DEVELOPMENT OF SDGs-INTEGRATED CAROUSEL-BASED MICROLEARNING CONTENT FOR ENHANCING STUDENTS' SCIENTIFIC LITERACY SKILLS ON ENVIRONMENTAL POLUUTION

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ABSTRACT

Students' low science literacy skills and the importance of integrating the Sustainable Development Goals (SDGs) into the teaching of the environmental pollution subtopic underscore the need for innovative learning media that support 21st-century learning. This study aims to develop SDGs-integrated, carousel-based microlearning content on the environmental pollution subtopic that is valid, practical, and effective for fostering students' science literacy skills. This development study employed the 4D model (define, design, develop, and disseminate) with a pilot test involving 25 10th-grade students at SMA Negeri 1 Sidayu, Gresik. Research instruments included a validation sheet, a lesson implementation observation sheet, a student response questionnaire, and a science literacy skills test. Data were analyzed using quantitative descriptive methods, while the effectiveness of the media was analyzed using a paired-sample t-test and N-Gain. The results showed that the SDGs-Integrated Carousel-Based Microlearning Content achieved a validity percentage of 98.8%, falling into the "highly valid" category. The practicality of the media was demonstrated by a lesson implementation rate of 96.3% and a student response rate of 98.6%, both of which fell into the "highly practical" category. The effectiveness of the medium was demonstrated by the results of a paired-sample t-test, with a significance value of 0.000 (<0.05) and an N-Gain value of 0.7035, which falls into the high category. Thus, the SDGs-Integrated Carousel-Based Microlearning Content is deemed valid, practical, and effective for developing students' science literacy skills in the subtopic of environmental pollution.

***Keywords**: microlearning content*, carousel, *Sustainable Development Goals* (SDGs)

ABSTRAK

Rendahnya keterampilan literasi sains siswa serta pentingnya integrasi *Sustainable Development Goals* (SDGs) dalam pembelajaran submateri pencemaran lingkungan mendorong perlunya inovasi media pembelajaran yang mendukung pembelajaran abad ke-21. Penelitian ini bertujuan mengembangkan *SDGs-Integrated Carousel-Based Microlearning Content* pada submateri pencemaran lingkungan yang valid, praktis, dan efektif untuk melatihkan keterampilan literasi

sains siswa. Penelitian pengembangan ini menggunakan model 4D (*define, design, develop,* dan *disseminate*) dengan uji coba terbatas pada 25 siswa kelas X SMA Negeri 1 Sidayu, Gresik. Instrumen penelitian meliputi lembar validasi, lembar observasi keterlaksanaan pembelajaran, angket respons siswa, dan tes keterampilan literasi sains. Data dianalisis secara deskriptif kuantitatif, sedangkan keefektifan media dianalisis menggunakan uji *paired sample t-test* dan *N-Gain*. Hasil penelitian menunjukkan bahwa *SDGs-Integrated Carousel-Based Microlearning Content* memperoleh persentase validitas sebesar 98,8% dengan kategori sangat valid. Kepraktisan media ditunjukkan oleh persentase keterlaksanaan pembelajaran sebesar 96,3% dan respons siswa sebesar 98,6% yang termasuk kategori sangat praktis. Keefektifan media ditunjukkan oleh hasil uji *paired sample t-test* dengan nilai signifikansi sebesar 0,000 (<0,05) dan nilai *N-Gain* sebesar 0,7035 yang termasuk kategori tinggi. Dengan demikian, *SDGs-Integrated Carousel-Based Microlearning Content* dinyatakan valid, praktis, dan efektif untuk melatihkan keterampilan literasi sains siswa pada submateri pencemaran lingkungan.

Kata Kunci: *microlearning content*, carousel, *Sustainable Development Goals* (SDGs)

A. Introduction

Science literacy skills are one of the key competencies that students need to possess in the 21st century. Science literacy encompasses not only mastery of concepts but also the ability to explain phenomena scientifically, evaluate information based on evidence, and apply scientific knowledge in decision-making (OECD, 2023a). The importance of science literacy is reflected in the Programme for International Student Assessment (PISA), which identifies science literacy as one of the indicators of educational quality. However, the 2022 PISA results show that Indonesian students' science literacy achievement remains low, with an average score of 383 and a ranking of 67th out of 81 participating countries—a decline compared to the 2018 PISA results, which recorded a score of 396 (OECD, 2023a; OECD, 2019). This situation indicates that students' science literacy skills still need to be improved through learning that connects scientific concepts to real-world problems.

One factor contributing to low science literacy skills is a learning process that still focuses on mastering concepts and memorizing material.

Fauziyah et al. (2021) state that science instruction in schools still tends to emphasize mastery of material over the development of students' scientific thinking skills. As a result, students struggle to connect scientific concepts with phenomena in their surroundings and to apply scientific knowledge to solve everyday problems. Therefore, instruction must be designed contextually so that students can analyze problems, interpret scientific information, and use scientific evidence in decision-making (Dewantari & Singgih, 2020). One relevant context for developing science literacy skills is the subtopic of environmental pollution, as it involves various real-world issues closely related to students' lives and requires the ability to analyze causes, impacts, and mitigation efforts.

Learning about environmental pollution can be enriched through the integration of the Sustainable Development Goals (SDGs) as a global development agenda that emphasizes a balance among environmental, social, and economic aspects. Integrating the SDGs into learning enables students to understand the connections between scientific concepts and various environmental issues occurring at both the local and global levels. Furthermore, the Education for Sustainable Development (ESD) approach encourages students to develop the knowledge and skills needed to address sustainability challenges (UNESCO, 2020). Thus, integrating the SDGs into the environmental pollution sub-topic has the potential to create more contextual and meaningful learning experiences while supporting the development of students' science literacy skills.

The integration of sustainability issues into learning must be supported by media that align with the characteristics of today's learners. Generation Z is a generation that is familiar with digital technology and social media, so they tend to prefer content that is concise, visual, interactive, and easily accessible via mobile devices (Gherman et al., 2021; Samala et al., 2023). One strategy that aligns with these characteristics is microlearning, which involves presenting material in short learning units focused on specific topics (Pebriantika et al., 2024). Various studies indicate that microlearning can enhance student engagement and learning outcomes because it provides

a flexible learning experience that is easily accessible through digital platforms (Rusdi et al., 2020; Meliana & Seli, 2023; Monib et al., 2024).

One form of microlearning that has potential for use in biology education is the carousel. The carousel format presents information through a series of interconnected slides, allowing the material to be delivered step-by-step through a combination of short text, images, illustrations, and infographics. This presentation helps reduce students' cognitive load and facilitates their understanding of complex material (Susilana et al., 2022). Furthermore, the carousel format aligns with Generation Z's habits of accessing information through social media. However, the development of carousel-based microlearning content integrated with the SDGs to foster science literacy skills in the subtopic of environmental pollution remains limited.

Observations in the 10th-grade class at Sidayu State High School No. 1 indicate that instruction on environmental pollution is still dominated by conventional approaches and has not yet optimally utilized digital media. On the other hand, students showed a high level of interest in using mobile devices and digital media in their learning activities. This situation indicates a gap between students' learning characteristics and the instructional media used in schools. Therefore, this study aims to develop carousel-based microlearning content incorporating the SDGs on the subtopic of environmental pollution that is valid, practical, and effective for fostering students' science literacy skills.

B. Research Method

This study is a research and development (R&D) project aimed at producing valid, practical, and effective SDGs-integrated carousel-based microlearning content to develop students' science literacy skills in the subtopic of environmental pollution. The research model used is the 4D model proposed by Thiagarajan, which consists of four stages: define, design, develop, and disseminate.

The research was conducted at Sidayu 1 Public High School, Gresik. Product validation was carried out by two expert lecturers, including a subject matter expert and a media expert. A limited pilot test was

conducted with 25 tenth-grade students. The developed product consists of carousel-based microlearning content incorporating the SDGs on the subtopic of environmental pollution, presented via the Instagram platform. Research instruments included a validation sheet, a lesson implementation observation sheet, a student response questionnaire, and a science literacy skills test. The validation sheet was used to assess the validity of the media, while the observation sheet and response questionnaire were used to measure the practicality of the media. The science literacy skills test was used to measure the effectiveness of the media through a one-group pretest-posttest design. The research data were analyzed using quantitative descriptive methods to determine the levels of validity, practicality, and effectiveness of the developed microlearning content.

Validity data were obtained from the assessments of subject matter experts and media experts. The validity percentage was calculated using the formula:

$$Validity\ percentage = \frac{Score\ Obtained}{Maximum\ Score}$$

The percentage results were then interpreted based on the criteria in Table 1.

Tabel 1 Criteria for Interpreting Validity

Score (%)	Category
25-40	Invalid
41-55	Less Valid
56-70	Fairly Valid
71-85	Valid
86-100	Highly Valid

(Riduwan, 2018)

Microlearning content is deemed suitable for use if it achieves a validity percentage of ≥ 71% and is categorized as valid or highly valid.

The practicality of the medium is determined based on observations of how the learning is implemented and student response questionnaires. The practicality percentage is calculated using the following formula:

$$Practicality\ percentage = \frac{Score\ Obtained}{Maximum\ Score}$$

The percentage results were then interpreted based on the criteria in Table 2.

Tabel 2 Criteria for Interpreting Practicality

Score (%)	Category
25-40	Not practical
41-55	Poorly practical
56-70	Fairly practical
71-85	Practical
86-100	Highly Practical

(Riduwan, 2018)

Microlearning content is considered practical if it achieves a validity

percentage of ≥ 71% and is categorized as valid or highly valid.

The effectiveness of the medium was determined based on the results of students' pretest and posttest science literacy skills. The data were first tested for normality using the Shapiro–Wilk test. Next, the difference between pretest and posttest scores was analyzed using a *paired-sample t-test.* The improvement in students' science literacy skills was calculated using the N-gain formula as follows:

$$< g > \frac{Posttest - Pretest}{Maximum\ score - Pretest}$$

The N-gain value is then interpreted based on the criteria in Table 3.

Tabel 3 N-gain Score Criteria

Value	Category
g ≥ 0,7	High
0,3 ≤ g ≤ 0,7	Moderate
g < 0,3	Low

(Hake, 1999)

A medium is considered effective if there is a significant difference between the pretest and posttest scores ($p < 0.05$) and it achieves a minimum N-gain value in the moderate category.

C.Result and Discussion

This study produced SDGs-Integrated Carousel-Based Microlearning Content on the subtopic of environmental pollution, presented via the Instagram platform in a carousel format. The content consists of 18 posts, each measuring 1080 × 1350 pixels (4:5 aspect ratio), designed based on the principles of microlearning, namely, the presentation of material in a concise, focused, and easily accessible manner via digital devices. By presenting the material in concise learning units, students can learn concepts more flexibly without compromising the essence of the material being studied. These characteristics align with the view of Pebriantika et al. (2024), who state that microlearning presents material in small units, making it easier to understand and learn independently. Furthermore, the use of Instagram as a learning medium also aligns with the characteristics of Generation Z, who are accustomed to accessing information through social media and digital devices (Gherman et al., 2021; Samala et al., 2023). The appearance of the Biology.ez Instagram account, the presentation of material on environmental pollution, and one of the key features of microlearning content are shown in Figures 1, 2, and 3.

Figure 1 Displayof the Biology.ez Instagram account as a learning resource

Figure 2 Display of environmental pollution content in the SDGs-Integrated Carousel-Based Microlearning Content

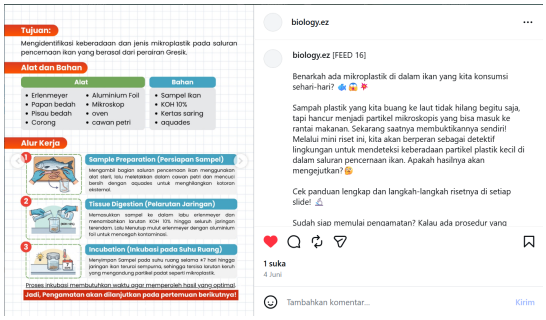

Figure 3 Screenshot of the Bio-Lab feature in the SDGs-Integrated Carousel-Based Microlearning Content

As shown in Figure 1, microlearning content was developed using the Instagram platform so that students could access the learning materials flexibly via digital devices. The material on environmental pollution was presented in stages in a carousel format that combined text, illustrations, and infographics to help students understand the concepts in a more structured way, as shown in Figure 2. In addition to presenting the material, the platform also integrates SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 14 (Life Below Water) through various pollution issues relevant to students' daily lives, making the learning experience more contextual. One feature that supports science literacy skills training is Bio-Lab (see Figure 3), which enables students to conduct mini-research on microplastics and test soil pH. In addition to the Bio-Lab, the platform also includes the Bio-Fact, Bio-Concept, Bio-Analyze, Bio-Action, and Bio-Ask features, which are designed to help students explain scientific phenomena, interpret and evaluate scientific information, and use scientific evidence in decision-making. Thus, the characteristics of the developed media not only support the delivery of material on environmental pollution but also facilitate the development of science literacy skills

in accordance with the OECD's science literacy framework (2023a).

Validity of SDGs-Integrated Carousel-Based Microlearning

The results of the validation of the SDGs-Integrated Carousel-Based Microlearning Content by subject matter experts and media experts are presented in Table 1.

Table 1 Results of the Validation of SDGs-Integrated Carousel-Based Microlearning Content

Aspect	Percentage	Category
Presentation	96.2%	Highly Valid
Content	100.0%	Highly Valid
language	97.7%	Highly Valid
Alignment of Microlearning Content with PBL Syntax in Hands-On Activity 1 (Mini Microplastics Research)	100.0%	Highly Valid
Alignment of Microlearning Content with PBL Syntax in Hands-On Activity 2 (Mini Soil pH Research)	100.0%	Highly Valid
Overall Average for All Aspects (%)	98.8%	Highly Valid

Based on Table 1, the SDGs-Integrated Carousel-Based Microlearning Content achieved an average validity percentage of 98.8%, falling into the "highly valid" category. All evaluation aspects scored above 96%, including presentation suitability at 96.2%, content suitability at 100%, language suitability at 97.7%, and the alignment of the microlearning content with the microplastics mini-research and soil pH mini-research activities, each at 100%.

The high validity score indicates that the content, learning activities, and visual design presented in the carousel format align with the learning objectives and the science literacy skill indicators intended to be developed. The content appropriateness aspect received a 100% score because the materials not only cover the concept of environmental pollution but also integrate sustainability issues through SDGs 12, 13, and 14, as well as activities that encourage students to use scientific knowledge to analyze environmental problems. Integrating real-world contexts into science learning is known to enhance the relevance of the material and support the development of students' science literacy (OECD, 2023b; Leal Filho et al., 2023). Furthermore, presenting the material in a concise and structured carousel format supports the principle of microlearning—that is, delivering information in small units that are easier for students to process

and understand (Pebriantika et al., 2024).

The presentation and linguistic aspects, which were rated as “highly valid,” indicate that the information is organized systematically, is communicative, and is appropriate for high school students. The use of a combination of short texts, illustrations, infographics, and an organized visual layout helps reduce students’ cognitive load when learning complex material. This finding aligns with the Cognitive Theory of Multimedia Learning, which explains that the appropriate integration of visual and verbal elements can enhance conceptual understanding and learning effectiveness (Mayer, 2021). Research by Samala et al. (2023) and Gherman et al. (2021) also shows that learning media based on digital platforms and social media can improve the accessibility of material while maintaining student engagement in the learning process.

A 100% compliance rate for the microplastics mini-research and soil pH mini-research activities indicates that the activities designed within the Bio-Lab feature are well-suited to facilitating the scientific inquiry process. These activities provide students with the opportunity to formulate scientific questions, develop hypotheses, make observations, analyze results, and draw conclusions based on the evidence obtained. Such investigative activities are a crucial component in the development of science literacy because they allow students to construct knowledge through direct scientific experience (OECD, 2023b). Thus, the SDGs-Integrated Carousel-Based Microlearning Content is deemed highly valid and suitable for developing students’ science literacy skills in the subtopic of environmental pollution.

The Practicality of SDGs-Integrated Carousel-Based Microlearning Content

The practicality of SDGs-integrated carousel-based microlearning content was evaluated based on the implementation of the learning activities over three sessions. The results of the learning implementation are presented in Table 2.

Table 2 Results of Learning Implementation Using Carousel-Based Microlearning Content

Aspects of observation	Percentage	Category
Session 1	94%	Highly implemented

Session 2	100%	Highly implemented
Session 3	95%	Highly implemented
Average	96.3%	Highly implemented

Based on Table 2, the implementation of learning using SDGs-Integrated Carousel-Based Microlearning Content achieved an average percentage of 96.3%, falling into the “very implemented” category. The implementation percentages for the first, second, and third sessions were 94%, 100%, and 95%, respectively. These results indicate that all stages of the learning process were carried out in accordance with the established design. The high level of implementation suggests that the medium was easy to use for both teachers and students during the learning process. Presenting the material in a carousel format allowed information to be delivered gradually and in a structured manner, making it easier for students to follow the learning flow. These characteristics align with the principles of microlearning, which presents material in short, focused learning units, making it more accessible and easier for students to learn (Pebriantika et al., 2024). Furthermore, the use of Instagram as a learning platform also facilitates access, as it is a medium with which Generation Z is already familiar (Gherman et al., 2021; Samala et al., 2023). Thus, the SDGs-Integrated Carousel-Based Microlearning Content is considered highly practical in terms of learning implementation.

Next, the practicality of the medium was also assessed based on students’ responses to the use of SDGs-Integrated Carousel-Based Microlearning Content. The results of the students’ responses are presented in Table 3.

Table 3 Results of Student Responses to Carousel-Based Microlearning Content

Aspect	Percentage	Category
Readability	97.3%	Highly practical
Presentation	97.7%	Highly practical
Content	100%	Highly practical
Language	96%	Highly practical
Average	98.6%	Highly practical

Based on Table 3, student responses achieved an average percentage of 98.6%, falling into the “very practical” category. All evaluation aspects received percentages above 96%, including readability at 97.3%, presentation at 97.7%, content at 100%, and language at 96%. The high student response rate indicates that the

developed media is capable of meeting students' learning needs in terms of both content and presentation. The content aspect, which received a 100% rating, indicates that the material on environmental pollution presented was deemed relevant, easy to understand, and helped students learn the concepts in a more meaningful way. Meanwhile, the high ratings for readability, presentation, and language quality show that the use of communicative language, engaging illustrations, and a systematic layout make it easier for students to understand the information presented. According to Mayer (2021), a well-organized combination of visual and verbal elements can help students process information more effectively. In addition, the Bio-Fact, Bio-Concept, Bio-Lab, Bio-Analyze, Bio-Action, and Bio-Ask features also encourage students to actively engage in learning through observation, investigation, data analysis, and environmental problem-solving. These findings align with the research by Samala et al. (2023) and Pebriantika et al. (2024), which show that microlearning can increase student engagement and provide a more flexible learning experience. Therefore, based on student responses, the SDGs-Integrated Carousel-Based Microlearning Content is deemed highly practical for use in learning.

The Effectiveness of SDGs-Integrated Carousel-Based Microlearning Content

The effectiveness of SDGs-Integrated Carousel-Based Microlearning Content was assessed based on improvements in students' science literacy skills after participating in lessons using the developed media. This improvement was analyzed using pretest and posttest results, normality tests, paired-sample t-tests, N-Gain, and the achievement of science literacy indicators. The average pretest and posttest scores for students' science literacy skills are presented in Table 4.

Table 4 Results of the Pretest and Posttest on Students' Science Literacy Skills

Test	Average
Pretest	52.8
Possttes	86.2

Based on Table 4, students' average pretest score was 52.8 and increased to 86.2 on the posttest. These results indicate an improvement in students' science literacy skills following instruction using SDGs-Integrated Carousel-Based Microlearning Content. Before testing the hypotheses, the pretest

and posttest data were tested for normality using the Shapiro-Wilk test to determine the data distribution. The results of the normality test are presented in Table 5.

Table 5 Results of the Shapiro-Wilk Normality Test

Variabel	df	Sig.	Keterangan
Pretest	25	0.057	Normal
Posttest	25	0.601	Normal
Selisih	25	0.074	Normal

Based on Table 5, the significance value for the pretest was 0.057, for the posttest was 0.601, and the difference in scores was 0.074. All significance values were greater than 0.05, indicating that the data were normally distributed and met the criteria for a parametric test using a paired-sample t-test. After the data were confirmed to be normally distributed, a Paired-Sample t-test was conducted to determine the significance of the difference between students' pretest and posttest science literacy scores. The results of the Paired-Sample t-test are presented in Table 6.

Table 6 Results of the Paired-Sample t-Test

Data Pairs	t	df	Sig. (2-tailed)
Posttets-Pretest	-17.772	24	0.000

Based on Table 6, a significance value (Sig., 2-tailed) of 0.000 (<0.05) was obtained; therefore, H_0 was rejected and H_1 was accepted. These results indicate that there is a significant difference between students' pretest and posttest science literacy scores after using the SDGs-Integrated Carousel-Based Microlearning Content. The magnitude of the improvement in students' science literacy skills was further analyzed using the N-Gain test. The N-Gain calculation results are presented in Table 7.

Tabel 7. Hasil N-Gain Keterampilan Literasi Sains

N	Min	Max	Mean N-Gain	Kategori
25	0.42	0.83	0.7035	Tinggi

Based on Table 7, the average N-Gain score was 0.7035, which falls into the "high" category. These results indicate that the use of SDGs-Integrated Carousel-Based Microlearning Content is effective in improving students' science literacy skills in the subtopic of environmental pollution. To determine the improvement in each science literacy skill indicator, an analysis of indicator achievement was conducted based on the pretest and posttest results. The percentage of achievement for each indicator is presented in Figure 4.

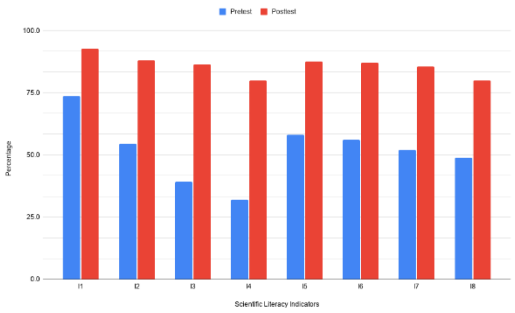

Figure 4: Percentage of Achievement of Science Literacy Skills Indicators on the Pretest and Posttest

Description:

I1 = Identify scientific phenomena

I2 = Explain the causes and effects of scientific phenomena

I3 = Interpret scientific data and evidence

I4 = Evaluate scientific information

I5 = Draw conclusions based on scientific evidence

I6 = Determine solutions to sustainable development issues

I7 = Formulate scientific questions

I8 = Formulate hypotheses

The results of this study indicate that SDGs-Integrated Carousel-Based Microlearning Content is effective in developing students' science literacy skills in the subtopic of environmental pollution. This effectiveness is demonstrated by improvements in science literacy skills across all measured indicators and is supported by statistical analysis showing an increase in students' abilities following instruction using the developed media. These findings indicate that microlearning content not only serves as a medium for conveying information but is also capable of facilitating the development of science literacy competencies through contextual, interactive, and environmental problem-solving-oriented learning. This is in line with the OECD (2023b) science literacy framework, which emphasizes the ability to explain scientific phenomena, interpret scientific data and evidence, and use scientific knowledge to make responsible decisions.

This improvement in science literacy skills is supported by the media's features, which combine concise presentation of material through the Bio-Fact and Bio-Concept features, investigative activities through Bio-Lab, and analysis of environmental issues through Bio-Analyze and Bio-Action. As shown in Figure 4, the indicators for formulating scientific questions and formulating hypotheses showed a significant increase after the learning activity. These results indicate that the microplastic mini-research activity and soil pH measurement provided a scientific inquiry experience that encouraged students to identify problems, formulate

tentative hypotheses, make observations, and draw conclusions based on the evidence obtained. According to the National Research Council (2000) and Lederman et al. (2014), student engagement in the scientific inquiry process is a crucial component in the development of science literacy because it cultivates scientific thinking skills and evidence-based reasoning. Furthermore, presenting material in a concise and structured microlearning format also helps students understand complex scientific concepts more effectively (Major & Calandrino, 2018; Nurdiyanti et al., 2026).

Improvements were also observed in the indicators related to interpreting data, evaluating scientific information, and devising solutions to sustainable development issues. These achievements demonstrate that students are able to connect the concept of environmental pollution with various real-world problems presented in the media. The integration of SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 14 (Life Below Water) provides a relevant context for students to analyze environmental issues and determine responsible solutions based on scientific evidence. UNESCO (2020) and Rieckmann (2018) emphasize that SDG-based education must equip students with systems thinking, decision-making, and problem-solving skills to address sustainability challenges. Therefore, improvements across all science literacy skill indicators, accompanied by high-category N-Gain results, indicate that SDGs-Integrated Carousel-Based Microlearning Content is effective for developing students' science literacy skills in the subtopic of environmental pollution.

D. Conclusion

The SDGs-Integrated Carousel-Based Microlearning Content on the subtopic of environmental pollution meets the criteria of validity, practicality, and effectiveness for developing students' science literacy skills. The validity of the media achieved a percentage of 98.8%, falling into the "highly valid" category. The practicality of the media was demonstrated by a learning implementation rate of 96.3% and a student response rate of 98.6%, both of which fall into the "highly practical" category. Furthermore, the media was deemed effective based on the results of a paired-sample t-test, which showed a significance value of 0.000 (<0.05) and an N-Gain value of 0.7035, classified as "high." Thus, the SDGs-Integrated Carousel-Based Microlearning Content is suitable for use as a learning medium to develop

students' science literacy skills in the subtopic of environmental pollution.

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