

## DEVELOPMENT OF ESD-INTEGRATED MATHEMATICS TEACHING MATERIALS IN THE MARITIME CONTEXT OF THE RIAU ISLANDS

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**ABSTRACT** This study aims to develop mathematics teaching materials integrated with Education for Sustainable Development (ESD) in the maritime context of the Riau Islands. The study was motivated by the importance of mathematics learning that not only develops conceptual understanding, but also fosters students' sustainability awareness, particularly in maritime regions facing environmental issues such as energy conservation and marine ecosystem degradation. This research employed a Research and Development (R&D) design based on Plomp's model, which consists of three phases: preliminary research, prototyping, and assessment. The research subjects were 32 eighth-grade students at SMP Negeri 1 Bintan, selected through purposive sampling. The instruments used included validation sheets and practicality questionnaires. The results showed that the developed teaching materials, consisting of lesson plans and student worksheets, met the criteria for high validity, with validity percentages ranging from 88% to 95%. The practicality test also showed a highly practical category, with percentages ranging from 80% to 90% based on teacher and student responses. The integration of ESD principles and the maritime context made mathematics learning more contextual, meaningful, and relevant to students' environment. These teaching materials also have the potential to support students' critical and systematic thinking while fostering awareness and responsible attitudes toward environmental sustainability. Therefore, the ESD-integrated mathematics teaching materials are feasible and practical to be used as an innovative learning alternative to support sustainable education.

**Keywords:** mathematics teaching materials, Education for Sustainable Development, maritime context, validity, practicality

**ABSTRAK** Penelitian ini bertujuan untuk mengembangkan bahan ajar matematika yang terintegrasi dengan *Education for Sustainable Development* (ESD) dalam konteks maritim Kepulauan Riau. Penelitian ini dilatarbelakangi oleh pentingnya pembelajaran matematika yang tidak hanya mengembangkan pemahaman konseptual, tetapi juga menumbuhkan kesadaran keberlanjutan siswa, khususnya di wilayah maritim yang menghadapi berbagai isu lingkungan seperti konservasi energi dan kerusakan ekosistem laut. Penelitian ini menggunakan desain *Research and Development* (R&D) berdasarkan model Plomp yang terdiri atas tiga fase, yaitu *preliminary research*, *prototyping*, dan *assessment*. Subjek penelitian adalah 32 siswa kelas VIII SMP Negeri 1 Bintan yang dipilih melalui teknik *purposive*

*sampling*. Instrumen yang digunakan meliputi lembar validasi dan angket kepraktisan. Hasil penelitian menunjukkan bahwa bahan ajar yang dikembangkan, berupa rencana pelaksanaan pembelajaran dan lembar kerja peserta didik, memenuhi kriteria validitas tinggi dengan persentase validitas berkisar antara 88% hingga 95%. Hasil uji kepraktisan juga menunjukkan kategori sangat praktis, dengan persentase berkisar antara 80% hingga 90% berdasarkan respons guru dan siswa. Integrasi prinsip ESD dan konteks maritim membuat pembelajaran matematika menjadi lebih kontekstual, bermakna, dan relevan dengan lingkungan siswa. Bahan ajar ini juga berpotensi mendukung kemampuan berpikir kritis dan sistematis siswa serta menumbuhkan kesadaran dan sikap bertanggung jawab terhadap keberlanjutan lingkungan. Dengan demikian, bahan ajar matematika terintegrasi ESD ini layak dan praktis digunakan sebagai alternatif pembelajaran inovatif untuk mendukung pendidikan berkelanjutan.

**Kata-kata kunci:** bahan ajar matematika, *Education for Sustainable Development*, konteks maritim, validitas, kepraktisan

## INTRODUCTION

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Education plays a vital role in creating a sustainable, equitable, and resilient society. This is because education provides the knowledge, skills, and values necessary to address global challenges such as climate change, environmental degradation, and social inequality (Nuwangi et al., 2023). Thus, education becomes a key aspect in identifying, understanding, and communicating various global issues so that individuals can recognize, influence, and address them appropriately (Helliwell & Ng, 2022).

The Riau Islands Province is characterized as a maritime and archipelagic region, as 96% of its total area consists of ocean, while only 4% is land. This region has significant potential in maritime resources, including fisheries, marine tourism, shipping, maritime transportation, and marine energy (Sholeh et al., 2023). However, various marine environmental issues, such as pollution, overfishing, and coastal ecosystem degradation, indicate that public awareness and understanding of the importance of preserving the ocean remain low. This situation calls for an active role from the education sector in fostering early awareness of the importance of sustainable marine resource management (Cristea et al., 2024).

In this context, Education for Sustainable Development (ESD) serves as a strategic approach to equip students with the knowledge, skills, values, and attitudes needed to contribute to environmental, social, and economic sustainability (Purnamasari et al., 2026; Suratmi et al., 2022). This approach aims to cultivate human resources who are able to actively contribute to community life and sustainable development for both current and future generations (Rahayu et al., 2024). ESD emphasizes awareness of the long-term consequences of individual behavior, thereby encouraging responsible actions for the sustainability of shared life. In the maritime context, ESD is highly relevant for integrating marine issues into the learning process so that students not only understand ecological concepts but are also able to apply them in real life (UNESCO, 2017).

The implementation of ESD in the learning process can encourage students to be active and responsible for their own learning journey (Vioreza et al., 2023). ESD is crucial to integrate into learning because it not only equips students with conceptual understanding but also instills critical thinking skills, moral values, and responsibility in making decisions for environmental and social sustainability (Agusti et al., 2019). In this context, the implementation of ESD across all subjects, including mathematics, is essential. Through ESD-based learning, students can be guided to understand the interconnection between humans and the ocean, the importance of preserving marine ecosystems, and how daily actions can affect the sustainability of the marine environment. Thus, the implementation of ESD in learning, especially in maritime contexts, is a strategic step in preparing an environmentally conscious and responsible younger generation capable of contributing to marine sustainability in the future.

Mathematics education is often viewed as an abstract subject disconnected from real-life contexts. In reality, mathematical concepts such as statistics, ratios, logic, and modeling are highly relevant for analyzing and understanding various sustainability issues, such as energy consumption patterns, population growth, waste management, and climate change (Primasti, 2021). Such learning not only strengthens students' understanding of mathematical concepts but also fosters their awareness of the importance of sustainable behavior. Mathematics education grounded in sustainable development principles provides an opportunity to support students' current development and the realization of their full potential (Hana et al., 2024). Therefore, the integration of ESD principles into mathematics education aims to equip students with the knowledge and skills necessary to understand and address sustainability issues using mathematical concepts and reasoning (Rahmania et al., 2024).

However, the implementation of ESD in mathematics education is still not optimal. Many mathematics teachers are not yet accustomed to linking mathematical concepts with sustainability issues. In addition, there is a lack of contextual learning resources and limited knowledge regarding the integration of ESD into learning (Amelia & Hamdu, 2022; Cahyani et al., 2024). Therefore, there is a need to develop ESD-integrated learning materials as a contribution to strengthening the role of mathematics education in sustainable development. Learning materials not only facilitate teachers in conducting instruction but also enhance student engagement, accessibility, and learning outcomes (Fatiyah et al., 2021; Wagino et al., 2024). Through ESD, students are expected to develop the ability to innovate, think scientifically and creatively, and solve problems.

Numerous studies on the integration of ESD into learning have been conducted (Kurniati et al., 2026; Purnamasari et al., 2026; Rahmania et al., 2024). However, most studies remain focused on social issues. Furthermore, the development of learning materials that integrate ESD within local contexts, particularly in maritime regions,

remains limited. On the other hand, mathematics learning materials used in schools are generally still conventional, lack context, and do not systematically address sustainability issues. As a result, students are less able to connect mathematical concepts with real-world problems in their surroundings, particularly those related to maritime life in the Riau Islands.

The novelty of this study lies in the development of mathematics learning materials that systematically integrate ESD principles with the maritime context of the Riau Islands. The developed materials not only include content and activities based on real-world problems but are also designed to foster ESD characteristics such as systemic thinking, forward thinking, decision-making, and awareness of environmental sustainability.

Based on this description, this study aims to develop ESD-integrated mathematics teaching materials in the maritime context of the Riau Islands. The developed materials are expected to improve the quality of mathematics learning and foster students' awareness and responsibility toward sustainability issues in their surrounding environment, particularly in the maritime region of the Riau Islands.

## **METHODS**

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This study aimed to develop mathematics teaching materials integrated with Education for Sustainable Development (ESD) in the maritime context of the Riau Islands. The teaching materials developed in this study consisted of lesson plans and student worksheets. Based on this objective, this study employed a Research and Development (R&D) approach using Plomp's development model. Plomp's model was selected because it provides a systematic and flexible development framework that emphasizes evaluation and revision to produce high-quality educational products (Yunus et al., 2023). According to Lidinillah (2018), the Plomp model consists of three phases: preliminary research, prototyping, and assessment.

The first phase was preliminary research. This phase involved initial investigations to identify the fundamental elements needed in developing mathematics teaching materials, including the curriculum used, students' characteristics, learning needs, and mathematical content aligned with school learning outcomes. The results of this phase served as the basis for designing teaching materials that were relevant to students' conditions and the maritime context of the Riau Islands.

The second phase was the prototyping phase. In this phase, the format and design of the teaching materials were selected and developed. The ESD context was also determined by considering maritime issues relevant to the Riau Islands, such as marine ecosystems, environmental sustainability, and the use of maritime resources. The prototype was designed to integrate mathematical concepts with contextual problems related to sustainability in maritime life.

The third phase was the assessment phase. This phase involved evaluating the developed teaching materials in terms of validity and practicality. Product validity

was assessed by experts in mathematics education to determine the appropriateness of the content, presentation, language, and integration of ESD and maritime contexts. After the product was declared valid, a limited trial was conducted to measure the practicality of the developed teaching materials based on teacher and student responses.

The subjects of this study were 32 eighth-grade students at SMP Negeri 1 Bintan. The subjects were selected using purposive sampling based on characteristics, needs, and criteria relevant to the product being developed. The data collection methods used in this study included interviews and questionnaires. Interviews were conducted to identify students' needs and characteristics as references in the development process. Meanwhile, questionnaires were used to obtain data on the validity and practicality of the developed teaching materials.

The instruments used in this study were product validation sheets and product practicality questionnaires. Before being used, the instruments were validated by a mathematics education lecturer. The data analysis process included processing questionnaire data, calculating the average response score, and interpreting the results based on predetermined categories. The product was considered valid and practical if the average score reached at least 70%.

**Table 1.** Validity and Practicality Categories

Interval Score	Validity Criteria	Practicality Criteria
$85\% \leq \bar{x} \leq 100\%$	Highly valid	Highly practical
$70\% \leq \bar{x} < 85\%$	Valid	Practical
$50\% \leq \bar{x} < 70\%$	Sufficiently valid	Fairly practical
$1\% \leq \bar{x} < 50\%$	Not valid	Not practical

Source: Putri et al. (2025).

## FINDING AND DISCUSSION

The product development process followed the Plump model, which consists of three phases: preliminary research, prototyping, and assessment. The preliminary research phase involves an initial investigation that includes curriculum analysis, student analysis, and content analysis. The curriculum analysis aims to examine the alignment between the curriculum and the needs and practices of mathematics learning in schools, particularly in the context of developing ESD based learning tools. This analysis covers the alignment between learning objectives, competencies, content, learning strategies, and assessment with the characteristics of the learning tools being developed. The results of the curriculum and content analysis indicate that teachers require learning materials capable of integrating mathematical concepts with sustainability issues so that students can engage in deep and contextual learning.

These learning materials are expected to assist teachers in implementing instruction that focuses not only on cognitive learning outcomes but also on fostering sustainable awareness and behavior in alignment with the national curriculum. The content within the learning materials needs to be connected to environmental and socio-economic contexts to make it more meaningful and contextual, such as the Pythagorean theorem.

Student analysis was conducted to identify the characteristics, needs, and real-world conditions of students in mathematics learning, which served as the foundation for developing ESD-based learning materials. The analysis results indicate that students possess significant potential for learning through deep and sustainability-based learning approaches; however, they require learning materials that are engaging, contextual, and facilitate active participation. The development of ESD-based learning materials is highly relevant for supporting deep learning objectives as it encourages students to think critically, reflectively, and act on real-world issues (Agusti et al., 2019)

The developed learning materials include lesson plans and student worksheets. Through ESD-integrated lesson plans, teachers are encouraged to implement innovative teaching methods so that the learning process is more active and student-centered. Additionally, teachers are expected to be able to link learning materials to real-world issues relevant to the maritime region of the Riau Islands. The role and competencies of teachers are essential for the effective implementation of ESD in the learning process (Ningsih & Juandi, 2019). Through ESD-integrated worksheets, students can understand concepts by connecting them to real-world contexts, such as marine and coastal environmental issues, and think critically when analyzing sustainability challenges. Additionally, students are able to design solutions, communicate their results both orally and in writing, and help students understand that mathematics plays a crucial role in addressing various real-world challenges (Djam'an et al., 2024)

The prototyping phase involves developing research instruments and selecting the format and design of the learning materials. The instruments used are validity checklists and practicality checklists. The validity aspects include content validity, construct validity, and linguistic and presentation validity. Meanwhile, the practicality aspect covers user-friendliness, clarity of layout and language, feasibility in the learning process, student engagement and appeal, and the usefulness of the product.

Based on the initial analysis, it was noted that learning materials must have a systematic structure, be easy to understand, and be capable of facilitating deep learning as well as the integration of sustainability issues. Therefore, every component of the Lesson Plan and Student Worksheets is designed with a consistent format, communicative language, and visually appealing presentation. Designing

instructional materials with a well-structured format helps create a structured, effective, and efficient teaching-learning process (Magdalena et al., 2024).

The design of the lesson plan prioritizes learning steps oriented toward exploratory activities, discussions, reflection, and the application of concepts within the maritime context of the Riau Islands. This is done to support the characteristics of deep learning, where students not only learn procedures but also understand the meaning of concepts and are able to apply them to solve sustainability problems. The selection of worksheet designs focuses on readability, clarity of instructions, the availability of space to document the thinking process, and the presentation of ESD contexts relevant to the maritime context of the Riau Islands.

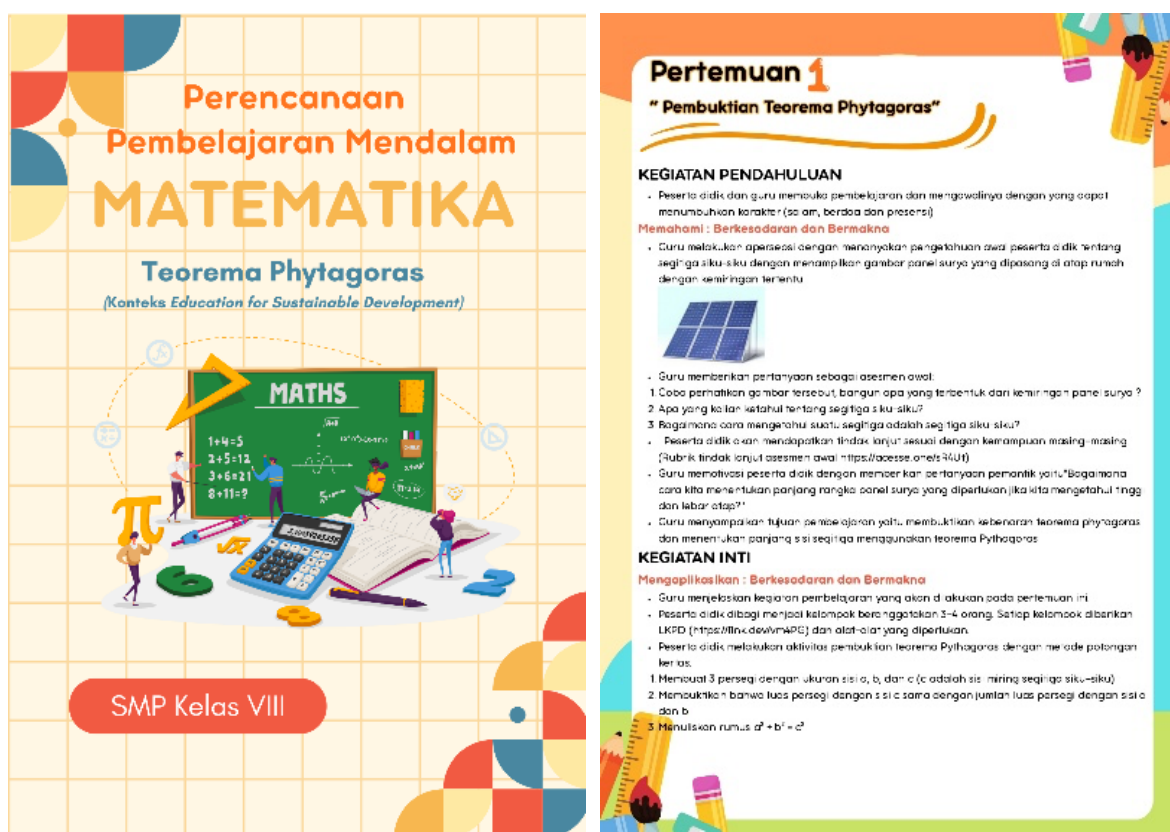



Figure 1. Lesson Plan Overview

The image shows a lesson plan that emphasizes the teacher's efforts to foster students' awareness and understanding of the learning process. Students not only learn geometric concepts but also see real-world examples of how mathematical concepts are applied in daily life. Students are introduced to solar panels, which are part of renewable energy sources supporting sustainable development. By integrating mathematical concepts within the context of sustainability, students can develop a deeper understanding of the relevance and application of mathematics in real life (Rahmania et al., 2024).

### KEGIATAN I "RUTE PALING EFISIEN"



Perhatikan gambar berikut !  
Seorang nelayan di Bintang berangkat dari Pulau Rusa Besar menuju Pulau Fishhead untuk mengambil hasil tangkapan, lalu ke Dermaga Tanjung Elong untuk menjual ikan. Biasanya, setelah selesai berjualan di Tanjung Elong, nelayan kembali ke Pulau Rusa Besar melalui Pulau fishhead.


Namun kali ini, ia ingin menguji apakah lebih hemat bahan bakar jika langsung pulang dari Tanjung Elong ke Pulau Rusa Besar tanpa singgah di Pulau fishhead.

1. Bagaimana nelayan dapat menentukan rute paling efisien agar bahan bakar lebih hemat?
2. Berapa persen efisiensi bahan bakar yang dapat dicapai?
3. Apa hal sederhana yang bisa kalian lakukan dalam kehidupan sehari-hari untuk ikut menghemat energi?

**AYO!** SELESAIKAN PERMASALAHAN DI ATAS

**MEMAHAMI MASALAH**  
Tuliskan apa yang diketahui untuk menjawab permasalahan yang ada. Buatlah sketsa sederhana untuk membantu memahami situasi tersebut

### UNTUK MENAMBAH PEMAHAMAN MU, SELESAIKAN SOAL BERIKUT !



Humam merupakan penyelam yang peduli terhadap lingkungan. Suatu ketika dia dan timnya akan melakukan penanaman karang untuk memperbaiki terumbu karang yang rusak. Kondisi Humam jika didokumentasikan ditunjukkan seperti gambar di bawah. Jika laut yang diselami adalah 20 meter dan dasarnya datar.

1. Berapa luas dasar laut yang dapat dicapai oleh Humam untuk menanam terumbu karang?
2. Jika setiap meter persegi dasar laut dapat ditanami 2 bibit karang, berapa total bibit yang dapat ditanam Humam dalam satu penyelaman?
3. Tuliskan ide atau langkah sederhana yang bisa kamu lakukan di kehidupan sehari-hari untuk ikut menjaga laut dari kerusakan!

**PENYELESAIAN**

Figure 2. Student worksheet

Figure 2 shows a student worksheet designed as a problem-based contextual learning activity. The context used is the activities of fishermen in maritime areas, specifically sea voyages to catch and sell fish and the planting of coral reefs. This context depicts a real-world situation requiring efficient route planning to optimize time and fuel usage as part of ESD issues. Through this problem, students are able to develop ESD competencies such as systemic thinking, sustainable decision-making, and responsibility for resource use. These findings align with the results of a study (Kurniati et al., 2026), which found that ESD contexts such as energy consumption present real-world problems that spark students' curiosity. Furthermore, situations relevant to their lives encourage students to analyze information, compare alternatives, and make data-driven decisions.

The Assessment Phase involves evaluating the developed instructional materials, including assessments of product validity and practicality. The product validity assessment was conducted by instructional experts in this case, two mathematics education faculty members. The results of the product validity assessment are presented in the following table.

**Table 2.** Product validity results

No	Component	Percentage	Category
<b>Learning Planning</b>			
1	Content suitability	95%	Highly Valid
2	Construction suitability	88%	Valid
3	Language and presentation suitability	90%	Highly valid
<b>Student worksheet</b>			
4	Content Suitability	90%	Highly valid
5	Construction & Learning	95%	Highly valid
6	Language & Display	90%	Highly valid

Overall, the assessment of the validity of the integrated ESD mathematics learning materials met the criteria for high validity. The researcher accepted several suggestions from the validators to revise the materials so that the final product would be improved. Some of the validators' comments concerned typographical errors and formatting. After the product was declared valid, the next step was for the researcher to pilot-test the developed product with teachers and students. The pilot test was conducted with 32 eighth-grade students at SMP Negeri 1 Bintan.

**Table 3.** Practicality Results

No	Aspect	Students		Teachers	
		Percentage	Category	Percentage	Category
1	Ease of Use	88%	Practical	85%	Practical
2	Clarity of Display and Language	90%	Very practical	80%	Practical
3	Feasibility in Learning	89%	Practical	85%	Practical
4	Student Engagement and Attractiveness	90%	Very practical	90%	Very practical
5	Usefulness	88%	Practical	85%	Practical

Based on the assessment of the practicality of the responses from teachers and students, the ESD-integrated mathematics learning materials meet the criteria for being highly practical. Thus, these learning materials are easy to use and can be effectively implemented by both teachers and students.

From the results of the validity and practicality assessments, it can be concluded that the developed ESD-integrated mathematics learning materials meet the criteria for

being highly valid and practical. This indicates that the materials are not only appropriate in terms of content, structure, and language but are also easy to use and engaging in supporting the learning process in the classroom, as well as relevant to the characteristics of the environment. The integration of maritime contexts not only enriches the understanding of mathematical concepts but also fosters awareness of sustainability issues, particularly in the management of coastal and marine resources. Thus, this learning tool can serve as an alternative learning resource with the potential to enhance the quality of learning and student engagement in a sustainable manner. In line with previous research findings (Djam'an et al., 2024; Marwa et al., 2025), these valid ESD-integrated student worksheets are suitable for use as an alternative learning tool because they can foster the development of systematic thinking skills oriented toward students' sustainable attitudes toward the surrounding environment.

## **CONCLUSIONS AND RECOMMENDATIONS**

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Based on the research findings, it can be concluded that the ESD-integrated mathematics teaching materials in the maritime context of the Riau Islands, developed using the Plomp model, have met the criteria for high validity and high practicality. The validity of the teaching materials is shown through expert evaluations of content, construction, language, and presentation, all of which were categorized as highly valid. Meanwhile, the practicality test results from teachers and students indicate that the teaching materials are easy to use, engaging, and suitable for classroom implementation.

The integration of maritime contexts and ESD principles into the teaching materials makes mathematics learning more contextual, meaningful, and relevant to students' daily lives. In addition, these materials can support the development of critical and systematic thinking, as well as foster students' awareness and responsible attitudes toward environmental sustainability, particularly in relation to coastal and marine resource management. Thus, the developed teaching materials are suitable for use as an innovative alternative for sustainability-based mathematics learning.

Further research is recommended to examine the effectiveness of these teaching materials in improving specific competencies, such as mathematical literacy, critical thinking, or sustainability awareness, through experimental studies. Similar teaching materials can also be developed for other mathematics topics or adapted into digital and interactive formats to improve accessibility and the quality of learning.

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