

## Development of an Environmental Education Toolkit as a Strategy to Enhance Sustainable Environmental Awareness among Senior High School Students

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### ABSTRACT

**Purpose** – This study aimed to develop and evaluate an environmental education toolkit, consisting of a student guidebook and a supporting educational video, as a strategy to enhance sustainable environmental awareness among senior high school students.

**Methodology** – The research employed a Research and Development (R&D) design following the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) with a mixed-methods approach. The research subjects were 45 tenth-grade students of SMA Negeri 1 Dolok Silau, yielding N = 45 for the paired pretest-posttest comparisons. Data were collected through observation, questionnaires, tests, interviews, and documentation, and analyzed using the paired-samples t-test and the normalized gain (N-Gain) formula.

**Findings** – The needs analysis revealed that the school environment was not yet optimally organized and that students' environmental awareness had not developed independently, despite a fairly high level of readiness within the school community (88.2%). Validation by material, media, and education experts yielded average feasibility scores of 92.9%, 94.4%, and 94.2%, respectively, while the research instruments were rated 96%, giving an overall feasibility of 94.4% (very feasible). Paired-samples t-tests showed significant increases in both cognitive knowledge (62.89 to 85.04;  $t = 10.694$ ,  $df = 44$ ,  $p < 0.001$ ) and environmental awareness (77.55% to 89.88%;  $t = 10.441$ ,  $df = 44$ ,  $p < 0.001$ ), with moderate N-Gain scores of 0.550 and 0.529, respectively. Behavioral observation indicated a steady increase in pro-environmental participation from 52.50% to 96.88% across the implementation sessions.

**Contribution** – These findings indicate that the developed toolkit is valid, practical, and effective in fostering students' cognitive, affective, and behavioral environmental awareness, offering a replicable model for contextual environmental education in secondary schools.

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## INTRODUCTION

A well-organized, clean, and conducive school environment plays an important role in shaping students' environmental care, discipline, and clean-living habits. Learning environment and habituation theory affirms that the physical and social environment of a school serves as a vehicle for value and character formation through repeated, authentic experiences in students' daily lives (Pane & Patriana, 2016; Widyaningrum, 2016). However, not every school can manage its physical environment optimally as an educational resource, indicating that environmental issues in education remain a relevant challenge closely tied to broader environmental problems. Instilling environmental care from an early age has been further positioned as a preventive strategy against ecological disasters (Jayawardana, 2016).

Globally, environmental crises such as climate change, pollution, and biodiversity loss are increasingly alarming and significantly impact the sustainability of human life (IPCC, 2023; UNEP, 2022). Addressing these problems requires not only technical and policy interventions, but also changes in societal awareness, attitudes, and behavior. In this context, young people, particularly students, play a strategic role as agents of change, expected to cultivate environmentally friendly behavior in a sustainable manner (UNESCO, 2020; Suhartini et al., 2025).

Various environmental education efforts have been undertaken in schools by integrating environmental content into formal curriculum subjects, such as natural science, and through environmentally oriented school programs, including the Adiwiyata Program (Kementerian Lingkungan Hidup dan Kehutanan, 2018; Fortuna et al., 2023). Similar efforts have also been documented in teacher-training initiatives supporting the Adiwiyata Mandiri program (Rahayu et al., 2024). Nevertheless, an increase in cognitive knowledge about the environment does not automatically translate into behavioral change. Knowledge acquired in the classroom is often not internalized into students' daily practice, particularly when the school environment does not yet fully support the habituation of environmentally friendly behavior. This condition points to a persistent gap between formally taught environmental knowledge and students' actual behavior in everyday school life, a gap that is widely reported at the policy level but whose precise operational form only becomes visible when specific school settings are examined more closely.

Schools have a range of approaches to strengthening students' environmental awareness, from reinforcing the formal curriculum and offering environmentally themed extracurricular activities to school projects that promote contextual learning (Khaerani et al., 2020; Alpusari et al., 2025). However, the effectiveness of these approaches depends heavily on the availability of a systematic, easily implemented educational tool supported by adequate school conditions; without a clear tool and implementation guide, environmental programs such as Adiwiyata tend to remain incidental at the school level even where the policy framework itself is well established, and have not been able to shape pro-environmental behavior consistently. One school in which this general constraint takes a concrete, locally specific form is SMA Negeri 1 Dolok Silau.

A preliminary observation conducted at SMA Negeri 1 Dolok Silau showed that the school's environmental conditions did not yet fully support optimal environmental education. The physical environment was poorly arranged, green open space was not well managed, plant diversity was very limited, and supporting facilities such as environmental campaign posters, reading gardens, and environment-based learning media were almost unavailable. These conditions were reflected in student behavior that did not yet demonstrate environmental care, such as littering habits and low student involvement in maintaining school cleanliness. A subsequent perception questionnaire distributed to school stakeholders indicated that, although the environmental conditions were judged not yet ideal (69.8% of the maximum score), stakeholders showed high readiness to change (88.2%), suggesting that the core problem was not resistance among the school community but the absence of a systematic and applicable environmental education tool suited to the school's condition.

Based on these conditions, this study was conducted at SMA Negeri 1 Dolok Silau, Simalungun Regency, with a focus on developing an environmental education toolkit comprising a guidebook and an educational video. Conceptually, the toolkit is grounded in complementary cognitive and behavioral perspectives on learning. From a cognitive standpoint, presenting the same environmental content through a print guidebook

and a corresponding audio-visual video is consistent with the dual-channel assumption of multimedia learning theory, which holds that verbal and pictorial information processed through separate channels can be integrated into a more coherent and durable mental representation than either medium could produce alone, provided that extraneous cognitive load is minimized through clear layout, legible text, and well-signaled navigation (Mayer, 2009; Sweller, 1988). From a behavioral standpoint, the guidebook's structured activities, reflection prompts, and repeated habituation routines function as a deliberate system of modeling, guided practice, and self-reinforcement, in line with social cognitive theory's account of how observation, repeated performance, and feedback progressively shape durable behavioral patterns rather than momentary compliance (Bandura, 1986). Understood in this way, the toolkit is not merely an instructional supplement but a theoretically grounded mechanism intended to move students from cognitive awareness toward internalized, self-sustained pro-environmental habits, strengthened through school-culture reinforcement and habituation, with limited facilitation from the researcher to ensure the guidebook could be applied realistically according to the school's conditions. Increasing environmental knowledge alone does not automatically lead to changes in attitudes and actual behavior; without structured intervention, this gap risks producing a generation that understands environmental issues theoretically but has not learned to translate that understanding into concrete action (Lange & Dewitte, 2019; Sutrisno et al., 2026).

Through a Research and Development (R&D) approach, this study aimed to produce a contextually relevant, applicable, and adaptive environmental education toolkit that could serve as a model for replication in other schools with similar characteristics. The novelty of this study lies not merely in its geographic setting, but in the way it integrates several elements that are rarely combined within a single, empirically validated design: a dual-medium toolkit that deliberately pairs print and audio-visual formats on cognitive and behavioral grounds rather than for convenience; an ADDIE-based development process in which expert validation is treated as an iterative refinement mechanism rather than a one-off feasibility check; and a mixed-methods evaluation that simultaneously tracks the cognitive, affective, and psychomotor dimensions of environmental awareness within the same cohort of students. This combination allows the study to address the habituation gap identified above as a systemically designed intervention rather than an isolated instructional add-on. It provides a transferable framework for developing and evaluating similar toolkits in other school contexts facing comparable constraints.

Within this broader framework, the local ecological setting of Simalungun Regency, on the shore of Lake Toba, was deliberately incorporated as a substantive design element rather than a backdrop. Lake Toba's watershed faces well-documented pressures from deforestation, declining water quality, and the spread of the invasive Red Devil fish, which threatens native fish diversity and the livelihoods connected to the lake; embedding these issues directly into the guidebook's content gives students a frame of reference in which environmental concepts are not abstract global phenomena but observable, place-based problems that they and their families may encounter directly. This localization strategy is intended to reinforce the cognitive and behavioral mechanisms outlined above: recognizably local content is more readily encoded and retained, and pro-environmental behaviors modeled around locally salient problems are more likely to be perceived as personally relevant and worth sustaining. The study's contribution, therefore, rests on the combined novelty of its theoretically grounded, dual-medium toolkit design and its deliberate anchoring in the Lake Toba/Simalungun context, which together distinguish it from environmental education studies that address either general pedagogical design or local content, but rarely both within a single, evaluated intervention.

This study is therefore important as an effort to bridge the gap between formally taught environmental knowledge and students' daily practice, so that environmental awareness can grow, develop, and be sustained within school culture. Specifically, this study aimed to:

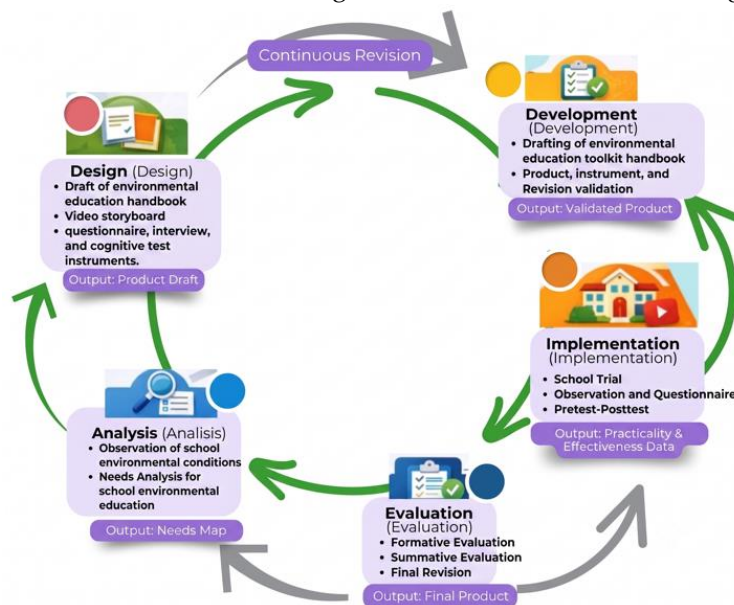
1. Describe students' initial environmental awareness prior to the use of the toolkit;
2. Describe the process of developing the environmental education toolkit;
3. Determine the feasibility of the developed toolkit based on expert validation;
4. Describe the implementation of the toolkit in supporting environmental awareness through habituation and school culture; and
5. Determine the improvement in students' environmental awareness after the toolkit was implemented.

## METHODOLOGY

### Research Design

This study used a Research and Development (R&D) design to produce an educational product and to test its feasibility and effectiveness in a school learning context. The development model applied was ADDIE, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Ramadhana et al., 2022; Oktavian & Ambarwati, 2026). The ADDIE model was chosen for its systematic yet flexible development flow, which allows for continuous evaluation and revision at every stage. A mixed-methods approach was used: a qualitative approach supported the needs analysis and product development stages through limited interviews, field documentation, and observation, while a quantitative approach served as the primary means of measuring the effectiveness of the developed toolkit.

In the Analysis stage, the researcher identified needs and problems related to students' environmental awareness through initial observations, a student needs questionnaire, a limited number of teacher interviews, and documentation of the school environment. In the Design stage, the researcher developed the structure and content of the guidebook, the storyboard for the educational video following a before-process-after narrative, and preliminary designs of supporting products (posters, educational stickers, and simple activity guides), taking into account the characteristics of senior high school students and the principles of contextual learning. In the Development stage, the draft materials were developed into an initial prototype: the guidebook was produced as an e-book with communicative, easy-to-understand language accompanied by activities and simple reflection prompts, while the video documented the initial condition, the implementation process, and the resulting changes. The product was then validated by material, media, and education experts and revised according to their feedback. In the Implementation stage, a limited trial was conducted with tenth-grade students, using the guidebook as the operational reference for environmental activities and habituation, supported by the educational video and other materials. In the Evaluation stage, the feasibility and effectiveness of the toolkit were assessed by integrating expert-validation results, cognitive test results, environmental-awareness questionnaire results, and behavioral-observation data, which were then used to inform final product refinement. A chart illustrating the research flow is shown in Figure 1.



**Figure 1.** Research and development process (ADDIE).

The effectiveness test used a one-group pretest-posttest design involving 45 tenth-grade students, without a control class, because the study focused on the development and limited trial of the product rather than a between-group comparison. Students were given a knowledge test and an environmental-awareness questionnaire before the toolkit was introduced (pretest). The researcher then acted as a facilitator, introducing the guidebook and explaining its objectives, structure, and implementation mechanism for a six-week, nine-

meeting period, with teachers serving as classroom companions and observers. Implementation activities included the socialization of environmental issues, waste-sorting habituation, planting and plant care, classroom environmental organization and cleanliness, an environmental campaign, and a closing reflection with a commitment declaration. On completion of the sequence, students were given a posttest using the same instruments used at the outset.

### **Participant**

The study was conducted at SMA Negeri 1 Dolok Silau, Simalungun Regency, North Sumatra Province, from January to May 2026. The research subjects were 45 tenth-grade students who implemented the toolkit, yielding  $N = 45$  for the paired-samples comparisons. Teachers and other school staff supported the implementation process but were not treated as the primary research subjects. The object of the research was the environmental education toolkit itself, comprising a student guidebook as the main product and supporting materials (an educational video, posters, and activity guides). Sustainable environmental awareness was operationalized through three dimensions: cognitive (environmental knowledge), affective (pro-environmental attitude), and psychomotor (pro-environmental behavior in real school-based action).

### **Data Collection**

Data were collected using five techniques. Observation was carried out at the needs-analysis stage (using a school-environment observation sheet and a student-behavior observation sheet) and during implementation (using an activity observation sheet embedded in the guidebook). Semi-structured, limited interviews were conducted with teachers, vice-principals, and selected students at the needs-analysis and evaluation stages to obtain supporting qualitative data. Questionnaires were administered to assess perceptions of the school environment, stakeholder readiness, and students' attitudes toward environmental care, both before and after implementation. Tests were used to measure students' environmental knowledge before and after implementation. Documentation, including photographs of the school environment before and after implementation and an implementation video, was used to provide empirical, descriptive support for the observation, interview, and test data.

### **Instrument**

The school environment and student behavior observation sheets were scored on a 1-4 scale (1 = very poor, 4 = very good) for 10 pro-environmental behavior indicators. An environmental-care attitude questionnaire, measured on a four-point Likert scale (strongly agree, agree, disagree, strongly disagree), was administered before and after implementation to capture the affective dimension. An environmental knowledge test consisting of 30 multiple-choice items, proportionally developed across three dimensions of Fink's Taxonomy of Significant Learning (Foundational Knowledge, Application, and Integration), was used to measure the cognitive dimension before and after implementation. The developed toolkit (guidebook and educational video) and the research instruments were also assessed using Likert-scale expert-validation sheets covering content feasibility, presentation, language, and appearance, completed by material, media, and education experts.

### **Data Analysis**

Qualitative data from observation, interviews, and documentation were analyzed descriptively through data reduction, data display, and conclusion drawing, with triangulation of technique and source used to strengthen data validity. Quantitative data were analyzed following several steps. Normality was tested using the Shapiro-Wilk test at a significance level of 0.05. Homogeneity of variance was not tested, as this assumption is only relevant to independent-samples comparisons and does not constitute a prerequisite for the paired-samples t-test, which evaluates within-subject differences from the same group measured twice (before and after treatment). When data were normally distributed, hypothesis testing used the paired-samples t-test to compare pretest and posttest scores; otherwise, the non-parametric Wilcoxon Signed-Rank Test would be used as a complementary check. The magnitude of improvement was further analyzed using the normalized gain

(N-Gain), calculated as the ratio between the actual gain score and the maximum possible gain score (Coletta & Steinert, 2020), and interpreted as high ( $g > 0.70$ ), moderate ( $0.30 \leq g < 0.70$ ), or low ( $g < 0.30$ ).

Product feasibility was assessed by material, media, and education experts using Likert-scale validation instruments accompanied by open comment columns, with the feasibility percentage calculated as the obtained score divided by the maximum possible score, multiplied by 100%. The resulting percentages were interpreted using the categories presented in Table 1.

**Table 1.** Categories for interpreting product and instrument feasibility

| Percentage | Category        |
|------------|-----------------|
| 81-100%    | Very Feasible   |
| 61-80%     | Feasible        |
| 41-60%     | Fairly Feasible |
| 21-40%     | Less Feasible   |
| 0-20%      | Not Feasible    |

*Source: adapted from Oktavian and Ambarwati (2026) and Sugiyono (2019)*

## FINDINGS

The results of developing the environmental education toolkit (guidebook and video) are presented according to the five stages of the ADDIE model, from the initial needs analysis through to the implementation and evaluation stages, which measured improvements in students' environmental awareness.

### Analysis Stage

Observation at SMA Negeri 1 Dolok Silau showed that the school had already made efforts toward environmental character formation through class duty rosters, communal work (*kerja bakti*), a weekly clean-up day (*Jumat Bersih*), and the introduction of environmental content in class. However, teacher interviews revealed that the school did not yet have a specific, structured environmental education guide; materials were adjusted only to the availability of existing teaching resources. Teachers, therefore, expressed a strong need for a targeted educational tool to bridge the gap between students' conceptual understanding of the environment and their real-world practice.

A perception questionnaire on the school's environmental conditions indicated an overall score of 69.8%, categorized as good, with the highest score on the environmental values aspect (75.8%) and the lowest on the pro-environmental behavior aspect (63.2%). This finding shows that students already held a favorable perception of the importance of protecting the school environment. At the same time, the application of pro-environmental behavior in daily life still needs strengthening. A subsequent readiness questionnaire for the development of the toolkit showed an average score of 88.2% (very good), with the environmental-values aspect again the highest (91.2%) and the pro-environmental behavior aspect the lowest (85.6%), indicating that students were highly ready to adopt a new environmental education medium. On this basis, the researcher developed a guidebook and educational video designed to provide contextual learning experiences through material, activities, reflection, and enrichment relevant to the school setting.

### Design Stage

The design stage produced an initial framework for the guidebook and the supporting video, adapted to the characteristics of students at SMA Negeri 1 Dolok Silau. The guidebook was designed flexibly and systematically for both classroom learning and habituation activities, presenting contextual content on waste management, climate change, forest fires, and the threat posed by the invasive Red Devil fish species in Lake Toba. The guidebook included active-learning activities, reflection prompts, evaluation sheets, and QR code enrichment links. Its structure comprised a front section (cover, instructions, objectives), a content section

(materials and activities), and a closing section (glossary, references, and author profile). The educational video, meanwhile, was designed as an audio-visual medium to reinforce conceptual understanding in a concrete and self-directed manner. Overall, the toolkit design comprised three main components: the guidebook, the educational video, and an implementation-documentation video, each fully elaborated as a storyboard prior to development. The initial media plan for the designed educational resources is presented in Table 2.

**Table 2.** Environmental Education Tools Design

| Book Cover                                                                         | Preface                                                                            | Instructions for Use                                                                | Chapter 1 Cover                                                                      |
|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|   |   |   |   |
| Sample Content Page                                                                | Motivational Quotes Page                                                           | Final Evaluation                                                                    | Educational Video Display                                                            |
|  |  |  |  |

### Development Stage

Three categories of experts validated the developed prototype: material/content experts, media experts, and education experts, each assessing the guidebook and the video against a Likert-scale instrument. A summary of the validation results for each product component is presented in Table 3.

**Table 3.** Categories for interpreting product and instrument feasibility

| Validator        | Product           | Percentage | Category      |
|------------------|-------------------|------------|---------------|
| Material expert  | Guidebook         | 92.5%      | Very Feasible |
| Material expert  | Educational video | 93.3%      | Very Feasible |
| Media expert     | Guidebook         | 98.75%     | Very Feasible |
| Media expert     | Educational video | 90.0%      | Very Feasible |
| Education expert | Guidebook         | 95.0%      | Very Feasible |

Based on the material expert's assessment, the guidebook obtained a score of 74 out of a maximum 80 (92.5%, very feasible) across the content-feasibility, presentation, language, and appearance aspects. In comparison, the video obtained 56 out of 60 (93.3%, very feasible) across content suitability, visual, audio, and presentation and flow aspects. Revisions were nonetheless made based on validator comments, including clarifying learning objectives and their alignment with the hidden curriculum, restructuring inter-chapter continuity, adding references and concrete examples, and including additional material on conservation, extinction, poaching, and sustainable development.

The media expert rated the guidebook at 79 out of 80 (98.75%, very feasible) and the video at 54 out of 60 (90%, very feasible), yielding a combined media-feasibility average of 94.4%. Revisions following the media expert's feedback included adding usage instructions for the flipbook's navigation and zoom features, enlarging the font size to 12-14 pt for improved mobile readability, integrating interactive multimedia elements such as hyperlinks, QR codes, embedded video, and audio, improving visual and audio quality, and adding variation in camera angles for the video.

The education expert, an academic with a background in biology education who has served as head of the Department of Biology at Universitas Negeri Medan, rated the guidebook at 76 out of 80 (95%, very feasible), covering content feasibility, presentation, language, and appearance. Revisions based on this validator's comments focused on grammatical consistency, replacing vague verbs (such as “understand”) with specific, measurable operational verbs in the learning objectives, adding captions to figures and checkmark symbols to certain activity instructions, reorganizing the weekly activity schedule, and standardizing the reference list to APA format.

In addition to the toolkit itself, the research instruments (the cognitive test, the questionnaire, and the interview guide) were validated by two education experts, obtaining average feasibility scores of 94.7%, 98.3%, and 96.5%, respectively. The recapitulation of all feasibility assessments for the toolkit and the research instruments is presented in Table 4.

**Table 4.** Recapitulation of the feasibility assessment for the toolkit and research instruments

| Validator                        | Percentage | Category      |
|----------------------------------|------------|---------------|
| Material                         | 92.9%      | Very Feasible |
| Media                            | 94.4%      | Very Feasible |
| Education (toolkit)              | 94.2%      | Very Feasible |
| Education (research instruments) | 96.0%      | Very Feasible |
| Overall average                  | 94.4%      | Very Feasible |

### Implementation Stage

Implementation was carried out over nine structured meetings. In the first meeting, students' initial conditions were measured through a pretest, questionnaire administration, and interviews. The product was then introduced in the second meeting, followed by cognitive activities and observations in the third and fourth meetings, during which students identified environmental issues, learned waste-sorting procedures, and completed an independent home assignment to audit their environmentally friendly habits. From the fifth to the seventh meeting, activities shifted to concrete action, including an environmental project involving planting and plant care, environmental organization and cleanliness, and an environmental campaign. The sequence concluded with reflection, the formulation of environmental solutions, and a joint commitment declaration in the eighth meeting, and closed in the ninth meeting with the posttest, a final questionnaire, closing interviews, and the installation of an environmental campaign banner.

### Improvement in Environmental Knowledge

The average cognitive-test score increased from 62.89 at pretest to 85.04 at posttest (N = 45). A Shapiro-Wilk normality test confirmed that the pretest ( $p = 0.717$ ), the posttest ( $p = 0.589$ ), and the pretest-posttest difference ( $p = 0.076$ ) were all normally distributed; homogeneity of variance was not tested, as it is not a prerequisite for the paired-samples t-test. A paired-samples t-test showed a statistically significant improvement ( $t = 10.694$ ,  $df = 44$ ,  $p < 0.001$ ), with an overall N-Gain of 0.550 (moderate). When analyzed by cognitive domain following Fink's Taxonomy, the largest gain occurred in Foundational Knowledge (N-Gain = 0.875, high), followed by Application (N-Gain = 0.645, moderate) and Integration (N-Gain = 0.025, low), as shown in Table 5.

**Table 5.** N-Gain analysis of students' environmental knowledge by cognitive domain

| Domain                 | Mean Pretest | Mean Posttest | N-Gain | Category |
|------------------------|--------------|---------------|--------|----------|
| Foundational Knowledge | 5.20         | 9.40          | 0.875  | High     |
| Application            | 6.31         | 8.69          | 0.645  | Moderate |
| Integration            | 7.36         | 7.42          | 0.025  | Low      |
| Average                | 6.29         | 8.50          | 0.515  | Moderate |

### Improvement in Environmental Awareness

The environmental-awareness questionnaire showed an increase in average score from 77.55% at pretest to 89.88% at posttest (N = 45), with an overall N-Gain of 0.549 (moderate). A paired-samples t-test on the raw

questionnaire scores confirmed a statistically significant improvement ( $t = 10.441$ ,  $df = 44$ ,  $p < 0.001$ ; mean difference = 12.34). When broken down by aspect, the largest improvement occurred in the environmental-care (peduli lingkungan) aspect, followed by the environmental-knowledge aspect. In contrast, the pro-environmental behavior aspect showed the smallest gain, as shown in Table 6.

**Table 6.** N-Gain analysis of students' environmental awareness by aspect

| Aspect                     | Initial Condition | Final Condition | N-Gain | Category |
|----------------------------|-------------------|-----------------|--------|----------|
| Environmental knowledge    | 79.54%            | 90.00%          | 0.511  | Moderate |
| Environmental care         | 76.11%            | 91.36%          | 0.638  | Moderate |
| Pro-environmental behavior | 77.65%            | 88.33%          | 0.478  | Moderate |
| Average                    | 77.77%            | 89.90%          | 0.542  | Moderate |

Interview data collected before and after implementation corroborated these quantitative findings. Before implementation, students generally already understood the importance of maintaining cleanliness, but their engagement was largely driven by school rules rather than personal initiative. After implementation, students demonstrated improved conceptual understanding of environmental issues, more active participation in environmental activities, more consistent application of environmentally friendly behaviors, and greater initiative in taking positive environmental action, including transferring these habits to their home environment, such as watering plants and maintaining household cleanliness.

### Development of Pro-Environmental Behavior

Behavioral observation, conducted continuously from the third to the eighth meeting across ten indicators on a 1-4 scale, showed a steady increase in the percentage of pro-environmental behavior from 52.50% at the third meeting to 96.88% at the eighth meeting. When analyzed by indicator, participatory behaviors such as enthusiasm, active discussion, teamwork, environmental concern, responsibility, and the application of environmentally friendly behavior all fell into the very good category (81.25%-87.50%). In contrast, indicators requiring greater independence, such as initiative in taking positive action (73.96%) and consistency in maintaining pro-environmental behavior (76.04%), remained in the good category, as shown in Table 7.

**Table 7.** Observed pro-environmental behavior indicators during implementation

| Indicator                                 | Percentage | Category  |
|-------------------------------------------|------------|-----------|
| Enthusiasm for participating              | 83.33%     | Very Good |
| Active discussion/participation           | 85.42%     | Very Good |
| Teamwork                                  | 85.42%     | Very Good |
| Environmental concern                     | 81.25%     | Very Good |
| Responsibility for tasks                  | 87.50%     | Very Good |
| Application of pro-environmental behavior | 83.33%     | Very Good |
| Waste-sorting awareness                   | 76.04%     | Good      |
| Discipline during activities              | 79.17%     | Good      |
| Initiative in positive action             | 73.96%     | Good      |
| Consistency in pro-environmental behavior | 76.04%     | Good      |

### Evaluation Stage

The evaluation stage integrated the results of expert validation, the cognitive test, the environmental-awareness questionnaire, and behavioral observation and documentation to assess the overall feasibility and effectiveness of the developed toolkit. Findings from each data source consistently indicated that the guidebook and educational video are feasible, well-received, and effective in improving students' environmental knowledge, awareness, and behavior. On this basis, the toolkit was confirmed as suitable for use as a strategy to enhance sustainable environmental awareness through habituation and school-culture reinforcement, while remaining open to further refinement, particularly in the range of learning activities and the long-term implementation strategy.

## DISCUSSION

Discussion of the findings is organized following the same five ADDIE stages used to structure the Findings section, linking the results obtained at each stage to relevant theory and prior research.

### Analysis Stage

Rather than confirming a simple lack of environmental awareness, the initial investigation at SMA Negeri 1 Dolok Silau pointed to a more specific problem: the school already possessed favorable conditions for change but lacked the instruments to convert them into sustained practice. The physical environment was poorly arranged, and supporting facilities were minimal. At the same time, environmental content was still delivered through incidental, unstructured activities such as duty rosters and communal work rather than a systematic educational tool. Read against learning-environment and habituation theory, which holds that the physical and social environment of a school functions as a vehicle for character formation only when it is deliberately organized and sustained (Pane & Patriana, 2016; Widyaningrum, 2016), this pattern is telling: the school's routines already contained the raw material for habituation, but without deliberate organization they remained isolated events rather than a cumulative developmental experience. This interpretation is reinforced by the juxtaposition of a relatively high readiness score among stakeholders (88.2%) against a still-developing behavioral score (69.8%, with the pro-environmental behavior aspect lowest at 63.2%), which together indicate that the core barrier was motivational readiness meeting an absence of structure, not resistance within the school community. The finding is consistent with the broader argument that increases in environmental knowledge alone do not automatically produce behavioral change unless supported by structured intervention (Lange & Dewitte, 2019; Sutrisno et al., 2026), and it supplied the empirical justification for developing a toolkit that specifically targets this habituation gap.

### Design Stage

Two design decisions in this stage merit closer scrutiny than a straightforward "content plus format" description would suggest. The first was the decision to anchor the guidebook's material to issues directly observable in the school's surroundings, such as waste management, climate change, forest fires, and the invasive Red Devil fish in Lake Toba, rather than to generic environmental topics. This choice reflects the view that environmental education media are more effective when they integrate socio-scientific issues that are close to learners' lived experience, so that the content does not remain abstract or detached from students' daily lives (Wahyuni & Mustadi, 2016; Wiryanti, 2017). The second was the decision to pair a print guidebook with a complementary audio-visual video rather than relying on a single medium; this followed directly from the cognitive rationale introduced earlier, in that presenting content through both verbal-textual and visual-audio channels was intended to support integration across dual processing pathways rather than simply to offer variety (Mayer, 2009). Existing evidence that digital and audio-visual tools strengthen sustainability awareness, specifically when they complement, rather than replace, structured print materials (Hajj-Hassan et al., 2024), lends further support to this dual-medium strategy, suggesting that the two design decisions, contextual grounding and dual-channel format, were mutually reinforcing rather than independent choices.

### Development Stage

The overall feasibility average of 94.4% (very feasible) echoes previous work showing that systematically designed learning tools have strong potential to strengthen environmental care (Kurnia & Suryadharma, 2016; Sholahuddin et al., 2021), but the more informative story lies not in that aggregate figure, but in the pattern of revisions the three expert categories requested to reach it, a pattern that clarifies what "quality" meant in practice for this product. Two of the media expert's requests are particularly instructive. The first adds explicit usage instructions for the flipbook's navigation and zoom features, responding to a well-recognized usability problem in digital reading formats: when readers must expend effort discovering how to operate an interface before they can engage with its content, that effort constitutes extraneous cognitive load that competes directly with the load required to process the material itself (Sweller, 1988). Embedding navigation instructions inside the guidebook, rather than leaving them to be inferred, is therefore not a cosmetic fix but a change that protects

the cognitive resources adolescent readers have available for actually learning the environmental content. The second, enlarging the font to 12–14 pt for improved mobile readability, addresses a related but distinct concern: text that is difficult to decode on a small screen imposes a perceptual cost before comprehension can even begin, a cost disproportionately borne by readers who, unlike adult validators reviewing the material analytically, are reading for sustained engagement rather than critical evaluation. Read alongside the multimedia principle that coherent, well-signaled presentation supports rather than competes with meaning-making (Mayer, 2009), both revisions can be understood as adjustments to the toolkit's digital ergonomics made specifically to protect its cognitive effectiveness for a senior-high-school audience, rather than as incidental formatting notes. The remaining revisions clarify learning objectives and their alignment with the hidden curriculum, restructuring inter-chapter continuity, replacing vague verbs with measurable operational verbs, and integrating interactive multimedia elements such as hyperlinks, QR codes, and embedded audio points in a complementary direction, toward strengthening pedagogical precision and multimodal richness once the material can actually be read and navigated with minimal friction. Taken together, this pattern suggests that expert validation in this study did not function merely as a gatekeeping step confirming an already-adequate product, but as an iterative diagnostic process that separately addressed the toolkit's readability, navigability, and pedagogical clarity, three dimensions that a single aggregate feasibility percentage cannot, by itself, distinguish.

### **Implementation Stage**

Not all of the cognitive gains observed in this study carry the same instructional meaning. The largest gain occurred in Foundational Knowledge, followed by a moderate gain in Application and a negligible gain in Integration, a gradient suggesting that the toolkit was considerably more effective at building basic conceptual understanding than at cultivating higher-order reasoning. This is broadly consistent with the observation that innovative learning interventions tend to transfer basic knowledge relatively easily, because students absorb theoretical information more readily than they develop the reasoning required to apply and integrate it (Lange & Dewitte, 2019; Suyitno et al., 2025), and it echoes the broader knowledge-behavior gap reported in environmental-education literature, in which strong foundational knowledge does not automatically translate into advanced analytical or applied competence (Hajj-Hassan et al., 2024). Rather than treating this as a shortfall of the toolkit, it is more accurately read as a boundary condition on what a single, relatively short intervention can be expected to achieve: reaching the level of applied problem integration is likely to require a longer period of reasoning practice and more varied case-based tasks than nine meetings can provide.

Direct engagement appears to have done more work in this study than content exposure alone. The moderate overall N-Gain in environmental awareness tracked closely with students' hands-on participation in waste sorting, school-environment organization, planting, and environmental campaigns, suggesting that it was the doing, not only the knowing, that moved the affective dimension. This is consistent with evidence that participatory environmental education fosters more meaningful awareness than content delivery alone (De Feo, 2026; Utami, 2026), and it supports the broader argument that direct, hands-on experience is more effective than theory alone in shifting an individual's underlying environmental attitudes (Candra et al., 2019; Deswita & Firmansyah, 2020).

The gap between participatory indicators (enthusiasm, discussion, teamwork, responsibility) and independence-related indicators (initiative in positive action, consistency in pro-environmental behavior) is often explained in studies of this kind simply by the short duration of the intervention. That explanation is incomplete here. A closer look at how the toolkit was actually used during implementation suggests that at least part of the gap reflects operational and technical constraints specific to this school setting rather than duration alone. First, several of the guidebook's enrichment features QR-code links to supplementary material and embedded video content depend on stable internet access and personal mobile devices, neither of which could be assumed uniformly across a rural, tenth-grade cohort; where connectivity or device access was inconsistent, students plausibly experienced the digital layer of the toolkit unevenly, diluting exactly the kind of self-directed, independent engagement that the initiative and consistency indicators were designed to

capture. Second, the researcher's role as an external facilitator, while necessary to introduce the toolkit and maintain fidelity to its design, means that the highest-visibility activities in the implementation sequence were also the most closely scaffolded ones; once that scaffolding is withdrawn, behaviors performed reliably under guidance are not guaranteed to persist under the ordinary conditions of daily school life without a comparable structure of teacher-led follow-up. Third, embedding new routines into an existing school schedule already organized around duty rosters, communal work, and a weekly clean-up day required activities to compete for time and attention with established habits, and the toolkit's nine-meeting window may simply not have been sufficient to displace or restructure those pre-existing routines. Taken together, these operational and technical limitations suggest that the observed knowledge-behavior gap is not solely a function of insufficient time, but also of infrastructural and institutional conditions that a guidebook and video, however well designed, cannot resolve on their own. This reading is consistent with experiential-learning theory's emphasis on sustained school culture as the mechanism through which behavioral impact becomes durable (Rahmawati et al., 2024; Purwanti, 2017), but it reframes that requirement as depending as much on infrastructural and institutional support reliable access to the toolkit's digital components, and continued teacher-led reinforcement after the research team's involvement ends as on the mere passage of time.

### **Evaluation Stage**

If any single conclusion can be drawn from placing the expert-validation, cognitive-test, questionnaire, and behavioral-observation results side by side, it is that they point in the same direction without depending on one another: the toolkit's technical and pedagogical adequacy, established independently through expert judgment, and its practical effectiveness, established independently through field data, corroborate rather than merely repeat each other. This convergence across independent data sources strengthens confidence in the toolkit's effectiveness beyond what any single measure could demonstrate. It is consistent with recommendations in the R&D literature to triangulate expert judgment with field-trial outcomes before confirming a product's readiness for wider use (Sugiyono, 2019). That confidence, however, should be read within the boundaries of what this specific evaluation design can support.

Two features of the evaluation design in particular limit how far these findings can be generalized. First, the effectiveness test used a one-group pretest-posttest design without a control class. In contrast, this design was appropriate to the study's developmental purpose of testing a specific product rather than comparing instructional methods; it cannot rule out the influence of maturation, concurrent school events, or the practice effect of taking a similar test twice as alternative explanations for the observed pretest-to-posttest gains, alongside the toolkit itself. Second, the sample was drawn from a single school and a single tenth-grade cohort, which constrains the extent to which the specific magnitude of the reported gains can be assumed to hold in schools with different geographic, socio-economic, or ecological characteristics; the toolkit's explicit grounding in Lake Toba-specific content, while a deliberate strength for the population it was designed for, is itself a further constraint on direct transfer to schools outside the Simalungun context without contextual adaptation. Neither limitation undermines the evidence that the toolkit functioned as intended in this setting. However, both indicate that the present findings should be read as evidence of feasibility and promise for a contextually grounded model, rather than as a generalizable claim about the toolkit's effectiveness across school populations.

### **CONCLUSION**

This study concludes that the developed environmental education toolkit, comprising a contextually grounded guidebook and a supporting educational video produced through the ADDIE model, is valid, practical, and effective in enhancing sustainable environmental awareness among senior high school students. Prior to implementation, students already held a favorable perception of the importance of environmental care. However, they had not yet developed independent pro-environmental habits, indicating a readiness that lacked only a systematic instrument for action. Expert validation across material, media, and education dimensions confirmed that the toolkit and its accompanying research instruments met the very feasible category, while implementation across nine structured meetings produced statistically significant gains in

students' cognitive knowledge and environmental awareness, together with a steady increase in observed pro-environmental behavior over the course of the intervention. Within the cognitive domain, gains were strongest for foundational knowledge and comparatively modest for applied and integrative reasoning, indicating that these higher-order competencies require longer-term habituation than a single implementation cycle can provide.

Beyond these developmental findings, the study carries direct practical implications for how schools translate environmental policy into daily practice. For teachers, the guidebook is designed to function as a ready-to-use lesson companion rather than a supplementary reading: its activity sheets, reflection prompts, and QR-code enrichment links can be incorporated directly into existing biology or natural-science lessons, or used to structure the environmental content of extracurricular and project-based activities, without requiring teachers to design new instructional materials from scratch. For schools, and particularly for those pursuing or maintaining *Adiwiyata* status, the toolkit offers a concrete operational bridge between the program's broader environmental-management requirements and the classroom- and habituation-level activities needed to meet them: the guidebook's weekly activity structure can be mapped onto existing routines such as duty rosters, communal work, and clean-up days, converting these into a more systematic habituation sequence rather than a set of isolated events, while the educational video and campaign materials can support the documentation evidence that *Adiwiyata* assessment typically requires. For education policymakers and teacher-training programs, the study offers a replicable development model rather than a fixed product: the ADDIE-based process of needs analysis, contextual content design, iterative expert validation, and mixed-methods evaluation demonstrated here can be adapted by other schools or districts to produce their own locally grounded toolkits addressing environmental issues specific to their setting, in the same way this study anchored its content in Lake Toba-specific concerns.

These conclusions should be read alongside the study's methodological boundaries. The evaluation relied on a one-group pretest-posttest design without a control class, a choice suited to testing a specific product's feasibility and effectiveness but one that cannot fully rule out maturation, concurrent school events, or testing effects as contributors to the observed gains alongside the toolkit itself. The behavioral-observation data, though triangulated with questionnaire and interview findings, were also collected by observers whose presence during a research intervention may itself have influenced how consistently students displayed pro-environmental behavior, a reactivity that a longer-term, less visibly "observed" follow-up would help to disentangle. In addition, the sample was limited to tenth-grade students in a single school, which restricts the extent to which the specific pattern and magnitude of results can be assumed to generalize to schools with different geographic, socio-economic, or ecological profiles.

Future research should therefore move in directions that directly address these boundaries rather than repeating the present design at a larger scale. A quasi-experimental design incorporating a matched control class, or a multi-site trial across several *Adiwiyata* and non-*Adiwiyata* schools within the same region, would allow the toolkit's effects to be distinguished more confidently from maturation and testing effects. A longitudinal follow-up assessing students' pro-environmental behavior three to six months after the intervention window closes would test whether the habits observed during implementation persist once the researcher's direct facilitation is withdrawn. Given the toolkit's reliance on QR codes and video-based enrichment content, future studies could also incorporate simple digital-engagement analytics, such as scan or view frequency, to examine whether variation in digital-component usage is associated with variation in learning and behavioral outcomes, and to clarify how far the operational and infrastructural constraints identified in this study's rural setting shape those outcomes. Finally, replicating the development process in schools anchored in different local ecological contexts would help determine whether the contextualization strategy used here for Lake Toba-specific content is a transferable principle or a setting-specific advantage.

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