf.v9i1.13818

Yusmar, F., & Fadilah, R. E. (2023). Analisis rendahnya literasi sains peserta didik Indonesia: Hasil PISA dan faktor penyebab. LENSA (Lentera Sains): Jurnal Pendidikan IPA, 13(1), 11–19. https://doi.org/10.24929/lensa.v13i1.283