Research Article

Creating the Storyline of Energy and Environmental Learning in the Indonesian Science Curriculum through Engineering Design Process

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Received: 25 February 2026
Revised: 21 April 2026
Accepted: 22 April 2026

ABSTRACT

Decision-making related to energy and the environment is a crucial driver of ecological resilience and sustainability. A clear pathway for energy and environmental learning is essential as part of the science education curriculum. Literature suggests that a conceptual storyline could demonstrate the linkage among science learning outcomes to develop understanding and awareness of energy and environmental issues. Thus, this research aims to analyse how science learning outcomes are related to energy and environmental learning, create suitable storylines, and provide recommendations for the Science-Technology-Engineering-Mathematics approach with an Engineering Design Process (STEM-EDP) units that facilitate energy and environmental learning. The design-based research (DBR), was used as the research methodology, in which real-life energy and environmental problems become the central focus of coherence. Meaningful participation of two science education lecturers and four professional science teachers was involved throughout focus group discussions during the research process. From 14 main topics in science subjects, panelists agreed on six main topics that were then analyzed further to determine the order in which they should be taught, ensuring coherence and helping students grasp the broader picture of issues related to energy and the environment. We propose that the storylines covered four environmental challenges. In addition, four STEM-EDP Projects were designed and discussed with the panellists, namely forest ecosystem, river ecosystem, clean water, and clean energy challenges. The finding also suggests that STEM-EDP model could make the storyline logically and actively connected. The engineering elements through the content of real-life problems guide the application of science, mathematics, and technology.

Keywords: Energy, Environment, Junior High School, STEM-EDP, Storyline, Tropical Forest.

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Introduction

In the era of modern technology, information spreads rapidly. During this massive transformation, the young generation faces daily exposure to information [1], some of which are related to science and come from unclear sources [2]. This era is called the post-truth era [3], which refers to a time when objective facts are less influential than public opinion. In the past, we were only familiar with truth or false information, but now we also encounter statements that may be false, but are too early to be stated as false information [4]. For students, this situation is challenging to fully understand and to solve problems.

In this context, science education faces a crucial challenge to provide science lessons based on scientific evidence that can counter various forms of misinformation [5]. Science education that fosters scientific and environmental literacy is needed so that students can distinguish between correct, incorrect, and still-undetermined information. The presence of a significant amount of information, combined with time constraints and limited cognitive capacity to process it, can significantly hinder accurate decision-making [6]. To address this, situated cognition theory provides a robust framework for understanding and designing learning experiences that are deeply embedded in real-world contexts [7]. It emphasizes that knowledge is inherently tied to the context in which it is acquired, including social, cultural, and physical environments. Contextual science learning can help shape students' scientific literacy [8]. To be contextual, science content needs to be taught coherently so that students can connect the material they learn with real-world situations [9]. Therefore, coherent materials in science education are needed.

Although the science curriculum and learning outcomes are familiar to teachers and students, the tendency to design the science lesson based on each separate unit leads to fragmented understanding. A storyline is an instructional unit consisting of a coherent sequence of lessons, in which each step is driven by students' questions that arise from their interactions with phenomena or from attempts to solve a problem [10]. Instead of a teacher simply following a textbook chapter by chapter, a storyline unfolds based on the flow that moves from one lesson to the next. Science lessons are not isolated activities, but are logically connected for students [11]. Storylines in science units allow a coherent learning environment and help students make sense of phenomena and achieve learning goals [12]. A student’s sense of belonging in class and willingness to contribute may be mutually reinforcing, highlighting the need to promote content-specific strategies that support collaborative knowledge building [13].

On the other hand, there is a global consensus to pursue development that pays more attention to the sustainability issue. The increasing complexity of global challenges related to energy security, climate change, and environmental degradation has led to the adoption of 17 goals that are well-known as Sustainable Development Goals (SDGs) [14]. Among these goals, clean energy and a sustainable environment became the focus related to science education at the junior high school level. Junior high school, as a pivotal stage in cognitive development, is crucial for laying a foundational understanding of the intricate and interconnected concepts within Energy and Environmental learning. However, most junior high school students in Indonesia showed moderate perception that the SDGs especially goals energy and environment [15].

Within the Indonesian context, there is a popular conception that this country is blessed with abundant natural resources [16]. These resources are often perceived as central to the welfare of most of Indonesian society [17]. Such conceptions can lead to immeasurable real conditions that are far from scientific evidence. In terms of the current status of energy and the environment, Indonesia faces major challenges, such as balancing energy sources [18], deforestation and biodiversity [19], water quality [20], air quality [21] and many more challenges. In contrast to the conception of enormous natural resources, scientific evidence shows different facts that need to be considered as part of energy and environmental learning. Comprehensive narratives about energy and environment are important for influencing, engaging, and communicating with audiences [22]. Therefore, students need to understand the bigger picture of these issues.

Learning the concepts of energy and environment is part of the Indonesian science curriculum that is distributed across all grades in junior high school (grades VII, VIII, IX). Previous research in this area often focuses on specific Learning Objectives and then develops learning materials. For example, in Science-Technology-Engineering-Mathematics (STEM) projects with the theme of global warming [23], disaster mitigation [24], or energy concepts [25]. However, understanding energy and the environment requires not only conceptual understanding but also the development of environmental awareness [26]. Furthermore, the national curriculum allows teachers to develop their own learning objectives, making the sequence of chapters in science lessons non-standardized. Curricular integration is complex and requires more than simply bringing together different subject areas around a theme or real-world problem [27]. There has been little research developing a coherent learning storyline for energy and environmental issues within the context of the Indonesian curriculum. This need necessitates a clear storyline for energy and environmental learning.

On the other hand, integrating science learning outcomes with technology, engineering, and mathematics is argued to make science learning more comprehensive. Students often faced difficulties due to a lack of experience with technology-based experiments, limited access to technical resources, and teachers who still prioritize theory over practices [28]. The STEM approach is a way of teaching that facilitates a transdisciplinary approach, where knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus helping to shape the learning experience [29]. In this way, energy and environmental problems become engineering problems that can better facilitate the learning process.

This study argues that a coherent storyline, a vertically aligned, logical progression of content and complexity, is essential for meaningful learning, ensuring that students build upon prior knowledge rather than encountering fragmented, isolated topics. By mapping the distribution of related concepts, learning objectives, and competencies across junior high school grades, this study seeks to reveal how the curriculum integrates sustainability values and supports students' scientific literacy. Moreover, we argue that students should experience lessons as connecting together to help students form a coherent and developing story that comes in line with the learning objective that related to energy and environment [30]. We summarize the contextual problem [30,31], STEM unit framework [27], and environmental awareness [32]. The expected outcome is a structured framework that strengthens the connections between energy and environmental content, promotes systems thinking, and aligns with the principles of Education for Sustainable Development. Ultimately, this research contributes to improving curriculum coherence and supports teachers in designing meaningful science learning experiences that foster students' awareness, responsibility, and action toward sustainable living.

To provide a clearer structure of the research process, this study is guided by the following research questions:

RQ 1. Which science learning outcomes are related to energy and environmental learning?

RQ 2. What are the suitable storylines for energy and environmental learning?

RQ 3. What are the recommendations for STEM-EDP units that facilitate energy and environmental learning?

Materials and Methods

This study employed a Design-Based Research (DBR) approach to structure the research framework, emphasizing an iterative process to develop and refine educational interventions and generate theoretical insights [33]. This methodology could identify challenges in curriculum implementation or gaps in methodological competencies [34]. The framework followed six sequential stages, which are focus, understand, define, conceive, build, and test [35]. Each stage was explicitly aligned with the research questions (RQ), as indicated in the overall research procedure, as shown in Figure 1. The focus and understand stages addressed RQ1, involving analysis of Indonesian science curriculum documents and identification of science learning outcomes. The define, conceive, and build stages addressed RQ2, which included identifying energy and environmental learning outcomes, integrating contextual problems, STEM approaches, the EDP, and environmental awareness, as well as developing and elaborating proposed storylines for each challenge. Finally, the test stage addressed RQ3, which involved expert discussions to validate and refine the developed storylines.

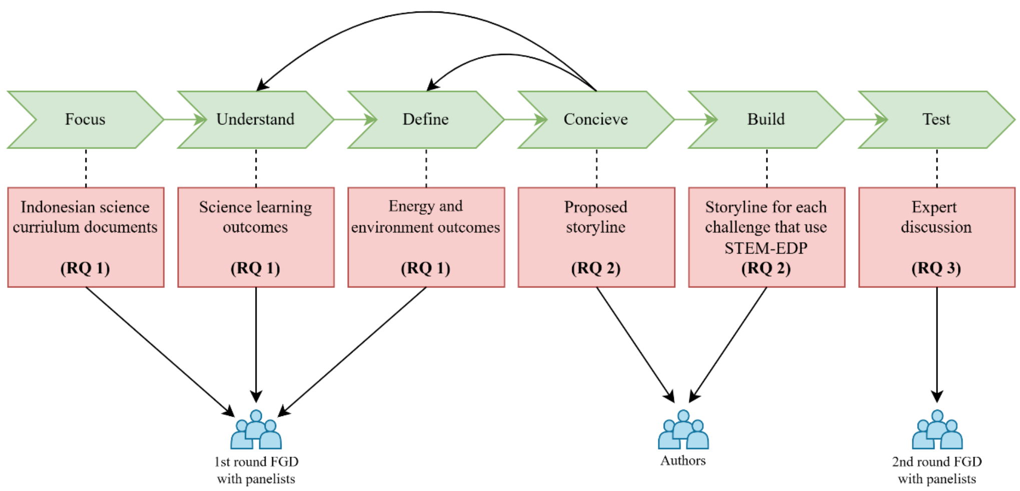

Figure 1 Design-based research framework.

The study applied qualitative content analysis to systematically interpret curriculum documents, condensing data into categories and themes based on valid inference [36]. This process integrated both researcher and practitioner perspectives. The findings were subsequently refined through focus group discussions to reach consensus.

The first step was the focus stage, in which we collected the Indonesian curriculum documents for junior high school that were published by the Indonesian government, as well as the science textbooks for junior high school. The second step was the understand stage, involving content analysis focused on science learning outcome (SLO), and examining which SLO were strongly related to energy and environmental learning. In the first round of FGD, we invited two senior lecturers from the science education department and four science teachers (Table 1) to reach expert and practitioner agreement by completing Table 2.

Table 1 Profiles of participating experts, including gender, years of experience, subject specialism, and professional roles.

Name Code	Gender	Years of Experience	Subject Specialism	Role
A	Female	19 years	Biology	Lecturer
B	Female	9 years	Physics	Lecturer
C	Male	17 years	Science	Teacher coordinator
D	Female	4 years	Science	Teacher
E	Male	3 years	Science	Teacher
F	Male	2 years	Science	Teacher

In the define stage, all SLOs from the national curriculum were evaluated by the experts to determine their relevance to energy and environment concepts. Each SLO was assessed using a five-point Likert scale ranging from strongly agree to strongly disagree. Percentage agreement was used as an initial measure of inter-rater reliability by calculating the proportion of instances in which the raters provided the same judgment [37]. The evaluation covered a broad range of SLOs, including those related to classifying living things, analyzing organ systems, understanding interactions between organisms and their environment, and examining physical and Earth science concepts. Fleiss' Kappa was applied to assess multi-rater reliability, which is a standard practice in recent educational research for validating thematic frameworks [38]. The Kappa coefficient can be interpreted as follows: values of 0 indicate no agreement; 0.01–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1.00, almost perfect agreement [39]. All discussions were recorded and analyzed to support the multi-rater results. These stages (focus, understand, and define) addressed RQ 1 by identifying relevant science learning outcomes related to energy and environment topics.

The conceive and build stages addressed RQ 2 by developing suitable storylines for energy and environmental learning based on the SLOs identified in the define stage. In the conceive stage, discussions among researchers were conducted based on a main question, “How can we develop logical storylines for energy and environment-related SLOs?”, while in the build stage guided by questions of “What are the synopses of the proposed storylines?” and “What are the specific learning objectives for each challenge?”. Researchers gave their opinions on the guiding questions. Discussions were conducted to reach agreement on the proposed storylines.

To address RQ 3, in the test stage, the overall storyline and four recommendations for STEM-EDP units were discussed with all experts and professional teachers in the second round of focus group discussions. This stage aimed to gather comments and suggestions and to reach consensus on the developed general storyline and the storylines for each challenge. All written and oral feedback from the panelists was recorded and analyzed to refine the proposed storylines.

Results and Discussion

Result

Science Learning Outcome and Its Relation to Energy and Environment

The Indonesian curriculum divides K–12 education into six phases, from Phase A to Phase F. The junior high school level is classified as Phase D. Integrated science learning outcomes at this phase encompass biology, physics, and a smaller portion of chemistry. This integration differs from thematic learning. Phase D spans three years of junior high school and offers considerable flexibility. From the six raters, the science learning outcomes, keywords, and percentage agreements as inter-rater reliability coefficients are presented in Table 2. Among these, the second and third SLOs show the most explicit connection to energy and environmental learning. The second SLO, which integrates concepts of ecological interaction, pollution, and climate change, achieved the highest inter-rater reliability (100%), indicating a strong consensus among raters that this outcome directly supports environmental understanding and action-oriented learning related to sustainability [40,41]. Meanwhile, the SLO involving work, energy, and heat (67%) also reflects a substantial link to energy literacy [42], as it addresses fundamental physics concepts underlying energy transformation and conservation.

Table 2 Inter-rater reliability percentages.

SLO	Content Keywords	Learning level	Inter-rater reliability	Interpretation
Identify the organizational systems of life and conduct analyses to discover the relationship between organ systems and their functions, as well as abnormalities that arise in specific organ systems (digestive, circulatory, respiratory, and reproductive systems)	Relationship between organ systems and their functions (respiratory system)	Identify (C2)	0.33	Fair
Identifying interaction between living things and their environment, and being able to design efforts to prevent and address pollution and climate change	Interaction between living things and their environment; pollution and climate change	Identify (C2) Design (C6)	1.00	Perfect agreement
Measure physical aspects, types of motion and force, understand the relationship between the concepts of work and energy, measure the temperature resulting from heat energy provided, and differentiate insulators and conductors	Work; energy; heat	Measure (C3) Differentiate (C2)	0.67	Substantial
Understand the structure of the Earth to explain natural phenomena that occur in disaster mitigation issues	Disaster mitigation	Understand (C2)	0.33	Fair

The varied levels of agreement among raters for different SLOs imply inconsistencies in how they applied each outcome to the specific context of the energy and environment relationship. For instance, SLOs concerning organ systems or Earth's structure were considered less directly related (33%) because their connections to energy or environmental issues are more implicit or contextual rather than explicit within the learning statements. These differences likely arise from each rater's disciplinary background, whether in biology, physics, or earth science, and from their perspective on how broadly "energy and environment" should be operationalized within integrated science learning. This indicates that while Indonesia's Phase D curriculum promotes an integrated approach, the thematic boundaries across science domains still influence how learning outcomes are perceived in relation to sustainability-oriented content [43].

Based on the learning outcomes in the junior high school science curriculum, there are 14 main topics in science subjects. Table 3 presents the results of the identification of science topics in Phase D that are related to energy or environmental issues. Table 3 shows that six of the fourteen main science topics are related to 'Energy' and 'Environment'. These six main topics were then analyzed further to determine the order in which they should be taught, ensuring coherence and helping students grasp the broader picture of issues related to energy and the environment.

Table 3 Key topics and their relevance to energy and environmental concepts.

No	Topic	Relation to	
		Energy	Environment
1	Identifying living things according to their characteristics		✓
2	Classification, properties, and changes of matter		
3	Life organization systems, functions, as well as abnormalities that arise on organ systems		
4	Interactions between living things and their environment in designing efforts to prevent and address climate change		✓
5	Heredity		
6	Biotechnology in the surrounding conventional environment		
7	Measurement of physical aspects in everyday life		
8	Variety of movements, force, and pressure		
9	Work and energy	✓	
10	Heat and its transfer on temperature changes	✓	
11	Waves and its uses in everyday life		
12	Magnetism and electricity can be used to solve challenges faced in everyday life, including the use of environmentally friendly electrical energy sources.	✓	
13	The relative position of the Earth-Moon-Sun in the solar system to explain natural phenomena and climate change		
14	Additives and addictive substances and make the right decisions to avoid		

Proposed Storylines of Energy and Environment Learning

From the results in Table 2 and Table 3, we proposed storylines of energy and environmental learning that are illustrated in Figure 2 and Table 4. Based on four science learning outcomes and the main challenges of the tropical environment, four STEM-EDP projects were developed. Three main challenges were agreed upon in the storylines: ecosystem, water, and energy, where the ecosystem challenge was divided into two sub-challenges, forest and river challenges.

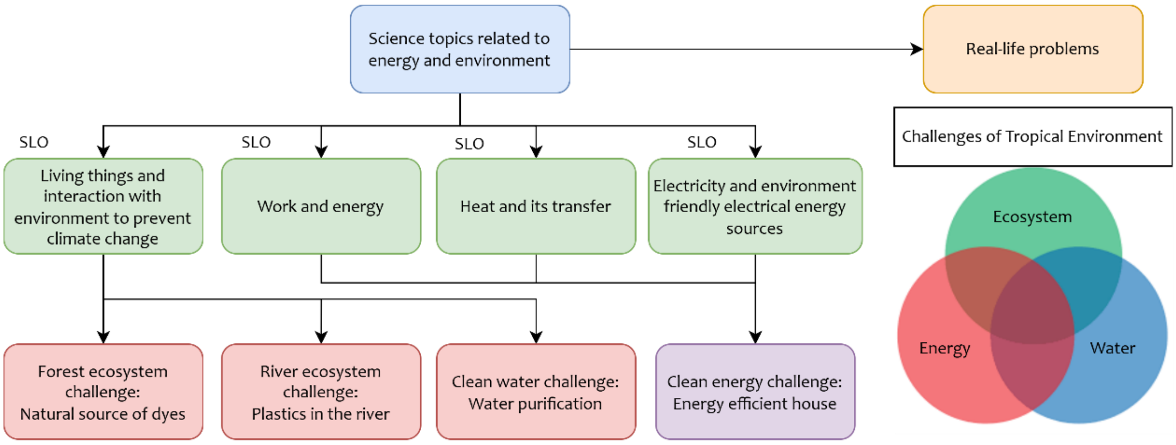

Figure 2 Storylines for energy and environmental learning linked to tropical environmental challenges.

Table 4 The Unit and Synopsis of Storyline.

Unit	Synopsis of Storyline
Forest ecosystem challenge	In this first unit, students begin an investigation into the phenomenon of "Ghost Forests" in Kalimantan. The Kalimantan Forest storyline utilizes real-time geospatial data on deforestation spike over the last ten years to ground students' learning in socio-scientific issues (SSI). Tropical forests are like giant libraries. Deforestation results not only in the loss of plants but also in the destruction of thousands of genetic resources that we have not yet had the chance to explore. Competing ideas for why the area of rainforest is significantly decreasing will motivate students to investigate a variety of additional data sources. This exploration raises further questions and more potential suspects to investigate. As part of their engineering activity, students explore the ethnobotanical potential of Kalimantan's forests. They discovered that forest loss not only threatens oxygen but also eliminates the "natural dye factory" that the Dayak people (indigenous tribe of Kalimantan) have used for centuries to weave their cultural identity. This activity connects plant biochemistry with cultural preservation and the creative economy.

Table 4 The Unit and Synopsis of Storyline. *(cont.)*

Unit	Synopsis of Storyline
River ecosystem challenge	After investigating the causes of forest cover loss in Kalimantan, students trace the impacts of that destruction downstream. Through this unit, students will analyze how soil eroded from damaged forests changes river water chemistry, destroys endemic fish habitats, and how natural dyeing practices can become an economic model that saves our waterways. If the forest upstream disappears, why do the fish downstream die too? Students learned that synthetic clothing dye waste is often dumped into rivers. Natural dyes from forests are much kinder to river ecosystems because they are biodegradable. Protecting forests is not just about trees; it is about protecting raw materials for creative industries that don't poison our rivers.
Clean water challenge	This unit is the culmination of the students' ecosystem journey. If nature has lost its 'natural filters' (forests and wetlands), can we design simple technologies to replace them? After understanding the impact of deforestation on river sedimentation, students are challenged to design a simple system to measure turbidity and a water filtration device based on natural materials. This project not only tests their engineering skills, but also scientifically proves why using natural materials, such as forest dyes, is far more supportive of river ecosystem health than synthetic materials that are difficult for nature to break down or for simple filters to remove.
Clean energy challenge	Students realize that one of the main causes of deforestation in Kalimantan is land clearing for coal mining (Fossil Energy). Mining destroys forests (Unit 1), causes erosion in rivers (Unit 2), and requires complex water filters (Unit 3). If we could get energy without digging up the ground and cutting down trees, could we save forests and rivers at the same time? This unit is the final chapter connecting economics, technology, and ecology. After witnessing the fragility of forests and rivers due to extractive activities, students take on the role of Green Energy Engineers. They design renewable energy solutions that are friendly to the local ecosystem. This project proves that the advancement of civilization does not have to sacrifice biodiversity but can go hand in hand with maintaining the purity of river water and the integrity of Kalimantan's tropical forests.

Table 5 presents the alignment between the science learning outcomes and four major environmental challenges, which are forest ecosystems, river ecosystems, clean water, and clean energy, along with the corresponding learning objectives and suggested duration for each project. Each project includes a sequence of skills such as conceptual understanding, investigation, design, construction, testing, and evaluation, reflecting the structure of the EDP.

Table 5 Alignment of science learning outcomes with environmental challenges, specific learning objectives, and recommended instructional hours for each STEM−EDP project.

Science Learning Outcome	Challenge	Learning Objectives	Hours
Living things and interaction with environmental to prevent climate change	Forest Ecosystem	1. Students are able to explain the structure and function of forest ecosystems. 2. Students are able to design and construct a model representing a forest ecosystem. 3. Students are able to assess natural dye sources for sustainability. 4. Students are able to develop an energy-saving method for fabric dyeing using natural materials. 5. Students are able to evaluate whether their design meets predetermined criteria and constraints.	10
	River Ecosystem	1. Students are able to observe and describe the structure and components of the river ecosystem. 2. Students are able to explain patterns of interaction among living organisms and analyze the environmental impacts of human activities on the river. 3. Students are able to explain the characteristics of plastic materials and evaluate their environmental impacts, including pollution caused by microplastics. 4. Students are able to design and construct a functional prototype that reuses plastic waste into a useful object. 5. Students are able to test, measure, and evaluate the strength, weight, and functionality of their prototype using appropriate scientific and mathematical methods. 6. Students are able to evaluate the effectiveness of their design in meeting predetermined criteria and analyze the potential environmental benefits of reducing plastic waste.	10

Table 5 Alignment of science learning outcomes with environmental challenges, specific learning objectives, and recommended instructional hours for each STEM–EDP project. *(cont.)*

Science Learning Outcome	Challenge	Learning Objectives	Hours
Living things and interaction with environmental to prevent climate change	Clean Water	1. Students are able to explain the water cycle and its role in providing clean water. 2. Students are able to identify various water sources and classify water as clean, dirty, or polluted based on observable characteristics. 3. Students are able to explain the concept of water turbidity and demonstrate how it is measured. 4. Students are able to design and build a simple turbidity measurement system using the principles of light. 5. Students are able to design and construct a water filtration system to purify dirty water. 6. Students are able to evaluate the effectiveness of their water filtration design using measurable criteria.	10
Work and Energy	Clean Energy	1. Students are able to distinguish between renewable and non-renewable energy sources and explain their roles in daily life. 2. Students are able to explain the process of coal formation, coal mining, and its impact on the environment. 3. Students are able to explain energy transformation, conservation, heat transfer, and material properties (conductors/insulators) in energy systems. 4. Students are able to design a model of an energy-efficient house using STEM principles and relevant material selections. 5. Students are able to test and evaluate the performance of their energy-efficient house model. 6. Students are able to improve their design based on testing results and criteria.	12
Total			42

Recommendations for the STEM-EDP unit that facilitate energy and environmental learning

To clarify general storylines in Figure 2 and Table 2, we developed a storyline for each individual STEM-EDP project. The storyline includes the main concept(s) addressed within each lesson, arranged chronologically, and connected by arrows that represent the strength of the connections among the concepts and the main learning goal [27]. It should show how learners build sophisticated ideas from prior ideas, using evidence that builds to the understanding described in the performance expectation, as students engage in the practices to explain phenomena [44]. Each storyline is bound with one main engineering problem that became the central context for the project. In the forest ecosystem challenge, students will be introduced to modern life around the forest and the challenges surrounding it. For the integrated STEM-EDP project, performance expectation was associated with developing solutions for a real-world problem that lay at the center of the graph. The central problem is how to design the naturally dyed fabrics (Figure 3). Eco-friendly dyed fabrics are a crucial issue from the ancestral era that is relevant until now [45]. A tropical environment closely related to society that lives around the riverbank area, as the main source of fresh water. In Figure 4, the performance expectation is to design plastic waste into useful objects. The following excerpt from the client letter provides more details about the challenge. We utilize the syntax of EDP that bounds environmental challenges as a central problem, learning the subtopic, planning, trying, testing, and deciding if the design meets the criteria.

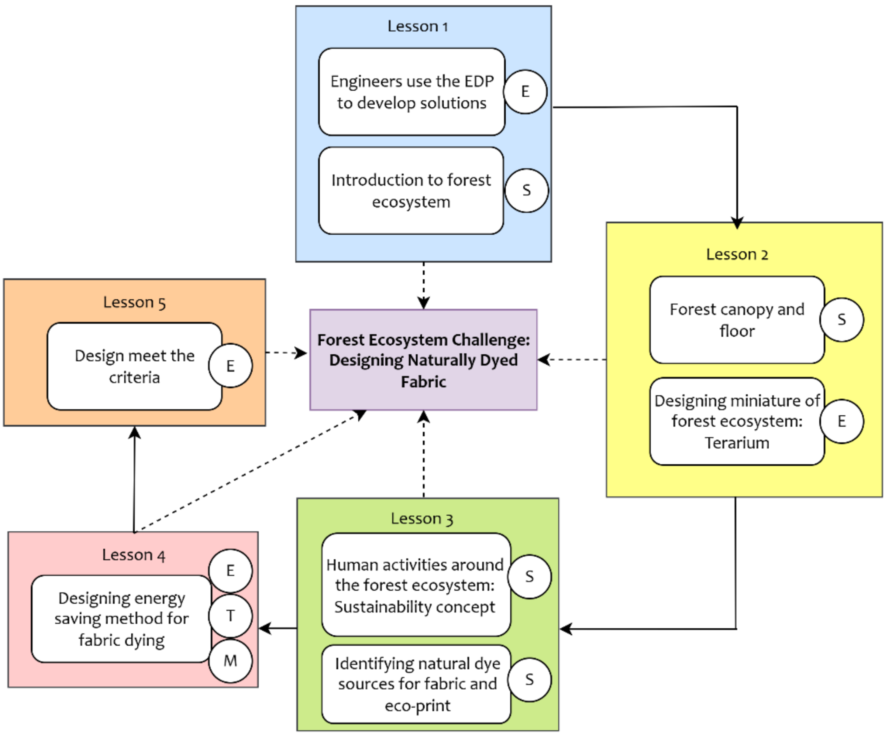

Figure 3 Storyline of forest ecosystem challenge.

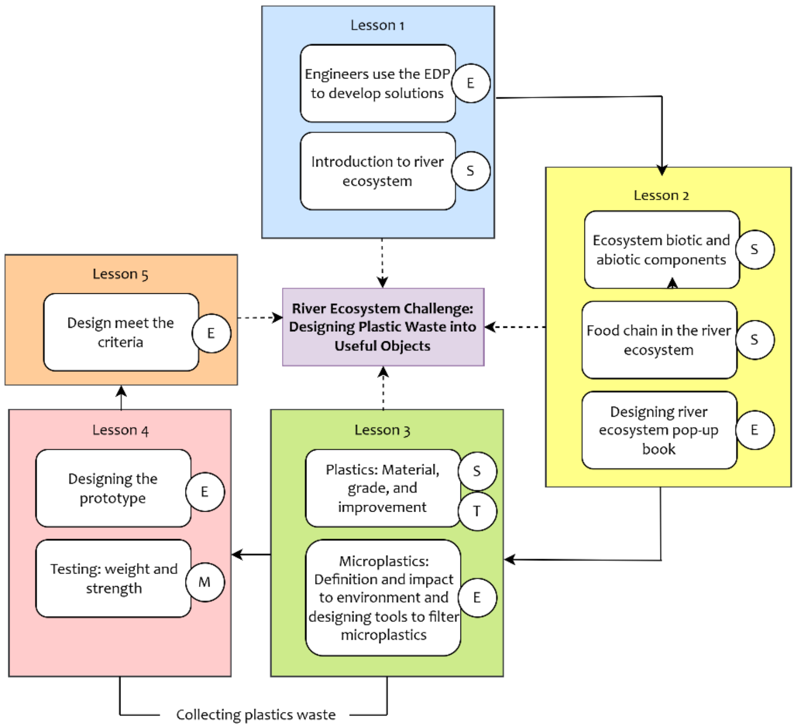

Figure 4 Storyline of the river ecosystem challenge.

With the foundation of understanding about the ecosystem established in the two previous challenges, the water problem became central in Figure 5 and the energy problem in Figure 6. The central theme, "Clean Water Challenge," is framed by five distinct lessons arranged chronologically around it. Lesson 1 introduces foundational concepts by stating that Engineers use the EDP to develop solutions (E) and provides an Introduction to the water cycle (S). This flows into Lesson 2, which is mostly science-focused (S), involving identifying water sources around and identifying the characteristics of clean, dirty, and polluted water. Subsequently, Lesson 3 integrates both disciplines, first covering the scientific concept of water turbidity and its measurement (S), followed by the engineering task of designing a water turbidity measurement system using the light principles (E). This preparatory work culminates in Lesson 4, the main design and application stage, which includes Engineering (E), Technology (T), and Mathematics (M) as students focus on designing water filtration for dirty water purification. Finally, the progression concludes with Lesson 5, which is the critical task of evaluating whether the design meets the criteria. The same chronological also for Figure 7, with a central theme about energy. Overall, the proposed storyline is expected to clearly map a pedagogical approach that scaffolds students' learning from core scientific principles to a complex, multi-disciplinary engineering design challenge.

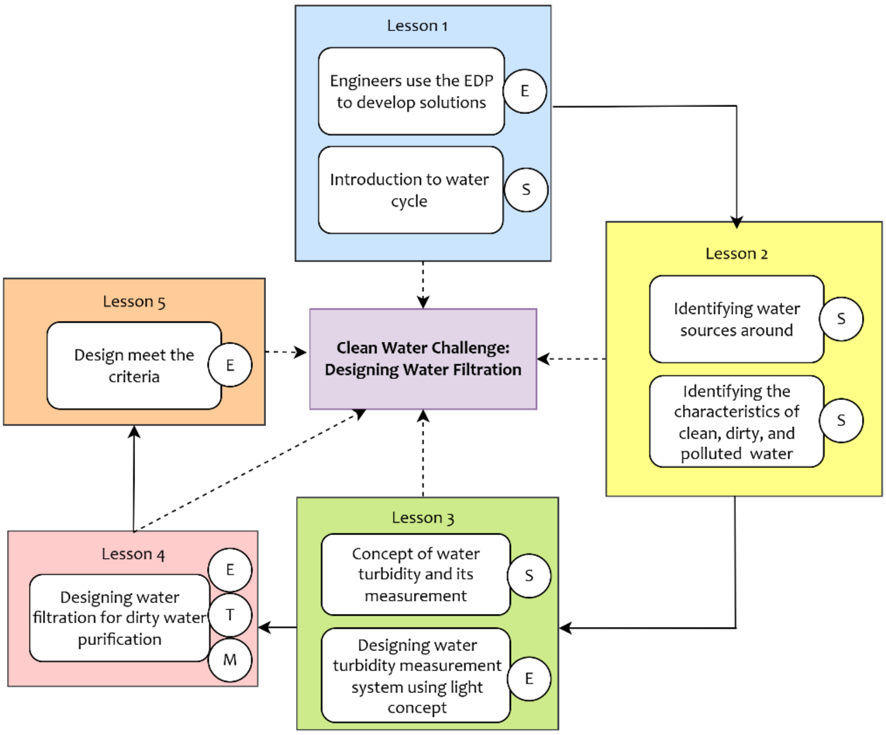

Figure 5 Storyline of the clean water challenge.

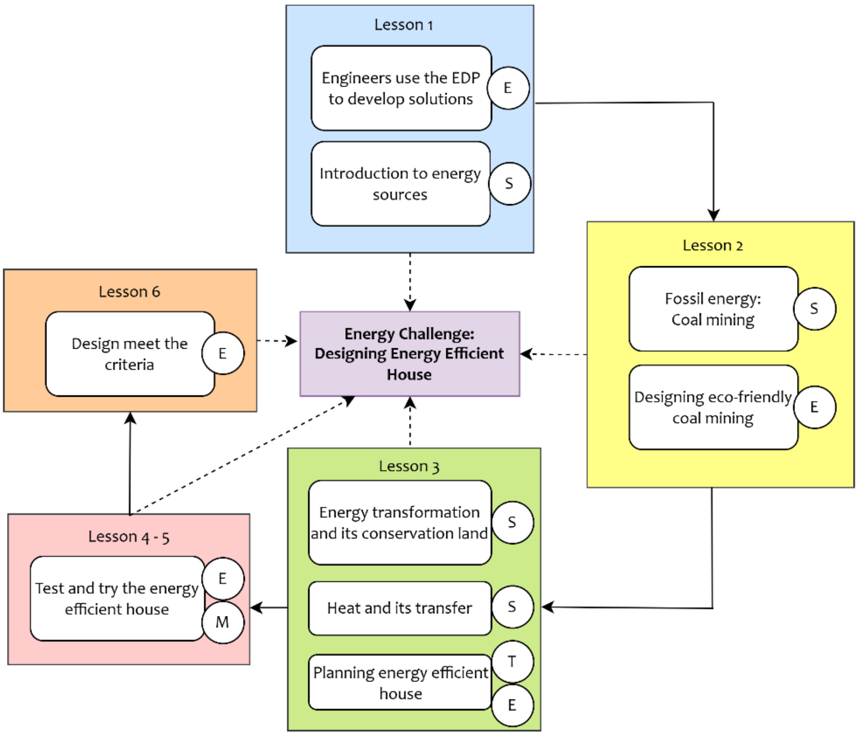

Figure 6 Storyline of the clean energy challenge.

Discussion

In this section, under the umbrella of situated cognitive theory, we discuss science learning outcomes that related to energy and environment, a suitable storyline, and the STEM-EDP unit. We close the discussion with some limitations and further possible implementation.

Supporting a coherent storyline through energy and environmental challenges

In the light of situated cognitive theory, the storyline serves as an authentic context that bridges conceptual knowledge with engineering challenges. Environmental challenges need clear learning storylines to support knowledge, and also awareness of the environment [46]. The challenges and putting pieces together are intended to make the path to science ideas clearer for students, rather than privileging students who may have already encountered canonical science ideas [10]. The focus is on developing understanding and designing prototypes of solutions to energy and environmental problems. The process goes beyond synthesizing the best explanation but also building a chain of STEM units and how they rule out other ideas.

Our studies of lecturers and teachers' enactment of storylines suggest promise in this approach. From the focus group discussion, science teachers reveal that "I rarely collect science learning outcome that related to energy and environment". From the perspective of a biology education lecturer, the topic of energy, strongly related to the flow of energy within an ecosystem, is a one-way process from the sun to living organisms and back to the environment in the form of heat. Moreover, from a physics education lecturer, energy is closely related to the form of energy and the law of conservation of energy. Creating meaningful storylines requires balancing coherence with flexibility, ensuring diverse perspectives and inputs [47]. Therefore, active participation among the experts and practitioners is valuable to bring balance to energy and environmental topics.

After the learning outcomes are agreed by the panelists, the discussion focuses on how to propose storylines that provide students with opportunities to engage with multi-faceted challenges, ecological concerns, and solutions to local problems, with the goal that these experiences will lead to improved sustainability and environmental decision-making. This storyline focused on an environmental phenomenon that can be attributed to human activities [48]. As a planned sequence, and with pressures of accountability, there are potential challenges in inviting students to participate in setting the direction for what the class will investigate (Figure 2). Understanding tropical ecosystems became the central starting point for students. In biodiverse-rich tropical ecosystems, we must build strong conceptual frameworks and pay greater attention to both ecological and human communities [49]. The involvement of the local community is also a critical aspect for the success of forest restoration [50]. Therefore, the first project focuses on the forest ecosystem challenge, followed by the river ecosystem challenge. As essential aspects of daily life, water and energy challenges also need to be properly introduced to students.

Within each challenge, we utilize the syntax of EDP that bounds environmental challenges as a central problem, learning the subtopic, planning, trying, testing, and deciding whether the criteria are met or not. EDP enhances cognitive abilities, procedural skills, and attitudinal growth in students [47].

It fosters creativity [51], problem-solving [52], and critical thinking [53], which are essential for tackling real-world challenges that, in this case, are challenges in tropical forests and energy. The EDP model supports the problem as a central issue that binds science, technology, and mathematics into comprehensive elements [54,55].

This study proposes a minimum time requirement of 42 hours for comprehensive storyline implementation. With conventional teaching techniques, 42 hours could generally cover more science content than using a storyline approach, as reflected in a teacher's comment that "using traditional methods, we can cover more topics within the same time." However, storylines are expected to provide more meaningful, in-depth, and contextual learning for students [47], enabling students not only to gain knowledge but also to develop better environmental awareness and become environmental problem-solvers in their daily lives, which is consistent with one of teacher's comment that "the storylines will increased awareness of real-world environmental issues and engage more actively in proposing solutions." Although all storylines recommend to be delivered sequentially, each STEM-EDP challenge could be taught as single unit.

Limitation and Future Possible Implementation

This research is limited to the initial development process through a DBR framework without student trial. During discussions, many storyline ideas emerged from the panelists. However, this research is based on the framework of science learning outcomes in a formal education setting in Indonesia that is strictly limited by learning hours. These challenges arise from design tensions between the coherence of contextualization and the need to address a collection of science standards and specific learning performances [56]. Moreover, exploration in other tropical countries would also be valuable in future studies. The four challenges and their sequence represent a consensus that considers the logic, context, and feasibility of implementation at the junior high school level.

Conclusions

Through our DBR process, five potential science learning outcomes were found to be strongly related to energy and environmental learning. Four engineering challenges were designed, namely the forest ecosystem challenge, river ecosystem challenge, clean water challenge, and clean energy challenge. Although the storylines were designed systematically from the general concept to a more specific project, the limitation of learning hours at junior high school represents a central challenge. This work highlights the importance of the practitioner and researcher collaboration to build coherent storylines in energy and environmental learning to facilitate comprehensive conceptual understanding and awareness.

Although this study reveals an energy and environmental storyline and the details of each challenge, further research is needed. The development of learning materials that implement each challenge is needed, with small- and large-scale trials with students. Moreover, energy and environmental learning requires support from the informal sector to support more holistic awareness. Exploring support from informal sectors such as family settings, science museums, outdoor learning facilities, etc., will be valuable to support the limitation of learning hours at formal settings.

Acknowledgements

This research was supported by the Ministry of Research, Technology, and Higher Education through the 2025 research grant (No. 562/UN17.L1/HK/2025). The authors gratefully acknowledge this funding, which made the completion of this study possible. We are also thankful to all experts and practitioners who support their valuable experience in this research.

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