Journal of Academic Biology and Biology Education
Vol. 3, No. 1, June 2026, pp. 96~109
ISSN: 3062-9705, DOI: 10.37251/jouabe.v3i1.3375

Fostering Environmental Care Attitudes through the Implementation of the Science-Technology-Society Learning Model in Elementary Schools

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Article Info

Article history:

Received Mar 21, 2026
Revised Apr 25, 2026
Accepted Jun 1, 2026
Online First Jun 4, 2026

Keywords:

Elementary School Students
Environmental Care Attitude
Science-Technology-Society
Sustainability Education
Sustainable Development Goals

ABSTRACT

Purpose of the study: This study investigated the implementation of the Science-Technology-Society learning model and its effectiveness in improving environmental care attitudes among elementary school students through contextual learning activities that integrate scientific concepts, technological developments, and environmental issues relevant to daily life.

Methodology: A Classroom Action Research design based on the Kemmis and McTaggart model was employed, involving planning, action, observation, and reflection stages conducted over three cycles. The participants were 23 elementary school students in Kampala District, Uganda. Data were collected using environmental care attitude observation sheets and Likert-scale questionnaires. Quantitative data were analyzed using descriptive statistics and percentage calculations, while qualitative data were examined through the interactive analysis model of Miles and Huberman.

Main Findings: The results showed a continuous improvement in students' environmental care attitudes throughout the intervention. Achievement levels increased from 69.28% in the pre-intervention stage to 77.79% in Cycle I, 79.71% in Cycle II, and 85.94% in Cycle III. Students demonstrated greater responsibility for maintaining environmental cleanliness, managing waste, caring for plants, and practicing environmentally responsible behavior in both learning activities and daily school routines.

Novelty/Originality of this study: This study contributes to environmental education research by identifying how the implementation stages of the Science-Technology-Society learning model foster environmental care attitudes among elementary school students. The findings provide evidence that contextual science learning can effectively promote environmental awareness and support sustainability education, contributing to the achievement of Sustainable Development Goals through character development at the primary education level.

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1. INTRODUCTION

Sustainable development is a global agenda that continues to be strengthened through the Sustainable Development Goals (SDGs) launched by the United Nations. One goal closely linked to education is Sustainable

Development Goal 4, which focuses on quality education, specifically Target 4.7, which emphasizes the importance of ensuring all students acquire the knowledge and skills to support sustainable development [1], [2]. Education serves not only to improve academic abilities but also to foster students' awareness and responsibility for various social and environmental issues [3], [4]. In this context, schools play a crucial role in preparing a generation capable of contributing to environmental sustainability [5], [6]. Therefore, environmental education is a key instrument in supporting the achievement of the SDGs.

Current environmental issues are increasingly complex and occur at various scales, from the local to the global level. Environmental pollution, climate change, exploitation of natural resources, and increasing waste volumes demonstrate that various conservation efforts have not been fully effective in changing people's behavior sustainably [7], [8]. This situation is closely related to Sustainable Development Goal 13, which addresses climate change, and Sustainable Development Goal 12, which addresses responsible consumption and production [9], [10]. Achieving these two goals requires active community participation, supported by environmentally conscious attitudes and behaviors [11], [12]. Therefore, fostering an environmental attitude from school age is becoming increasingly important in supporting the global sustainable development agenda.

Environmental awareness is an individual's tendency to demonstrate concern, responsibility, and commitment to environmental sustainability through concrete actions [13], [14]. This attitude does not emerge spontaneously but develops through an educational process that enables students to understand the relationship between human activities and their impact on the environment. Various studies have shown that effective environmental education can increase students' awareness, attitudes, and pro-environmental behavior [15], [16]. Therefore, developing learning strategies relevant to environmental issues is a crucial aspect of 21st-century education [17], [18]. Learning that connects scientific concepts with real-world problems in society is considered more effective in fostering an environmentally conscious attitude than learning that focuses solely on mastering concepts.

One approach that demonstrates these characteristics is the Science-Technology-Society learning model. The Science-Technology-Society learning model places emerging issues in society as the learning context, enabling students to understand the interrelationships between science, technology, and everyday life [19], [20]. Through this model, students not only learn scientific concepts but are also encouraged to analyze the social and environmental impacts of scientific and technological developments [21], [22]. Problem-solving-oriented learning activities enable students to actively engage in identifying environmental issues and seeking appropriate alternative solutions [23], [24]. This involvement has the potential to foster stronger environmental awareness and responsibility.

Although various studies have examined environmental education and sustainability-based learning, there are still research gaps that need to be addressed. Research by Chuang et al. [25] found that digital game-based learning can improve environmental literacy and environmental attitudes in elementary school students. Koparan Research [26] showed that the use of augmented reality-assisted text can increase awareness of environmental issues and sustainable development. Meanwhile, Tsai et al. [27] reported that the Science Technology Society learning model is effective in improving students' environmental literacy. However, these studies have focused more on improving environmental literacy, environmental knowledge, or the effectiveness of media and learning models in general. Studies specifically analyzing the implementation steps of the Science Technology Society learning model in developing students' environmental awareness are still very limited.

The novelty of this research lies in its focus on identifying and analyzing the stages of implementation of the Science Technology Society learning model that contribute to improving students' environmental awareness. Unlike previous research, which generally assesses the final outcome in the form of environmental literacy or learning outcomes, this study seeks to explain the learning mechanisms that enable the formation of environmental awareness [28], [29]. Analysis is conducted at each learning stage, from the introduction of environmental issues, exploration of the relationship between science and technology, discussion of the impact on society, to the formulation of solutions to environmental problems. This approach is expected to provide a more comprehensive understanding of the process of developing environmental awareness through science learning [30], [31]. Thus, this research can enrich the development of theory and practice of environmental education based on sustainable development.

The urgency of this research is based on the need to strengthen education's contribution to supporting the achievement of the Sustainable Development Goals, particularly quality education, responsible consumption and production, and climate change mitigation. Increasingly complex environmental challenges require schools to not only produce students who master scientific knowledge but also possess attitudes and responsibilities toward the environment [32], [33]. Learning models that connect science, technology, and society are seen as having great potential to achieve these goals because they provide contextual and life-relevant learning experiences for students. However, information on how the implementation stages of these learning models shape environmental awareness still requires further study [30], [34]. Therefore, this study aims to determine the steps for implementing the Science Technology Society learning model that can improve students' environmental awareness.

2. RESEARCH METHOD

2.1. Type of Research

This study employed Classroom Action Research to enhance students' environmental awareness through the implementation of the Science-Technology-Society learning model [35], [36]. The model was designed to connect scientific concepts, technological developments, and environmental issues, enabling students to develop greater environmental responsibility and awareness. The research followed the Kemmis and McTaggart framework, which consists of planning, action, observation, and reflection stages implemented through repeated cycles to continuously improve learning outcomes [37], [38]. The study was conducted collaboratively between researchers and classroom teachers. Teachers implemented the learning activities, while researchers prepared instructional materials, collected data, conducted observations, and facilitated reflection sessions to evaluate and refine the intervention [39], [40]. This collaboration ensured that the learning model was implemented effectively and aligned with the research objectives. The research involved elementary school students in Kampala District, Uganda, an urban area facing environmental challenges such as waste management issues, pollution, and limited public awareness of environmental conservation. The site was selected because of its relevance to environmental education and its connection to the Sustainable Development Goals, particularly those related to quality education, responsible consumption and production, and climate action.

2.2. Action Research Design

This study used a Classroom Action Research design based on the Kemmis and McTaggart model, which emphasizes continuous improvement through iterative cycles of planning, action, observation, and reflection [41], [42]. The action and observation phases were carried out simultaneously, allowing real-time monitoring of the learning process. The results of observations were used as the basis for reflection to evaluate the effectiveness of the actions, while the reflection outcomes informed improvements for the next cycle. This cyclical process was repeated to ensure progressive enhancement of learning until the success indicators were achieved. The study was conducted in two cycles, with additional cycles planned if necessary. Each cycle included several learning sessions using the Science-Technology-Society learning model, focusing on integrating scientific concepts, technological developments, and societal environmental issues to improve students' environmental awareness [43], [44].

2.3. Data Collection Techniques

Data were collected using observation and questionnaire techniques. Observation was conducted systematically to monitor the development of students' environmental awareness during the learning process. It was guided by structured observation sheets based on indicators such as environmental cleanliness, waste management, participation in environmental conservation activities, and responsibility toward the school environment [45], [46]. These observations were used to identify behavioral changes across each learning cycle. In addition, questionnaires using a Likert scale were administered to measure students' environmental awareness more comprehensively. The instrument included statements related to environmental responsibility, waste management, resource conservation, and involvement in environmental protection activities [47], [48]. The questionnaires were distributed before the intervention and at the end of each cycle to assess changes in students' environmental awareness after the implementation of the Science-Technology-Society learning model. The questionnaire results complemented the observational data, providing a more complete evaluation of the effectiveness of the learning process.

2.4. Data Analysis Techniques

Data analysis was conducted using both quantitative and qualitative approaches to describe the improvement in students' environmental awareness after the implementation of the Science-Technology-Society learning model. Quantitative data from observations and questionnaires were analyzed using descriptive statistics in percentage form [49], [50]. The achievement level was calculated by dividing the obtained score by the maximum score and multiplying it by 100%. Qualitative data from observations and field notes were analyzed using the interactive model of data reduction, data display, and conclusion drawing. In the reduction stage, relevant data were selected and simplified according to the research objectives. The data were then presented in narrative descriptions, tables, and graphs to support interpretation. Finally, conclusions were drawn and verified by continuously reviewing all data collected in each cycle. The integration of quantitative and qualitative findings was used to evaluate the effectiveness of the Science-Technology-Society learning model in improving students' environmental awareness [19], [51]. while ongoing verification ensured the consistency and validity of the results.

2.5. Research Procedures

In general, the research procedure can be seen in Figure 1.

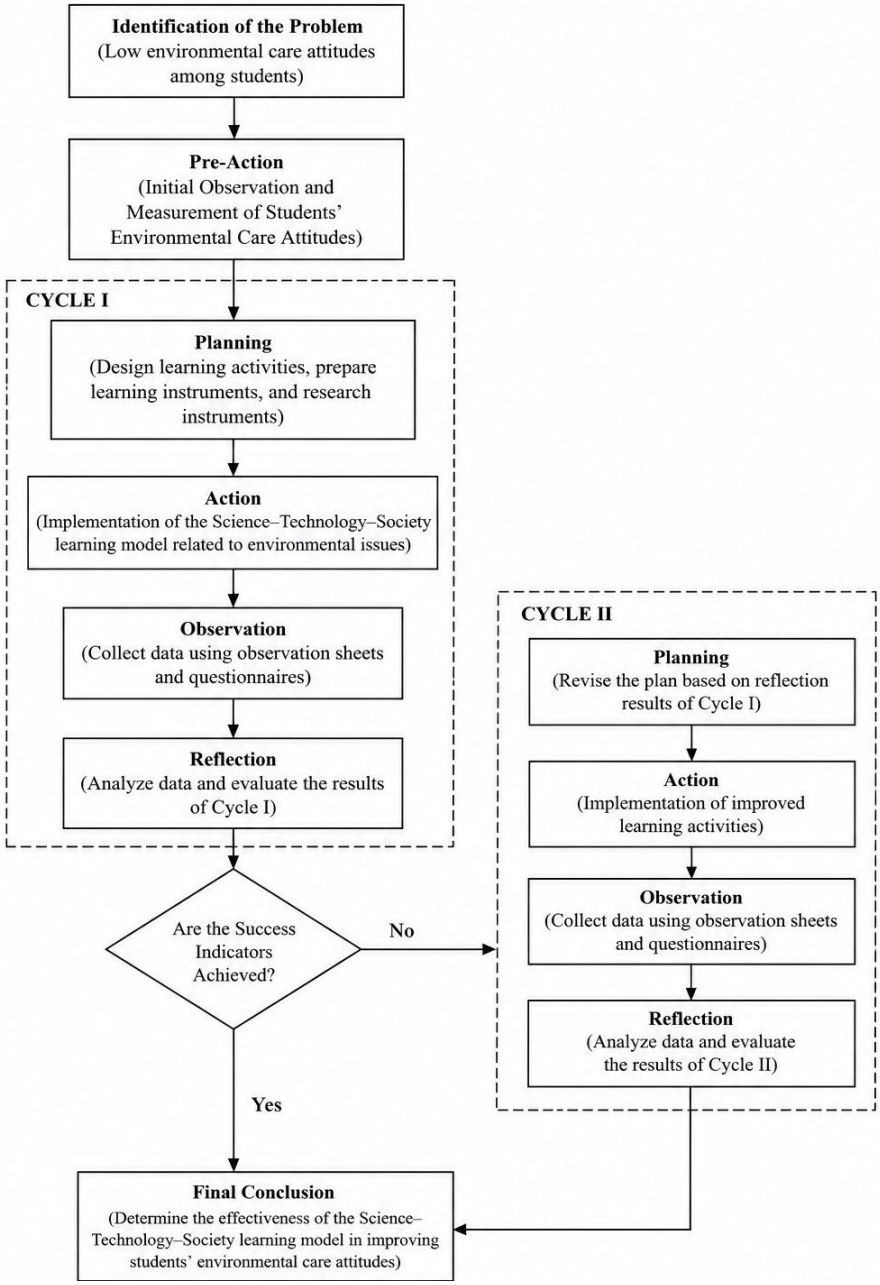

Figure 1. Research Procedure Flowchart

This study was carried out in two cycles based on the Classroom Action Research model developed by Kemmis and McTaggart. Each cycle included four stages: planning, implementation of action, observation, and reflection. During the planning stage, researchers and teachers collaboratively developed learning materials, prepared research instruments, and designed instructional activities using the Science-Technology-Society learning model [52], [53]. In the implementation stage, learning activities were conducted by integrating scientific concepts, technological developments, and environmental issues relevant to students' daily lives. Throughout this process, observations were made to gather data on students' environmental awareness. The collected data were then analyzed during the reflection stage to assess the effectiveness of the actions taken. The results of this reflection were used to refine and improve the next cycle until the predetermined success indicators were achieved.

3. RESULTS AND DISCUSSION

3.1. Results of Cycle I

Observations from Cycle I indicated positive changes in students' environmental awareness following the implementation of the Science, Technology, and Society learning model. Throughout the learning process,

students demonstrated high enthusiasm in participating in various activities related to environmental issues, such as group discussions, simple experiments, and poster creation on environmental conservation themes [31], [54]. Active student engagement during learning indicated that the use of contextual environmental issues increased their attention and participation in learning activities.

Based on observations, most students demonstrated behaviors reflecting environmental awareness, such as disposing of waste according to its type and using experimental materials wisely. However, some students still required teacher guidance to clean equipment and work areas after the practicum activities were completed. Furthermore, personal hygiene habits after learning activities, such as washing hands, also required teacher guidance. These findings indicate that although environmental awareness increased, the formation of consistent habits still requires reinforcement in subsequent cycles.

In addition to observational data, students' environmental awareness was assessed using a questionnaire administered at the end of each cycle. The pre-action results showed that 5 students (22%) were in the high category, while 18 students (78%) were in the medium category, with an average score of 83.13. These findings indicate that before the intervention, most students demonstrated a moderate level of environmental awareness, although it had not yet been fully reflected in their daily behavior. The results obtained at the end of Cycle I showed an improvement compared to the initial condition. This increase suggests that the Science-Technology-Society learning model helped students better understand the relationship between human activities, technological development, and environmental impacts. However, the outcomes of Cycle I had not yet reached the predetermined success indicators, indicating the need for further refinement and improvement in Cycle II.

Table 1. Distribution of Students' Environmental Awareness Attitudes in Cycle I

Category	Score Range (%)	Score Range (%)	Percentage (%)
High	≥ 80	13	56,52
Medium	60–79	10	43,48
Low	< 60	0	0,00
Amount		23	100,00

Table 2. Descriptive Statistics of Environmental Care Attitudes in Cycle I

Statistics	Score
Number of Students	23
Highest Score	116
Lowest Score	70
Total Scores	2147
Average Score	93.35
Percentage of Achievement	77.79%
General Category	Moderate

The results of the environmental awareness questionnaire in Cycle I indicated an improvement compared to the pre-action stage. As shown in Table 1, 13 students (56.52%) were categorized in the high level, while 10 students (43.48%) were in the medium category, and no students were in the low category. Furthermore, the descriptive analysis presented in Table 2 revealed that the average score of students' environmental awareness reached 93.35, with an achievement percentage of 77.79%. Although these findings demonstrate a positive development in students' environmental attitudes, the achievement level had not yet met the predetermined success criteria. Therefore, further refinement of the learning process through the continued implementation of the Science-Technology-Society learning model was required in Cycle II to enhance students' environmental awareness.

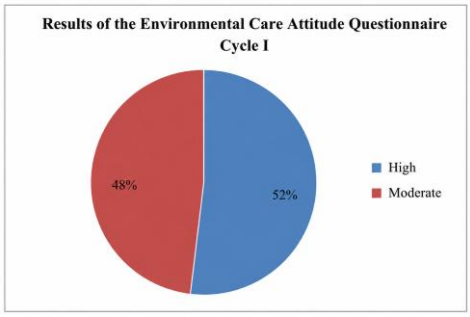

Figure 2. Pie chart of the results of the Environmental Attitude Questionnaire, Cycle I

Reflection results from Cycle I indicated that the implementation of the Science Technology Society learning model had a positive impact on the development of students' environmental awareness. Students were

enthusiastic and active during the learning activities. Furthermore, most students were able to dispose of waste appropriately, both organic and inorganic. These findings indicate that learning that connects science concepts to real-life environmental issues can increase students' awareness of the importance of environmental protection.

However, several obstacles were encountered during the implementation of the action. Limited learning facilities, particularly unstable electricity supply, prevented the optimal use of technology-based media. Furthermore, some student groups still required teacher guidance on cleaning tools and materials after practical activities. Personal hygiene habits, particularly proper handwashing after learning activities, were not yet fully practiced independently by all students.

Based on these reflections, several improvements were planned for Cycle II. Video-based learning media were replaced with alternative media in the form of articles, images, and reading materials relevant to environmental issues. Teachers also emphasized the importance of maintaining environmental cleanliness through discussions and contextual examples. In addition, students were given explanations and demonstrations on how to wash their hands properly as part of cultivating clean and healthy living habits [55], [56]. These improvements are expected to address various obstacles encountered in Cycle I and increase students' environmental awareness in Cycle II.

3.2. Results of Cycle II

Observations in Cycle II showed an improvement in students' environmental awareness compared to Cycle I. During the learning process, students appeared more active and enthusiastic in participating in various activities implementing the Science, Technology, and Society learning model. The classroom environment appeared cleaner and more organized, and students began to demonstrate positive habits in maintaining a clean learning environment [57], [58]. These changes demonstrate that learning activities that integrate environmental issues with real-life activities can foster better environmental awareness.

Based on observations, students have become accustomed to disposing of waste according to its type and are actively caring for plants in the school environment. Student enthusiasm was also evident during the experiment to create a simple water purification technology [59]. They actively participated in sourcing experimental materials from their surroundings and demonstrated a sense of responsibility for the activity. Furthermore, students began to demonstrate initiative in maintaining environmental cleanliness, such as immediately cleaning up dirty areas or water spills without waiting for instructions from the teacher.

Positive developments were also observed after the practicum activities were completed. Most students independently cleaned up the experimental equipment and materials and disposed of any remaining waste in the designated bins. The habit of washing hands after learning activities has also begun to be practiced more consistently compared to Cycle I. These findings indicate that the implementation of the Science Technology Society learning model not only improves students' understanding of environmental issues but also encourages the development of environmentally conscious behavior in their daily activities.

In addition to observational data, students' environmental attitudes in Cycle II were also assessed using a questionnaire. The results indicated that the highest score achieved was 117, while the lowest score was 75. The total score obtained by all students was 2,200, with an average score of 95.65 and an achievement level of 79.71%. Based on the categorization results, 14 students (60.87%) were classified in the high category and 9 students (39.13%) in the medium category, while no students were in the low category. When compared to Cycle I, the proportion of students in the high category increased from 56.52% to 60.87%, whereas the medium category decreased from 43.48% to 39.13%. These findings indicate that the Science-Technology-Society learning model contributed positively to the improvement of students' environmental awareness.

Table 3. Distribution of Students' Environmental Awareness Attitudes in Cycle II

Category	Score Range (%)	Frequency	Percentage (%)
High	≥ 94	14	60.87
Medium	56-93	9	39.13
Low	< 56	0	0.00
Amount		23	100.00

Table 4. Descriptive Statistics of Environmental Concern Attitudes in Cycle II

Statistics	Score
Number of Students	23
Highest Score	117
Lowest Score	75
Total Scores	2200
Average Score	95.65
Percentage of Achievement	79.71%
General Category	High

Based on this data, the results of observations of students' environmental care attitudes in cycle II can be described in the pie chart presented in the following pie chart.

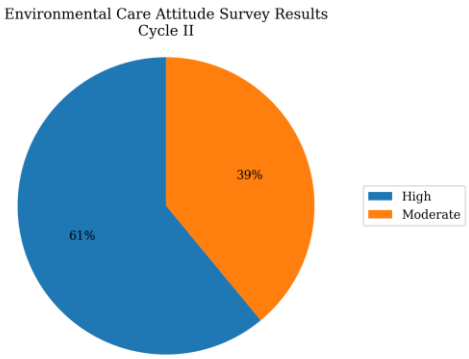

Figure 3. Pie chart of the results of the Environmental Attitude Questionnaire Cycle II

Reflection results from Cycle II indicate that the implementation of the Science, Technology, and Society learning model had a positive impact on the development of students' environmental awareness. During the learning process, students appeared more active, enthusiastic, and engaged in various activities related to environmental conservation. Compared to Cycle I, students began to demonstrate greater independence in maintaining environmental cleanliness and carrying out various activities that reflected an environmentally conscious attitude.

Based on observations, students have become accustomed to cleaning the learning area after completing practical activities. Leftover experimental materials are disposed of in the appropriate trash bins, while used tools and materials are returned in clean condition. Furthermore, students have begun to demonstrate initiative in maintaining classroom cleanliness without requiring teacher direction. For example, when water spilled due to a leak in an experimental bottle, students spontaneously cleaned the area without waiting for instructions from the teacher. This behavior demonstrates an increased awareness and responsibility for the surrounding environment.

The questionnaire results indicated an improvement compared to Cycle I. The proportion of students in the high category increased from 56.52% to 60.87%, while the proportion in the medium category decreased from 43.48% to 39.13%. In addition, the average environmental awareness score rose from 93.35 in Cycle I to 95.65 in Cycle II. These findings suggest that the implementation of the Science-Technology-Society learning model contributed to a gradual improvement in students' environmental awareness.

However, the results obtained in Cycle II did not fully meet the established success indicators. Some students still demonstrated a moderate level of environmental awareness, requiring reinforcement measures to increase the consistency of environmental awareness behaviors in their daily lives [32], [60]. Therefore, the research continued into the next cycle by refining the learning strategy, reinforcing positive behaviors, and increasing student involvement in activities oriented towards solving environmental problems.

3.3. Results of Cycle III

Observations in Cycle III showed a more significant improvement in students' environmental awareness compared to the previous cycle. During the learning process, students demonstrated active participation and high enthusiasm in various activities related to the environment and health. Classrooms appeared clean, comfortable, and well-maintained, reflecting students' growing awareness of the importance of maintaining a clean learning environment.

This development in environmental awareness was evident in students' habits of caring for plants, maintaining classroom cleanliness, and disposing of waste appropriately. Furthermore, students demonstrated greater responsibility for learning facilities by returning practical equipment to its proper place after use. During learning activities, students actively answered questions, engaged in discussions, and participated in various activities related to health and the environment. These findings indicate that students are beginning to understand the relationship between daily behavior, health, and environmental sustainability.

This improvement in environmental awareness is also reflected in students' clean and healthy living behaviors. They are beginning to understand the importance of consuming nutritious food, washing hands before eating, exercising regularly, and maintaining a clean environment. Not only did some students adopt these habits themselves, but they also began encouraging their friends to take actions that support health and environmental preservation. These changes indicate that the environmental values instilled through the Science, Technology, and Society learning model are beginning to be internalized in their behavior.

In addition to observational data, students' environmental awareness in Cycle III was evaluated using a questionnaire. The results showed that the highest score obtained was 120, while the lowest score was 83. The

total score reached 2,372, with an average of 103.13 and an achievement level of 85.94%. Based on the categorization results, 19 students (82.61%) were classified in the high category and 4 students (17.39%) in the medium category, while no students were in the low category. Compared to Cycle II, the proportion of students in the high category increased significantly from 60.87% to 82.61%, whereas the medium category decreased from 39.13% to 17.39%. These findings indicate that the implementation of the Science-Technology-Society learning model was highly effective in optimizing students' environmental awareness in Cycle III.

Table 5. Distribution of Students' Environmental Awareness Attitudes in Cycle III

Category	Score Range (%)	Frequency	Percentage (%)
High	≥ 94	19	82.61
Medium	56-93	4	17.39
Low	< 56	0	0.00
Amount		23	100.00

Table 6. Descriptive Statistics of Environmental Concern Attitudes in Cycle III

Statistics	Score
Number of Students	23
Highest Score	120
Lowest Score	83
Total Scores	2372
Average Score	103.13
Percentage of Achievement	85.94%
General Category	High

Overall, the findings of the study demonstrate a continuous increase in students' environmental awareness across all action cycles. The mean score improved from 83.13 at the pre-action stage to 93.35 in Cycle I, 95.65 in Cycle II, and 103.13 in Cycle III. Similarly, the achievement percentage showed a consistent upward trend from 69.28% to 77.79%, 79.71%, and finally 85.94%. These results indicate that the Science-Technology-Society learning model was effective in enhancing environmental awareness among elementary school students. Based on these findings, the distribution of students' environmental awareness in Cycle III is illustrated in the pie chart presented in Figure 4.

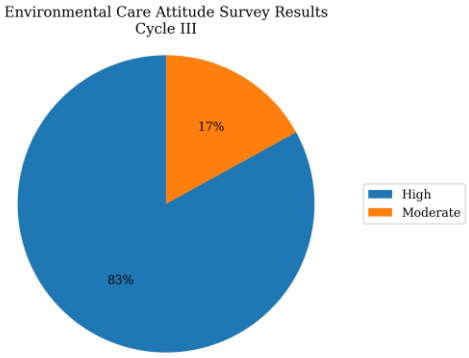

Figure 4. Pie chart of the results of the Environmental Attitude Questionnaire Cycle III

To provide a clearer illustration of the effectiveness of the Science-Technology-Society learning model, the percentage of students' environmental awareness achievement was compared across all stages of the study. As shown in Figure 5, consistent improvement was observed from the pre-action stage to Cycle III, indicating a positive contribution of the applied learning model to strengthening students' environmental awareness attitudes.

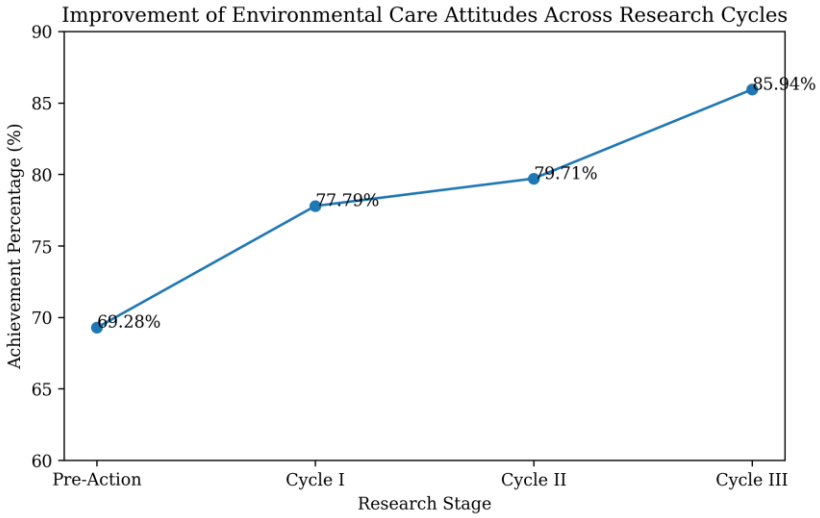

Figure 5. Increase in Students' Environmental Awareness Attitudes Across the Research Cycle

Figure 5 illustrates a steady increase in students' environmental awareness throughout the research cycles. The achievement percentage rose from 69.28% in the pre-action stage to 77.79% in Cycle I, 79.71% in Cycle II, and 85.94% in Cycle III. The most notable improvement occurred between the pre-action stage and Cycle I, suggesting that the initial implementation of the Science-Technology-Society learning model had a strong influence on students' environmental awareness and behavior. The findings also indicate that repeated engagement in contextual environmental learning activities contributed to the gradual strengthening of positive environmental attitudes among students.

The Science-Technology-Society learning model was shown to effectively enhance students' environmental care attitudes by providing contextual, problem-based learning experiences. In this approach, students are not only introduced to scientific concepts but also guided to understand their connection with technological development and real environmental issues in society. Active involvement in environment-related activities enables students to construct meaningful learning experiences, making environmental values easier to internalize [61], [62]. These results are consistent with constructivist theory, which posits that knowledge and attitudes develop more effectively when learners actively engage with real-life contexts and relevant environmental problems.

The increase in environmental care attitudes that occurred during the implementation of the action shows that learning that integrates environmental issues into learning activities can be an effective means of forming students' character. Through activities such as waste management, plant care, environmental cleanliness practices, and discussions about the impact of human activities on the environment, students get the opportunity to connect knowledge with real action [63], [64]. This process encourages the development of ecological awareness which is not only cognitive in nature, but is also reflected in daily behavior. Thus, the Community Science Technology learning model contributes to bridging the gap between environmental knowledge and environmental practices that is often found in basic education.

The findings of this study are strongly aligned with the achievement of the Sustainable Development Goals. From an educational standpoint, the results support Goal 4 (Quality Education), particularly the targets emphasizing education for sustainable development and sustainable lifestyles. By integrating environmental issues into learning activities, students are equipped with the competencies needed to understand and respond to future environmental challenges. In addition, the improvement in students' awareness of waste management, environmental cleanliness, and responsible resource use contributes to Goal 12 (Responsible Consumption and Production) [9], [65]. At the same time, fostering environmental awareness and conservation attitudes from an early age provides a strong foundation for supporting Goal 13 (Climate Action) through the development of sustainable and environmentally responsible behaviors.

The findings of this study are in line with the results of a systematic study conducted by Ardoin et al. [66] which shows that environmental education contributes to improved attitudes, values, knowledge, and concrete actions that support environmental conservation. The study confirms that environmental education programs that connect learning to local issues and encourage active student involvement tend to result in more sustainable behavioral changes. This condition aligns with the implementation of the Science Technology Society learning model in this study, which utilizes environmental issues surrounding students as a learning context.

The findings of this study are supported by several previous studies showing the effectiveness of environmental education in fostering positive environmental attitudes and behaviors. Ardoin et al. [67] found

that environmental education for school-age children enhances cognitive and affective development as well as strengthens their connection to the environment, particularly through direct interaction with nature, which encourages positive attitudes. Similarly, Otto and Pensini [68] reported that combining environmental knowledge with experiences in nature increases students' ecological behavior, especially when they are actively involved in real environmental activities such as waste management and plant care. In addition, Maurer and Bogner [69] emphasized that environmental attitudes are more strongly linked to behavior than knowledge alone, indicating that value-based and experience-oriented learning is more effective in promoting pro-environmental actions. These findings align with the present study, where students demonstrated increased environmental awareness and began applying it in daily school practices, including maintaining cleanliness, managing waste, and caring for plants.

From a pedagogical perspective, the success of the Science, Technology, and Society learning model can be explained by its ability to create student-centered learning. Learning no longer focuses on the transfer of information from teacher to student, but rather on the process of exploration, discussion, observation, and reflection on problems encountered in the surrounding environment [70], [71]. This allows students to develop a deeper understanding of the consequences of human actions on the environment. When students realize that simple behaviors such as disposing of waste properly, caring for plants, or maintaining a clean environment have a tangible impact on environmental quality, their tendency to implement these behaviors in their daily lives becomes stronger.

These findings have important practical implications for teachers, schools, and education policymakers. The Science-Technology-Society learning model offers an effective way to integrate environmental education into science instruction without requiring complex facilities or advanced technological resources [19], [72]. By utilizing local environmental issues as learning contexts, this model is particularly suitable for schools in developing countries with limited educational resources. Therefore, its broader implementation could strengthen sustainability-oriented education across diverse educational settings.

However, several limitations should be noted. This study was conducted in a single elementary school, which may restrict the generalizability of the results. In addition, environmental care attitudes were measured through observation and self-report questionnaires, which may not fully reflect long-term behavioral changes. Furthermore, the Classroom Action Research design emphasizes instructional improvement rather than causal inference. Future studies are recommended to involve larger samples, different educational levels, and more robust research designs, such as quasi-experimental or longitudinal approaches, to better examine the long-term impact of the Science-Technology-Society learning model on environmental sustainability competencies.

This research also has practical implications for schools and education policymakers in developing countries. Integrating the Science Technology Society learning model into elementary school learning can be an effective strategy for strengthening environmental education without requiring complex technological facilities. Learning activities can utilize various local environmental issues as learning resources easily found around the school. Therefore, this model has great potential for application in various educational contexts, especially in areas that still face limited learning facilities and infrastructure.

4. CONCLUSION

This study shows that the Science-Technology-Society learning model effectively improves environmental care attitudes among elementary school students. By linking scientific concepts with technological development and real environmental issues, the model helps students build environmental awareness, responsibility, and active engagement in conservation activities. The results indicate that contextual and sustainability-oriented learning experiences are important in shaping pro-environmental attitudes at an early age. In addition, the study supports the achievement of Sustainable Development Goals, particularly Goal 4 (Quality Education), Goal 12 (Responsible Consumption and Production), and Goal 13 (Climate Action). These findings highlight the potential of the Science-Technology-Society approach as a practical and scalable strategy for integrating environmental education into elementary science learning. Future research is recommended to examine its long-term impact in different educational settings and to explore its integration with digital technologies and broader sustainability education frameworks.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the schools, teachers, and students who participated in this research. Their cooperation and contributions were crucial to the successful completion of this study.

AUTHOR CONTRIBUTIONS

Conceptualization, G.A., H.J., and P.K.S.; Methodology, G.A. and H.J.; Software development, H.J.; Validation, G.A., H.J., and P.K.S.; Formal analysis, G.A. and H.J.; Investigation, G.A.; Resources provision,

P.K.S.; Data curation, G.A.; Writing of the original draft, G.A.; Writing review and editing, H.J. and P.K.S.; Visualization, H.J.; Supervision, P.K.S.; Project administration, P.K.S.; Funding acquisition, P.K.S. All authors have reviewed and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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