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Socio-scientific Issue around the Mahakam River: A STEM Activity Supported with Animated Video Development

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ABSTRACT

This research aims to develop a STEM–Engineering Design Process (STEM–EDP) student worksheet integrated with animated learning videos contextualized through socio-scientific issues (SSI) related to the Mahakam River ecosystem. The development was motivated by the lack of learning materials in junior high school science that meaningfully connect scientific concepts with local environmental problems while promoting higher order thinking and authentic STEM practices. This study employed a Research and Development design using the ADDIE model, limited to Analysis, Design, and Development stages. Four experts in content, media, and instructional design, together with a professional science teacher, participated in validating the product, while 86 Grade VII junior high school students from two schools in East Kalimantan were involved in assessing its practicality. Data was collected through expert validation sheets and student response questionnaires using a four-point Likert scale, and scores were analyzed by converting them into percentages to determine validity and practicality categories. The expert validation results showed an average score of 93%, indicating a very good level of feasibility, with animated videos receiving the highest score of 96%. Student responses also demonstrated strong acceptance, with an average score of 83.96% categorized as very good, reflecting high levels of clarity, engagement, and relevance. These findings indicate that integrating SSI, STEM–EDP frameworks, and animated media strengthens students' conceptual understanding and supports meaningful learning experiences. Overall, the developed learning materials are theoretically valid and practically feasible, offering a pedagogical innovation that bridges scientific content, environmental context, and engineering-based problem solving for junior high school science education.

A. INTRODUCTION

Innovations in science education should be understood as a new implementation of new objectives, education content, methods, and form; a common work of teachers and learners (Kondrashev et al., 2024). In the National Curriculum, the need for instructional innovation has become increasingly prominent, as science learning is directed toward achieving Learning Outcomes and Learning Objectives that emphasize the connection between scientific concepts, students' local environments, and the development of character and twenty-first-century competencies. By embedding climate science into the curriculum, educators can link classroom instruction to students' lived experiences while fostering a sense of agency and responsibility toward their communities and the planet

(Olateju & Frempong, 2022). This effort aligns with the orientation of contemporary science education, which highlights the importance of integrating scientific ideas with students' environmental realities to cultivate relevant scientific literacy and informed decision-making (Sari et al., 2025).

In East Kalimantan, the Mahakam River serves as a vital source of livelihood, knowledge, and local strategies for daily living (Putra et al., 2023), offering strong potential to contextualize science learning through real-world issues along its banks (Easton & Alice, 2025). Using a STEM approach, worksheets can guide students to identify, analyze, and solve environmental and social problems related to the river, thereby enhancing conceptual understanding, critical thinking, creativity, and problem-solving skills while fostering locally relevant innovations (Kelley & Knowles, 2016; Simeon et al., 2022). Integrated STEM learning emphasizes real-world problems, engineering design, contextual and content integration, engagement in STEM practices, development of twenty-first-century skills, and exposure to STEM careers (Roehrig et al., 2021). Studies also show that STEM-based worksheets improve students' understanding of environmental interrelationships through activities such as modeling, tool design, and ecological analysis (Lafifa et al., 2023).

Socio-scientific issues (SSI) are controversial topics grounded in scientific and social dimensions (Cayci, 2020). The primary aim of SSI-based education is to provide a meaningful context in which students can understand scientific information through engagement with relevant societal issues (Mang et al., 2021). SSI approaches hold significant potential for science learning, particularly in addressing complex environmental challenges such as those occurring in the Mahakam River ecosystem (Sadler et al., 2016). Issues such as declining water quality and threats to local species offer concrete examples that allow students to explore scientific content while examining its broader social implications (Badeo & Duque, 2022).

The Engineering Design Process (EDP) is central to STEM learning, involving stages such as identifying problems, designing solutions, building prototypes, testing, evaluating, and improving designs (Asimakopoulos et al., 2024). According to Nguyện et al. (2025), integrating EDP into STEM instruction provides a practical framework for students to apply scientific and technological knowledge in real-world contexts, thereby enhancing problem-solving abilities and interdisciplinary understanding. Within ecosystem learning, this framework can guide students to design environmentally oriented solutions, such as creating simple models or formulating mitigation strategies for ecological issues.

Animated videos play an important role in helping students visualize otherwise unobservable phenomena, strengthen concept retention, and enhance learning motivation (Jones et al., 2018). The integration of technology, particularly animated videos, has been shown to increase engagement and deepen students' understanding of scientific concepts. When applied within SSI contexts, animated videos help make complex issues more accessible, while their replayable nature enables students to review information as needed (Jayanti et al., 2024).

Previous studies have examined these domains separately. Integrating the Engineering Design Process (EDP) within STEM enhances students' problem-solving and design skills (Erlita & Sari, 2025), while the SSI approach effectively connects scientific concepts with environmental issues, though often without specific local context (Kirana et al., 2022). Animated videos have also been shown to support the understanding of abstract concepts among middle school students (Rosdiana & Ulya, 2021). However, most STEM-SSI developments remain generic and rarely integrate local environmental issues, and no study has fully combined STEM–EDP, SSI, and animated videos within a single worksheet.

In practice, many junior high school worksheets still emphasize low-level cognitive tasks and lack connections to local environmental contexts (Setiawati et al., 2023). This gap results in less meaningful ecosystem learning, particularly in relation to the Mahakam River. To address this, the present study develops a STEM–EDP-based worksheet integrated with animated videos featuring local environmental issues. Its novelty lies in combining local context, STEM–EDP, and animated media into a single instructional tool. Accordingly, this study aims to develop the media and evaluate its validity through expert appraisal and its practicality through student responses.

B. METHODS

1. Research Design

This study employed Research and Development (R&D) design. The development model used was ADDIE, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model is widely recognized in the instructional design field as a systematic guide for producing effective and efficient learning materials, including modules, worksheets, and textbooks (Hess & Greer, 2016; Luo et al., 2024). However, due to time constraints, this research was limited to the Analysis, Design, and Development phase, focusing on product validation and student responses.

2. Research Subjects

The subjects of this study consisted of three (4) experts: a material expert, a media expert, a learning design expert, and a professional science teacher. In addition, a total of 86 Grade VII students participated in the response test. These students came from two different schools: 53 students from a junior high school in Samarinda City and 29 students from a junior high school in Muara Jawa District, East Kalimantan. The selection of two different schools was intended to capture diverse student responses and ensure that the developed media was contextually relevant to different learning environments.

3. Development Procedures

This study followed three stages of the ADDIE model—Analysis, Design, and Development (Spatioti et al., 2022). The Analysis stage included needs, curriculum, and student analyses, revealing the need for contextual learning media that connect science concepts with local environmental issues, particularly the Mahakam River. Findings also showed that learning remained lecture-based and students had low interest in local topics, forming the basis for developing a more engaging product.

In the Design stage, a comprehensive plan was developed, including lesson plans, student worksheets, supporting materials, and an animated video on the Mahakam River ecosystem. STEM-based activities were systematically integrated into the worksheets to support problem-solving and inquiry. Validation instruments and student response questionnaires were also prepared to assess the product.

In the Development stage, the design was transformed into a complete learning product consisting of lesson plans, materials, activities, and animated videos. The product was evaluated through expert validation and student acceptability testing to ensure feasibility and usability. Expert validation assessed content, presentation, design, language, and STEM alignment, while student responses measured clarity, engagement, and practicality.

4. Data Analysis Techniques

Analysis of Learning Material Validity

Validity analysis was conducted to determine the feasibility of the learning materials prior to implementation. Content validity through expert judgment is essential in development research to ensure alignment between the product's content, structure, and instructional objectives (Fernández-Gómez et al., 2020). Validators were provided with the initial teaching module draft, animated video links, and validation sheets for assessment.

The evaluation criteria were defined according to each validator's expertise. The subject matter expert assessed content feasibility, format, relevance, and language, while the media expert evaluated the accuracy of content representation and visual quality of the animated videos. The instructional design expert focused on pedagogical aspects, including content feasibility, language, presentation, graphics, and integration of STEM–EDP steps.

The teaching module was evaluated based on content validation (rationale, objective achievement, and material depth) and construct validation (visual design, language, and integration of STEM–EDP). Qualitative feedback from experts was systematically analyzed and used to revise the product until it met feasibility standards. All evaluations used a four-point Likert scale , as shown in Table 1, and the total scores were converted into a validity percentage using Equation (1).

Table 1. Scoring Criteria for Learning Material Validity

Score	Criteria
1	Poor
2	Fair
3	Good
4	Very Good

$$\%Validity = \frac{Total\ Score}{Maximum\ Score} \times 100\% \quad (1)$$

Analysis of Student Response

Student response analysis was conducted to assess the level of acceptance, usability, and students' perceptions of the learning materials as part of formative evaluation (Mertasari & Candiasa, 2022). The instrument measured five indicators: visual appearance, material content, material presentation, language, and STEM integration, covering both design quality and instructional clarity. Visual aspects evaluated layout attractiveness and clarity, material content assessed students' understanding of Mahakam River socio-scientific issues, presentation examined the logical flow of activities, language ensured readability appropriate for seventh-grade level, and STEM integration measured students' ease in following the STEM–EDP instructions. Responses were collected using a four-point Likert scale, as shown in Table 2, and converted into percentages using Equation (2) to determine the overall practicality of the product.

Table 2. Scoring Criteria for Student Responses

Score	Criteria
1	Strongly Disagree
2	Disagree
3	Agree
4	Strongly Agree

$$\%Student\ Response = \frac{Total\ Score}{Maximum\ Score} \times 100\% \quad (2)$$

The resulting validity and response percentages were then classified based on the criteria presented in Table 3, which includes categories ranging from Very Poor to Very Good. These categories align with commonly used approaches in instructional material development research.

Table 3. Classification Category of Student Responses

Score (%)	Category
0 - 20	Very Poor
21 - 40	Poor
41 - 60	Fair
61 - 80	Good
81 – 100	Very Good

C. RESULT AND DISCUSSION

1. Results of the STEM–EDP Worksheet: River Ecosystem and Learning Video

The STEM–EDP worksheet on river ecosystems was developed based on the Engineering Design Process (EDP) cycle, consisting of Define, Learn, Plan, Try, Test, and Decide stages. This structure guides students to identify environmental problems in the Mahakam River, design and test solutions, and evaluate them using engineering principles. Through this process, learning becomes more systematic, inquiry-based, and solution-oriented.

The worksheet integrates the seven key characteristics of the STEM-integrated framework (Roehrig et al., 2021), including a real-world problem focus, integration of local context, interdisciplinary content, engagement in STEM practices, development of twenty-first-century skills, an emphasis on engineering design, and exposure to STEM careers. These components are organized into a conceptual structure that aligns STEM principles with EDP stages to support meaningful and contextual learning.

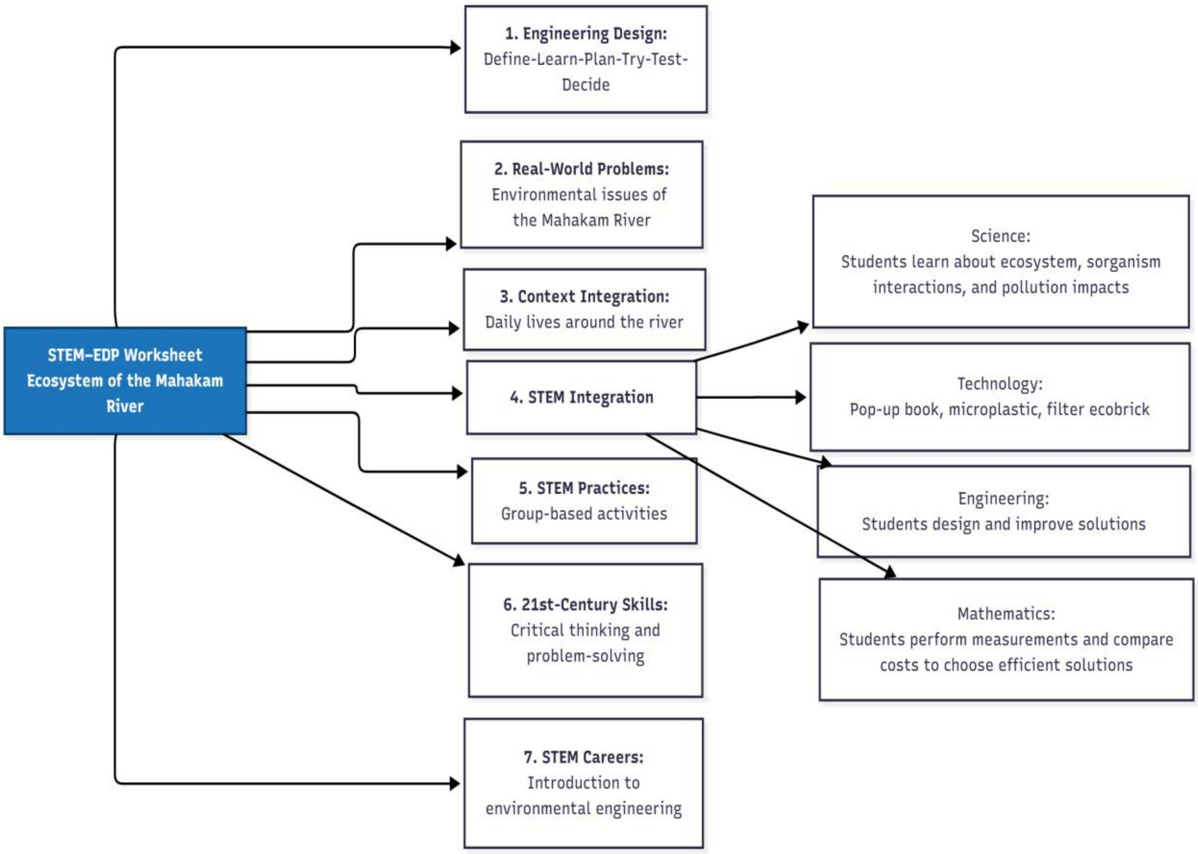

Figure 1. Seven characteristics of the STEM-EDP worksheet

Following the conceptual structure, Figure 2 presents the visual design of the developed STEM-based worksheet. The cover page (a) introduces the Mahakam River ecosystem through its title and thematic illustration, while section (b), *Introducing the Mahakam River*, provides initial context and background. Section (c) focuses on microplastics, linking river pollution issues with scientific explanations and STEM-based activities, whereas section (d) presents the Eco Bricks worksheet, guiding students to apply recycling practices through problem-based learning. Overall, these components demonstrate how the worksheet integrates environmental themes with STEM approaches to support meaningful and contextual learning.

(a) (b) (c) (d)

Figure 2. Visual design of the STEM-based worksheet: (a) cover page, (b) Worksheet of Introducing the Mahakam River, (c) Worksheet of Microplastic: Pollution of the Mahakam River, (d) Worksheet of Ecobrick: Recycling Plastic Waste.

Figure 3 presents the instructional video outputs, including the introduction, guiding animated character, and conceptual animations that clarify the material. The video, *"Suara dari Borneo,"* combines real footage of the Mahakam River with animations to represent environmental issues comprehensively. Real recordings show actual conditions, such as water quality and waste, while animations illustrate abstract concepts like microplastics and ecosystem interactions to support students' understanding.

(a) (b) (c)

Figure 3. Visual results of the instructional video: (a) Intro frame of the learning video, (b) Animated character display, (c) Animation of conceptual explanation.

Each worksheet sub-section is supported by a dedicated instructional video, with three videos aligned to the main learning activities: introducing the ecological and social context of the Mahakam River, explaining pollution and microplastics, and guiding students through the EDP to develop solutions. This alignment creates a coherent, multimodal, and accessible learning experience that helps students visualize complex concepts, maintain engagement, and connect abstract ideas with real-world issues. By combining authentic footage and animation, the integration strengthens conceptual understanding and supports active learning throughout the STEM–EDP process.

2. Validation Results of the Learning Materials

The learning materials were evaluated by four science education experts using a four-point Likert validation sheet (Table 4).. All components scored above 91% and were categorized as "very good," including the teaching module (92.50%), learning tools (91.25%), content material (91.75%), and animated video (96.00%), resulting in an overall average of 93.00%, indicating high theoretical feasibility. The highest score was obtained by the animated video, reflecting its strong role in supporting students' understanding of abstract concepts. This finding underscores the importance of integrating animated media into the worksheet, as it enhances attention, retention, and comprehension of complex scientific ideas (Staneviciene & Žekienė, 2025).

Table 4. Validation Results of the Learning Materials

Learning Materials	Valid. 1	Valid. 2	Valid. 3	Valid. 4	Average	Percentage (%)	Category
Teaching Module	3,81	3,37	3,73	3,91	3,70	92,50	Very Good
Learning Tools	3,66	3,48	3,81	3,64	3,65	91,25	Very Good
Content Presentation	3,78	3,27	3,62	4,00	3,67	91,75	Very Good
Animation Video	3,75	3,87	4,00	3,75	3,84	96,00	Very Good
Overall Average					3,72	93,00	Very Good

The consistently high scores across all validation aspects indicate that the materials meet the standards of content feasibility, design, language clarity, and alignment with STEM principles. Theoretically, the materials are in line with previous findings emphasizing that STEM-based instructional materials can improve motivation and conceptual understanding through contextual and integrative learning activities (Bakirci et al., 2022; Kelley & Knowles, 2016).

3. Student Response Results

Student responses indicated the practicality of the learning materials. Based on the criteria in Table 4, all aspects fall within the "very good" category (81–100%), including visual appearance (84.70%), content (85.67%), presentation (82.59%), language (82.15%), and STEM integration (84.68%), with an overall average of 83.96%. These results indicate that the materials are engaging and relevant to students' needs. However, slightly lower scores in language and presentation suggest the need for clearer wording and improved information flow to better accommodate diverse student abilities.

Table 5. Student Response Results

Aspect	Score	Percentage (%)	Category
Visual Appearance	3,39	84,70	Very Good
Content	3,42	85,67	Very Good
Presentation and Flow	3,30	82,59	Very Good
Language	3,29	82,15	Very Good
STEM Integration	3,39	84,68	Very Good
Average	3,36	83,96	Very Good

The consistency between expert validation and student responses indicates that the developed STEM-based learning materials are in the "very good" category, meeting feasibility standards while being practical for classroom use (Sholeh & Haryanto, 2024). These materials have strong potential to address curriculum gaps, particularly in representing the EDP more comprehensively, and offer a contextual pedagogical innovation aligned with tropical environmental and energy issues. Although no empirical effectiveness test was conducted, the materials are theoretically capable of enhancing critical thinking and problem-solving skills through the integration of Mahakam River SSI and the STEM–EDP framework. This combination encourages evidence evaluation, perspective analysis, and systematic problem-solving, supporting higher-order thinking as highlighted in previous studies (Nguyện et al., 2025; Simeon et al., 2022), and provides a solid basis for future experimental research.

D. CONCLUSION AND SUGGESTIONS

This study concludes that the developed STEM–EDP learning materials on the Mahakam River ecosystem are theoretically feasible and practically effective, as indicated by expert validation (93%) and student responses (83.96%) in the "very good" category. The integration of animated videos and local environmental context enhances conceptual understanding, inquiry, and engagement, while contributing a unified approach that combines STEM, SSI, EDP, and local issues to support scientific literacy and environmental awareness. Future research should extend to implementation and evaluation stages to examine impacts on learning outcomes and problem-solving skills through experimental or quasi-experimental studies, with further improvements in language, activity sequencing, and the development of interactive or adaptive digital features to enhance accessibility and engagement.

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