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Empowering environmental awareness through the development of digital booklet on coastal ecosystems (DICE) based on the SETS

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Abstract

Biology education examines various environmental issues, including coastal ecosystem degradation, which reflects the lack of human character or concern for the environment. The low level of knowledge and environmental awareness among students regarding coastal ecosystems may be caused by insufficient education and the lack of appropriate learning materials. This study aims to develop the *Digital Booklet on Coastal Ecosystems* (DICE) as a valid, feasible, and effective teaching material to enhance students' environmental awareness. The research employed the ADDIE development model**,** which consists of five stages, analysis, design, development, implementation, and evaluation. Data collection techniques involved non-test instruments (student needs analysis questionnaires, expert validation sheets, readability questionnaires, and environmental awareness attitude scales), as well as interviews (teacher needs analysis). The sample consisted of 9 students for the small-group trial and 31 students for the large-group trial, selected using simple random sampling. Data analysis was conducted using a paired sample t-test and normalized gain (n-gain)**.** The validation results from two biology education experts yielded a score of 3.27 (very valid). The readability tests conducted by students and teachers met the required assessment criteria, indicating that the teaching material is feasible for use in learning. The hypothesis test yielded a significance level of $p < 0.005$, indicating a statistically significant difference between the pre-test and post-test scores. The gain score was 0.57 (moderate improvement), and the normalized gain effectiveness was 57% (moderately effective). In conclusion, DICE was successfully developed as a valid, feasible, and moderately effective teaching material for improving students' environmental awareness.

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Introduction

In biology learning, one of the environmental issues studied in environmental education is coastal ecosystems. This is also emphasized in the learning outcomes of 10th-grade students, who are expected to be able to create solutions to local, national, or global environmental issues related to ecosystems and their interactions, as well as environmental change (Kemendikbud, 2022). Coastal ecosystems play a crucial role in supporting human life and biodiversity (Rombe et al., 2024). Increased human activity in coastal areas frequently leads to environmental degradation, including pollution, overfishing, and the degradation of coastal habitats (Jamil et al., 2024). Damage to coastal ecosystems is a manifestation of the lack of human character or

attitude of caring about the environment (Sarkity et al., 2023).

Increasing awareness and knowledge of the importance of protecting the environment and reducing environmental problems can be done through education.(Indahri, 2020; Iwan et al., 2023). In the independent learning curriculum, in addition to developing cognitive aspects, it also focuses on developing students' character. (Sudrajat, 2023). One of the characteristics emphasized in the Merdeka curriculum is environmental stewardship. Environmental stewardship refers to actions taken to prevent environmental damage and attitudes toward repairing damage that has already occurred (Desfandi, 2015). Therefore, education is used as a means of forming character, so that with environmentally oriented education, concern for the environment can be well integrated (Ahyani & Waliulu, 2023).

Coastal ecosystems play a vital ecological, economic, and social role, yet students are understanding and awareness of these ecosystems remain considerably low. Current instructional practices in schools still rely on limited, outdated, or poorly contextualized learning materials that do not effectively support comprehensive learning about coastal environments (Reizhal et al., 2020). This issue is further compounded by teachers limited skills in designing and implementing creative, innovative, and student centered-learning media that can enhance engagement and stimulate meaningful learning (Nugroho et al., 2023). Consequently, students often exhibit low learning motivation and disengagement, leading to suboptimal development of environmental awareness and care. In addition, previous studies indicate that ineffective environmental education particularly regarding coastal ecosystems contributes significantly to students low levels of environmental awareness (Arofah & Pujilestari 2020), that students environmental awareness is still largely low.

This is particularly concerning, as research by Handayani et al. (2022) and Evita et al. (2023) demonstrates a strong positive relationship between environmental knowledge and environmental attitudes. Therefore, insufficient environmental knowledge directly limits students ability to understand, evaluate, and address environmental problems, ultimately weakening their sense of environmental responsibility. Given these conditions, there is an urgent need to develop innovative, engaging, and accessible learning media that can bridge the gap between curriculum expectations and students actual learning experiences. Such learning media should not only improve conceptual understanding of coastal ecosystems but also foster stronger environmental attitudes and promote responsible environmental behaviour. Addressing this gap is essential for ensuring that environmental education effectively contributes to the development of environmentally literate and ecologically responsible future generations.

Environmental teaching materials, particularly those related to coastal ecosystems, can be maximized by integrating a learning model. Selecting a learning model that is appropriate and aligns with the material's characteristics can create high-quality learning conditions, thereby achieving learning objectives (Abidin, 2019). The SETS (Science, Environment, Technology, Society) learning model has the characteristic of connecting science with other elements such as technology, the environment, and society (Atmojo et al., 2020; Mahlianurrahman et al., 2023). SETS is highly effective in enhancing students' ability to innovate and find solutions to environmental problems, while also stimulating their higher-order thinking skills (Azura et al., 2022). Environmental materials, particularly those related to coastal ecosystems, are insufficient when studied solely based on the material concept alone. However, the application of the material concept to the environment, society, and technology must also be examined to maximize understanding of the material (Winarti et al., 2016).

Learning models can be integrated into teaching materials, one of which is the digital booklet that will be developed. Digital booklets refer to digitized booklets that contain concise material, complemented by attractive images, and are easily accessible via mobile devices, making them more efficient and environmentally friend (Sinaga et al., 2023; Ayunda & Luftfi, 2022; Setyana & Ngabekti, 2024; Andini & Saifuddin, 2023). Research appears to have been conducted to develop SETS-based digital teaching materials, but the findings are still limited. Most research on developing SETS-based teaching materials is still in the process of developing printed booklets or has not yet been digitized, and none has focused on coastal ecosystems. This refers to research by Pralisaputri et al, (2016) and Afni (2022). This study aims to develop DICE: Digital Booklet on Coastal Ecosystems Based on SETS as a valid, feasible, and effective teaching material in improving students' environmental awareness.

Method

This research uses the Research and Development method with the ADDIE research and development model, which has five stages, namely Analyze, Design, Development, Implementation, and Evaluate (Branch, 2009). In the analysis phase, a comprehensive identification of needs and problems was conducted based on relevant and credible sources. The design phase involved formulating clear learning objectives, selecting essential content, and constructing the structure of the instructional materials in alignment with the results of the needs analysis. During the development phase, the product was produced according to the established design framework and subsequently subjected to expert validation by specialists in the corresponding field. The implementation phase resulted in a product that was ready for use by the targeted research subjects. The evaluation phase consisted of both formative and summative evaluations. Formative evaluation was carried out throughout each stage of the development process to identify required revisions, ensuring that the product met the intended objectives and learner needs. In contrast, summative evaluation was conducted during the implementation phase after the final version of the product had been completed, with the purpose of assessing the overall feasibility, quality, and effectiveness of the developed product.

In the analysis stage, needs analysis and problem identification were conducted from relevant sources. In the design stage, learning objectives were formulated, the primary material to be presented was selected, and teaching materials were then prepared with an adapted structure concept based on the analysis of student needs. During the development stage, product development was conducted based on the design created in the design stage, and validation testing was conducted by two biology education experts, namely lecturers from the Biology Education Study Program at Jakarta State University. In the implementation stage, the product was tested in small groups to determine student responses regarding the product that had been developed. In the large group test, effectiveness testing was conducted to measure students' environmental awareness attitudes using a pre-experiment one-group pretest-posttest design. In the evaluation stage, formative and summative assessments were conducted to evaluate the results of the developed product. The research design is illustrated in Figure 1.

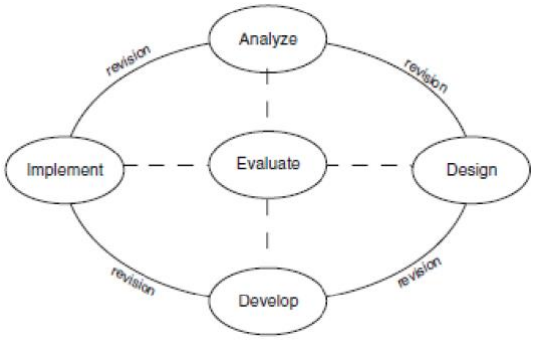


Figure 1. ADDIE Model (Branch, 2009)

The sample population from SMA Negeri 75 Jakarta was selected. The minimum number of samples was calculated using the Slovin formula, resulting in 31 students being selected from a total population of 34 students. The sample used was 31 students selected using simple random sampling. The data collection technique in this study was obtained from the results of observations and a student needs analysis conducted using questionnaires. A teacher needs analysis was conducted through interviews. In expert validation, an assessment questionnaire was used, covering aspects of material, media, and language. In the teacher readability test and student readability, a non-test instrument was used in the form of a questionnaire that assessed aspects of content, appearance, and benefits. In the environmental care attitude instrument, a non-test instrument was used in the form of a questionnaire with a Likert Scale, based on the attitude dimensions according to Azwar (2012), namely cognition, affection, and conation.

In data analysis, descriptive analysis methods were used. The validity test of the environmental awareness attitude instrument uses the Pearson Product-Moment formula, and the reliability is assessed using the Cronbach's Alpha formula. The validity results of the 40-item environmental awareness attitude instrument are declared valid and reliable with a high category interpretation based on Masidjo (2010). The results of the validation and product trials are analyzed using quantitative analysis techniques. The data obtained will be converted according to the BSNP scale (2014), and the results of the teacher readability test and small group test will be presented using the Likert scale (Sugiyono, 2023). After the final average score is obtained, expert validation can be determined based on the interpretation of the validation test scores from Ratumanan and Laurens (2011).

A normality test was performed on the result scores. *Pretest* and posttest with a significance level (α) = 0.05 using the Shapiro-Wilk test. The homogeneity test used the Levene test with (α) = 0.05. After going through the prerequisite test, a hypothesis test was conducted. In this study, a hypothesis test was conducted using the Simple Paired T-Test. It concluded with an N-gain test to assess the increase in students' environmental awareness following the product implementation. Then it was calculated using the N-Gain formula. The gain score results were interpreted based on categories as outlined by Meltzer (2002), and the normalized gain value was interpreted with Hake's categories (1999).

Results and Discussion

Analysis Stage

The analysis stages in this research were conducted through teacher interviews, student observations, and literature studies. The use of gadgets in biology learning has received support from teachers and students. This aligns with research by Putri et al. (2021), which suggests that students utilize gadgets for digital literacy, searching for materials, or gathering other information. In terms of the availability of teaching materials, biology learning remains limited to the use of printed books, PowerPoint slides, and digital literacy via gadgets, with no variation in media or more innovative teaching resources. This is supported by research, which states that incorporating innovation in alternative teaching materials can serve as a learning support to improve students' understanding of the material (Mukhlas et al., 2022).

Students often struggle to understand certain aspects of biology. One of the factors contributing to students' difficulties in understanding coastal ecosystems is the limited availability of teaching materials, which are generally outdated and lack extensive or contextual information. The limited teaching materials also contribute to the ineffectiveness of the learning process (Herawati & Muhtadi, 2020).Students need supporting teaching materials that can visualize concepts and relate them to real-life situations, fostering environmental awareness, even if it is not immediate. Teachers believe that engaging teaching materials should captivate students, avoid monotony, and present the material interactively and contextually. Learning that can improve long-term memory will be more meaningful if it is implemented contextually by discussing problems relevant to everyday life (Darmawan & Nawawi, 2020).

Design Stage

Literature studies and observations from the analysis stage serve as the basis for planning during the design stage. The design is created to ensure the development process is on target and to estimate the resources and time required for the evaluation stage (Mulyatiningsih, 2012). The following is the initial product design, as shown in Figure 2.

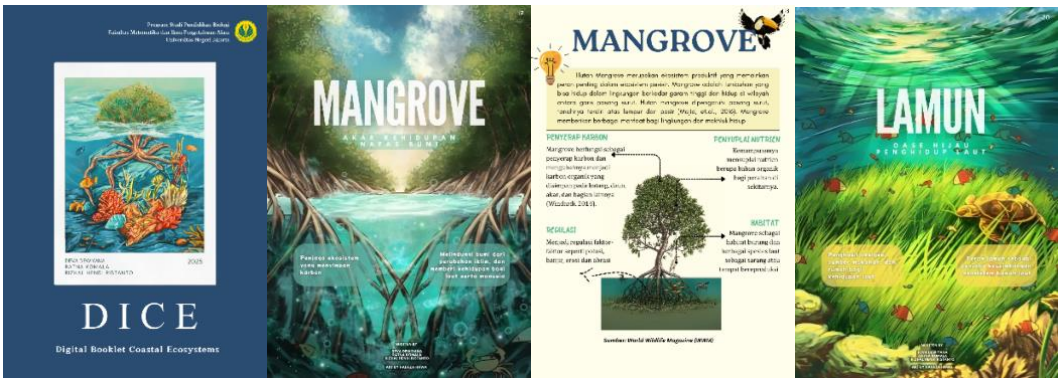




Figure 2. Example Initial Product Design Results

Development

The validation assessment by material experts yielded an average score of 3.24, which is categorized as valid and suitable for use with minor revisions. Based on the experts comments, several inputs and suggestions were provided for improvement. The validation assessment by media experts obtained an average score of 3.31, which falls into the very valid category and indicates that the product can be used without revision. Likewise, the validation conducted by language experts resulted in an average score of 3.26, also categorized as very valid and feasible for use. Although both expert groups stated that the product did not require revision, they still provided several constructive comments and suggestions to enhance the overall quality of the product. The results of the accumulated product validity are presented in Table 1.

Table 1. Accumulation of Expert Validation Results

Material Aspect	Media Aspects	Linguist
3.24	3.31	3.26
(Valid)	(Highly valid)	(Highly valid)
	Average Value	
	3.27	
	(Highly valid)	

In the material validation test, the highest average score was obtained for the supporting aspect of material presentation. The supporting aspect of presentation emphasizes the appropriateness of illustrations to the material being presented. Good illustrations make the depiction of material relevant to the topic and easy to understand. This aligns with research. Putri & Astuti (2014) suggest that illustrations in textbooks, which are relevant to the content, are crucial for helping students grasp information more quickly. Having supporting illustrations that are appropriate and relevant to the material will stimulate children's curiosity and motivation to read the digital booklet, thus improving their understanding of the material (Mahardika, 2021).

In the media validation test, the highest average score was achieved for the appeal aspect. The numerous features that students can utilize to gain a deeper understanding of the knowledge, as well as the unique appearance of each page in the digital booklet, increased student interest in using this product. This is because these features are designed to stimulate students' intellectual development and support the teaching and learning process in the classroom (Tyas et al., 2024). A well-structured textbook layout enhances comprehension,

readability, and facilitates students' ability to locate important information.(Indriani et al., 2023)The use of interactive multimedia can enhance students' technological skills and stimulate their enthusiasm and interest in learning (Larasati et al., 2020). Based on the results of the expert validation test, the language aspect was categorized as very valid. In the language validation test, the highest average score was obtained for the readability aspect. Material should be presented in language that is engaging, clear, easy to understand, and free from multiple interpretations. Ineffective language can lead to misinterpretation and difficulty understanding. This aligns with research indicating that the information in the material is easy to understand because it is presented in efficient and communicative sentences (Ningtyas & Rahmawati, 2023). Ineffective language in textbooks can hinder the delivery of information and reduce the accuracy of learning (Tyas et al., 2024).

Implementation

Teacher Readability Test

Based on the biology teacher readability test results, the developed digital booklet received an average score of 3.30, indicating that it can be used in learning. This indicates that the developed product meets the assessment criteria in the teacher response questionnaire, which covers aspects of content, appearance, and usability. The results of the teacher readability test are shown in Table 2.

Table 2. Teacher Readability Test Results Graph

Assessment Aspect	Average
Content	3,40
Visual	3,14
Benefit	3,33

Readability testing is important to ensure that the teaching materials used are appropriate for students' understanding and abilities. Teachers play a crucial role in determining whether learning texts are too complex, too simple, or suitable for students. Readability is a crucial aspect in digital booklet development because it influences how easily students understand the content (Himala et al., 2016). Mastun (2017) states that the primary aim of developing teaching materials is to increase the efficiency and effectiveness of learning, both in terms of time, resources, and energy, thereby making it easier for students to understand the material being studied. This finding aligns with the study's results. Magdalena et al. (2023) emphasized that selecting appropriate teaching materials helps teachers manage learning time more efficiently.

Small Group Test

Based on the results of the small group test administered to students, it can be seen that the SETS-based digital booklet product on coastal ecosystems received an overall average score of 3.61 and can be used with minimal student input. Through the comment column on the questionnaire instrument, it was found that students assessed the digital booklet product as appropriate, as it helped them understand coastal ecosystems better and care more about them. In addition, students were also very interested in the digital booklet display, which packages coastal ecosystem information, making it easier for them to understand the material presented. This aligns with research indicating that digital booklets serve as an effective medium for

delivering information to readers (Prananta & Safitri, 2023). The application of digital booklets in biology learning has the potential to support the achievement of learning objectives and help students understand concepts well (Astuti, 2021). This is due to the advantage of digital booklets, namely that they can be used in various places and at any time, making them more practical and efficient. Based on the feedback provided by students during the trial phase, several limitations of the product were identified. The limitation of the SETS-based digital booklet is the requirement for internet access to support several of its features, which also necessitates that students provide their own internet data. The results of the small-group trial are presented in Table 3.

Table 3. Small Group Test Results Graph

Assessment Aspect	Average
Content	3,70
Visual	3,62
Benefit	3,52

Large Group Test

In the cognitive dimension, the average pretest score of students was 25.26 with a standard deviation of 2.76. After the learning process using the digital booklet, the average score increased to 29.87, accompanied by a decrease in the standard deviation to 1.69. The N-Gain value of 0.68 is included in the moderate category, and the significance test showed $p < 0.001$, which indicates a significant difference between the pre-test and post-test. The decrease in standard deviation indicates that students' understanding became more evenly distributed after using the digital booklet.

In the affective dimension, the average pretest score of 39.29 increased to 47.26 after the intervention, with a decrease in standard deviation from 4.76 to 2.82. The N-Gain value of 0.63 is in the moderate category, and the significance test results also showed $p < 0.001$. This indicates a significant increase in the affective aspect of students. The digital booklet is designed not only to convey information cognitively, but also through an attractive visual approach and contextual narratives that touch on emotional aspects, such as facts about coastal ecosystem damage. These elements are effective in increasing students' empathy, interest, and concern for environmental issues.

Meanwhile, in the conation dimension, the average score increased from 56.52 to 66.45, accompanied by a decrease in the standard deviation from 6.54 to 4.23. The N-Gain value of 0.51 falls within the moderate category, with a significance value of $p < 0.001$, indicating a statistically significant difference between the pre-test and post-test. Learning with digital booklets not only provides knowledge but also encourages students to think critically and actively engage through reflective invitations and activities that foster real-world action. The increase in scores in the conation dimension reflects the growing intention and awareness of students to take real action in protecting the environment. The following are the test results for each dimension of environmental care attitudes, as presented in Table 4.

Table 4. Test Results for Each Dimension of Students' Environmental Awareness Attitudes

Environmental Attitude Indicators	Average		*N-Gain* (Category)	*Paired Sample T Test Pretest-posttest*			
	Pre-test (±SD)	*Post-test* (±SD)		df	Sig. Two-Sided P	α	Conclusion
Dimensions of Cognition	25.26 (2.76)	29.87 (1.69)	0.68 (currently)	30	<0.001	0.05	There is a significant difference
Affection Dimension	39.29 (4.76)	47.26 (2.82)	0.63 (currently)	30	<0.001	0.05	There is a significant difference
Dimension of Conation	56.52 (6.54)	66.45 (4.23)	0.51 (currently)	30	<0.001	0.05	There is a significant difference

The prerequisite test was conducted using IBM SPSS 27. The normality test, using the Shapiro-Wilk method, yielded significance values of 0.393 (pretest) and 0.431 (posttest), indicating that the data were normally distributed. The homogeneity of variance test yielded a significance value of 0.104, indicating that the data were homogeneous. Based on the calculation results, the N-Gain test result was 0.57. Based on the Gain Score category, it can be interpreted as moderate. In the N-Gain effectiveness estimate category, it suggests that the use of the DICE product, specifically the Digital Booklet on Coastal Ecosystems, is quite effective in increasing students' environmental awareness. Based on the calculation results, the N-Gain test result was 0.57. Based on the Gain Score category, it can be interpreted into the moderate category, while in the N-Gain effectiveness estimate category, it can be interpreted that the use of the DICE product: Digital Booklet on Coastal Ecosystems is quite effective in increasing students' environmental awareness.

Table 5. Summary of Effectiveness Test Results

Test Form	Average value	N-Gain	*Gain Score*	N-Gain Effectiveness
Pre-test	121.06	0.57	Medium category	Quite effective
Post-test	143.58			

The components of attitude consist of cognition (beliefs or concepts), affection (emotions), and conation (behavioural tendencies), which interact with each other in a complex manner.(Mawardi, 2019). These three dimensions complement each other, forming a holistic attitude that demonstrates digital booklets not only convey information but also encourage comprehensive attitudinal change. Increasing environmental knowledge should be grounded in strong emotional engagement. When individuals are emotionally connected to environmental issues, changes in attitudes and mindsets will occur. These changes will ultimately lead to increased understanding (thoughts) and mastery of the skills necessary for environmental management (actions) (Ritonga et al., 2024).

Various interrelated factors influence students' environmental awareness. One of these is daily habits at home, where the behavior of family members can serve as concrete examples in fostering environmental awareness (Qodriyanti et al., 2022). Furthermore, individual awareness

also plays a crucial role; the higher a student's awareness of the importance of environmental preservation, the more likely they are to act in an environmentally friendly manner. Students' knowledge of environmental issues also forms the basis for developing responsible attitudes and actions. Equally important, exposure to organizations, both formal and informal, such as educational institutions and communities, that work in the environmental field also plays a significant role, as it can inspire and motivate them to contribute to environmental conservation efforts (Hargreaves, 2016).

The use of SETS-based digital booklets on coastal ecosystems aims to increase students' environmental awareness through environmental education in biology lessons. Environmental education enhances knowledge, which in turn fosters positive attitudes and a desire to take action for the environment. This means that the more students know about the environment, the greater their awareness and motivation to adopt a positive attitude toward it (Larasati et al., 2020). This aligns with research by Handayani et al. (2024), which suggests that environmental care values should be instilled in children from an early age through education and character development to prevent adverse impacts, support sustainable development, and ensure the survival of both humans and the environment.

Education ecology and the environment need to be presented engagingly and contextually to engage students. Their effectiveness depends on the approach, models, methods, and learning media used (Ridwan et al., 2024). Through the use of SETS-based digital booklets, students are encouraged to understand how science, the environment, technology, and society are interconnected, thereby becoming more sensitive to environmental issues affecting coastal ecosystems and developing innovative solutions. This is in line with research Perdana & Rosana (2023) also found that virtual experimental media based on augmented reality, using the SETS model, can improve problem-solving skills and environmental awareness attitudes.

Evaluation Stage

Formative evaluation in the development of the SETS-based digital booklet was carried out across all stages of the process. In the analysis stage, evaluation was conducted through a literature review and a needs analysis of teachers and students to determine the urgency of developing the media. The results indicated that students require a digital learning resource on coastal ecosystems that can effectively enhance their environmental awareness. In the design stage, evaluation was performed by translating the analysis results into storyboards and material planning, resulting in an initial design that aligned with user needs. In the development stage, evaluation continued through expert validation by material, media, and language specialists, which led to several revisions related to content accuracy, visual presentation, and linguistic clarity. During the implementation stage, formative evaluation was conducted through readability testing and small-group trials, demonstrating that students could use the digital booklet easily and understand the material well. Overall, the formative evaluation results showed that each development stage contributed to improving the product’s quality until it reached an acceptable level of feasibility as a learning medium.

Summative evaluation was conducted after the final product was completed to assess the overall strengths and weaknesses of the digital booklet. The evaluation results indicated several advantages of the SETS-based digital booklet, including practicality, efficiency, support for independent learning, and accessibility without time or location constraints. Its visually appealing and interactive design was shown to increase students’ reading interest and learning motivation, while the use of clear and easy-to-understand language facilitated better

comprehension of the material. However, several limitations were also identified, such as the need for internet access to optimize certain features, the limited availability of digital devices in some schools, and the necessity for students to provide their own internet data. Interpretatively, the summative evaluation suggests that despite these technical constraints, the SETS-based digital booklet remains a highly potential and feasible instructional tool for contextual, interactive coastal ecosystem learning and for strengthening students' environmental awareness.

Conclusion

DICE: *Digital Booklet on Coastal Ecosystems* was successfully developed through the ADDIE model and validated as a feasible learning resource. Implementation results showed that the digital booklet improved students' environmental awareness, and the N-Gain analysis categorized its effectiveness as sufficient. These findings indicate that DICE has strong potential to be used as an alternative digital medium for learning coastal ecosystem concepts.

Credit Authorship Contribution Statement

Deva Dewiyana Sari: Conceptualization, Methodology, Software, Visualization, Formal analysis, Writing – original draft, Writing – review & editing. **Ratna Komala**: Conceptualization, Methodology, Formal analysis, Resources, Supervision. Rizhal Hendi Ristanto: Conceptualization, Methodology, Formal analysis, Resources, Supervision.

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