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

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ABSTRACT

Purpose of the study: This study aimed to investigate the implementation of the Science-Technology-Society learning model and examine its effectiveness in improving environmental care attitudes among elementary school students through contextual learning activities that integrate science concepts, technological applications, and environmental issues encountered in daily life.

Methodology: This study employed Classroom Action Research based on the Kemmis and McTaggart model, consisting of planning, action, observation, and reflection stages conducted across 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 analyzed following the Miles and Huberman interactive model.

Main Findings: The implementation of the Science-Technology-Society learning model successfully improved students' environmental care attitudes across all action cycles. The achievement percentage increased 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. Students demonstrated greater responsibility for waste management, environmental cleanliness, plant maintenance, and environmentally responsible behavior during learning activities and daily school practices.

Novelty/Originality of this study: This study extends previous environmental education research by identifying specific implementation stages of the Science-Technology-Society learning model that foster environmental care attitudes among elementary school students in a developing-country context. The study contributes new evidence on how contextual science learning can support environmental sustainability education and advance the achievement of Sustainable Development Goals through attitude formation 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 used Classroom Action Research with the aim of improving students' environmental awareness through the implementation of the Science, Technology, and Society learning model. Classroom action research was chosen because it allows researchers to systematically implement corrective actions in the classroom learning process [35], [36]. Through this research, teachers and researchers can identify learning problems, implement corrective actions, observe changes, and reflect on them to continuously improve the quality of learning.

In this study, the action taken was the implementation of the Science, Technology, and Society learning model, designed to connect scientific concepts with technological developments and societal problems, particularly those related to environmental issues. Through this approach, students are expected to develop optimal awareness, responsibility, and environmental awareness. This study utilizes the classroom action research model developed by Kemmis and McTaggart, which consists of four stages: planning, action, observation, and reflection [37], [38]. These four stages are implemented repeatedly in several cycles until improvements are achieved in line with the research objectives. Each cycle is used to evaluate the effectiveness of the actions taken and determine improvement steps for the next cycle.

The research was conducted collaboratively between researchers and classroom teachers. Teachers act as learning implementers, while researchers are responsible for developing learning materials, conducting observations, collecting data, and conducting reflections with teachers [39], [40]. This collaboration is intended to ensure that the implementation of the Science Technology Society learning model is in accordance with the research design and has an impact on improving students' environmental awareness.

This research was conducted with elementary school students in Kampala District, Uganda, an urban area in a developing country facing various environmental challenges, such as waste management, environmental pollution, and low public awareness of environmental conservation. The selection of the research location was based on the relevance of the environmental issues faced and the importance of strengthening environmental education in supporting the achievement of the Sustainable Development Goals (SDGs), specifically the goals of quality education, responsible consumption and production, and action on climate change.

2.2. Action Research Design

This study employed a Classroom Action Research design based on the model developed by Kemmis and McTaggart. This model was chosen because it provides a systematic framework for improving learning practices through a series of iterative and reflective actions. The design consists of four main stages: planning, action, observation, and reflection. These four stages are implemented in an interconnected cycle to achieve the goal of continuous learning improvement. In the Kemmis and McTaggart model, the action and observation stages are conducted simultaneously throughout the learning process [41], [42]. The results of the observations are then used as a basis for reflection to evaluate the effectiveness of the actions taken. Findings from the reflection stage serve as a reference for developing plans for the next cycle. Thus, each cycle serves as a continuous improvement process until the research success indicators are achieved. This research was conducted in two cycles, with the possibility of additional cycles if the results obtained do not meet the established success indicators. Each cycle consists of several learning sessions implementing the Science, Technology, and Society learning model [43], [44]. The focus of the actions is directed at improving students' environmental awareness through learning activities that integrate scientific concepts, technological developments, and environmental issues in society.

2.3. Data Collection Techniques

Data collection in this study was conducted through observation and questionnaire techniques. Observations were used to directly observe the development of students' environmental awareness throughout the learning process. Observations were conducted systematically using observation sheets compiled based on indicators of environmental awareness, such as concern for environmental cleanliness, waste management, participation in environmental conservation activities, and responsibility for the school environment [45], [46]. Observation data was used to determine changes in student behavior during each learning cycle.

In addition to observations, this study also used a questionnaire to measure students' environmental awareness. The questionnaire was structured on a Likert scale and included a number of statements related to environmental awareness, environmental responsibility, waste management, resource conservation, and participation in environmental conservation activities [47], [48]. The questionnaire was administered before the implementation of the learning activities and at the end of each cycle to determine the level of change in students' environmental awareness following the implementation of the Science, Technology, and Society learning model. Data obtained from the questionnaire was used to complement the observation results, providing a more comprehensive picture of the effectiveness of the learning activities.

2.4. Data Analysis Techniques

Data analysis in this study was conducted quantitatively and qualitatively to obtain an overview of the improvement in students' environmental awareness following the implementation of the Science Technology Society learning model. Quantitative data were obtained from observations and a questionnaire on environmental awareness, which were analyzed using descriptive statistics in percentage form [49], [50]. The success rate was calculated by comparing the obtained scores with the maximum possible score, then multiplying by 100%. Qualitative data obtained through observations and field notes were analyzed using an interactive model that included data reduction, data presentation, and conclusion drawing. In the data reduction stage, the researcher selected, simplified, and focused data relevant to the research objectives. Next, the reduced data were presented in narrative form, tables, and graphs to facilitate interpretation of the research results. The final stage involved drawing conclusions and verifying them by reviewing all data collected in each cycle. Conclusions were drawn based on the results of the quantitative and qualitative data analysis to illustrate the effectiveness of the implementation of the Science Technology Society learning model in improving students' environmental awareness [19], [51]. The verification process was carried out continuously throughout the study to ensure the consistency and validity of the findings.

2.5. Research Procedures

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

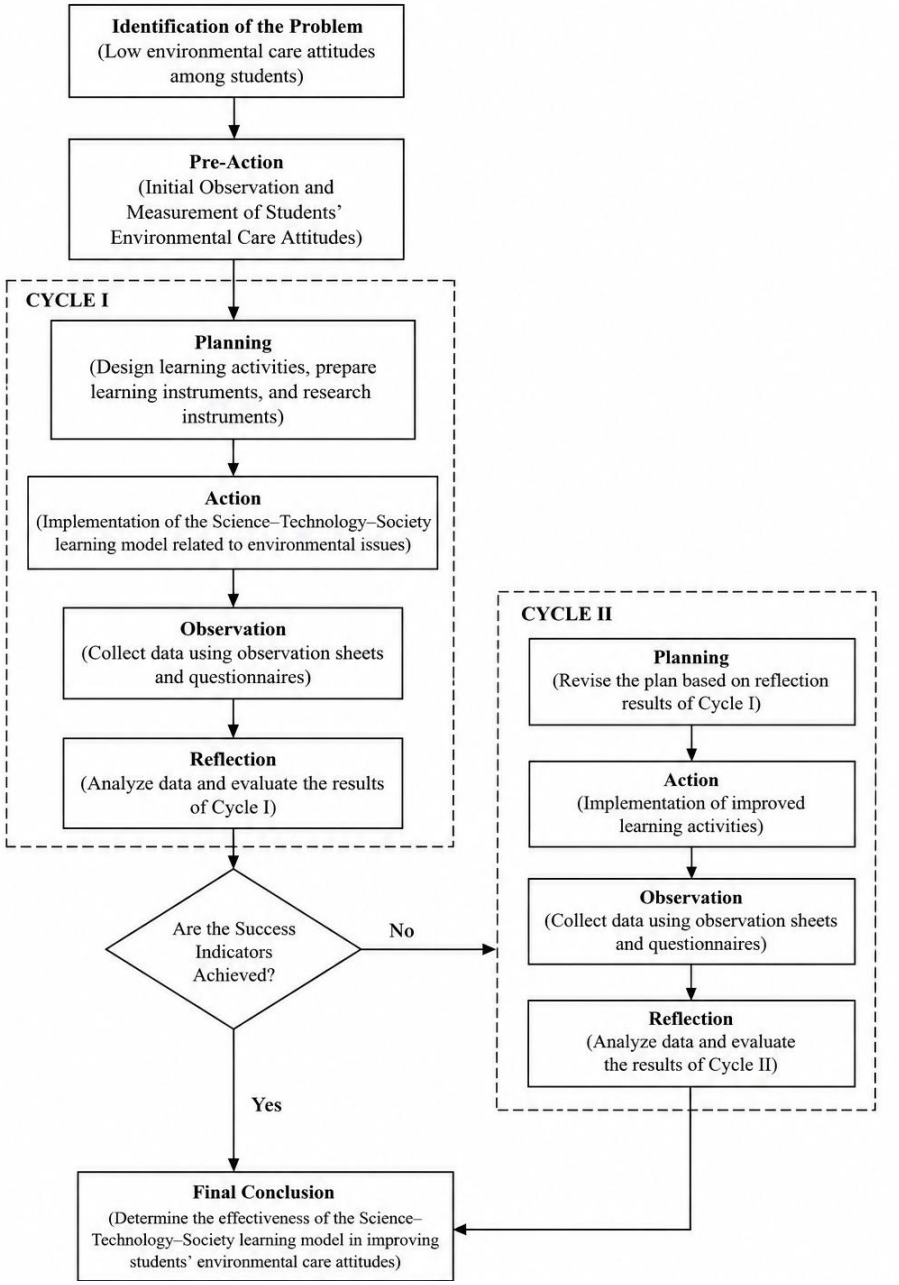

Figure 1. Research Procedure Flowchart

This research was conducted in two cycles, referring to the Classroom Action Research model developed by Kemmis and McTaggart. Each cycle consists of four stages: planning, action implementation, observation, and reflection. In the planning stage, the researcher and the teacher developed learning materials, prepared research instruments, and designed learning activities based on the Science, Technology, and Society learning model [52], [53]. Furthermore, in the action implementation stage, the learning process was carried out by integrating science, technology, and environmental issues concepts relevant to students' lives. During the action implementation, observations were conducted to collect data on the development of students' environmental awareness. The data obtained were then analyzed in the reflection stage to evaluate the success of the actions taken. The results of the reflection were used as a basis for improvements in the next cycle until the research 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 observations, students' environmental awareness was also measured using a questionnaire administered at the end of the cycle. The pre-action questionnaire results indicated that 5 students (22%) were in the high category and 18 students (78%) were in the medium category, with an average score of 83.13. These results indicate that before implementing the Science Technology Society learning model, most students had a moderate environmental awareness attitude, but had not yet demonstrated optimal behavior in their daily lives.

Measurement results at the end of Cycle I showed an increase in environmental awareness scores compared to the initial level. This increase indicates that the Science Technology Society learning model is able to encourage students to better understand the relationship between human activities, technological developments, and their impact on the environment. However, the results obtained in Cycle I did not fully achieve the established success indicators, requiring improvements 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 showed an improvement compared to the pre-action condition. Based on Table 1, 13 students (56.52%) were in the high category and 10 students (43.48%) were in the medium category. There were no students in the low category. In addition, the results of the descriptive analysis in Table 2 show that the average score of students' environmental awareness attitudes reached 93.35 with an achievement percentage of 77.79%. Although these results indicate positive development, the achievement percentage obtained still does not meet the established success indicators. Therefore,

improvements in learning through the implementation of the Science Technology Society learning model need to be continued in Cycle II.

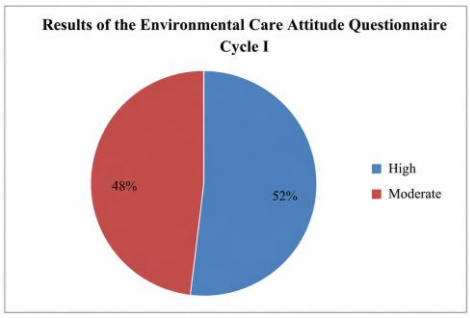

Figure 2. Pie chart of the results of the Environmental Attitude Questionnaire, Cycle I

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 observations, improvements in environmental attitudes were also measured using a questionnaire administered at the end of Cycle II. The analysis showed that the highest score obtained by students was 117, while the lowest score was 75. The total score obtained by all students reached 2200, with an average score of 95.65 and an achievement level of 79.71%. Based on the questionnaire categorization results, 14 students (60.87%) were in the high category and 9 students (39.13%) were in the medium category. No students were in the low category. Compared to Cycle I, the percentage of students in the high category increased from 56.52% to 60.87%, while the percentage of students in the medium category decreased from

43.48% to 39.13%. These results indicate that the implementation of the Science Technology Society learning model has a positive impact on improving 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.

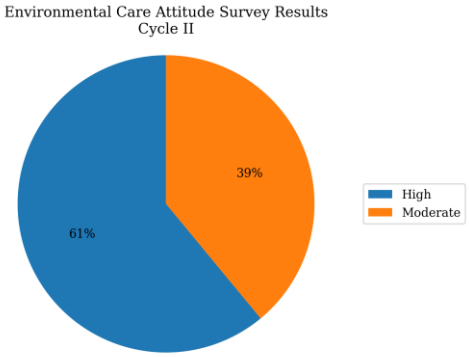

Figure 3. Pie chart of the results of the Environmental Attitude Questionnaire Cycle II

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 also showed an improvement compared to Cycle I. The percentage of students in the high category increased from 56.52% to 60.87%, while the percentage of students in the moderate category decreased from 43.48% to 39.13%. The average environmental awareness score increased from 93.35 in Cycle I to 95.65 in Cycle II. These findings indicate that the implementation of the Science, Technology, and Society learning model was able to gradually improve 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 observation, improvements in environmental awareness were also measured using a questionnaire administered at the end of Cycle III. The analysis showed that the highest score obtained by students was 120, while the lowest score was 83. The total score obtained by all students reached 2,372, with an average score of 103.13 and an achievement level of 85.94%. Based on the questionnaire categorization results, 19 students (82.61%) were in the high category and 4 students (17.39%) were in the medium category. No students were in the low category. Compared to Cycle II, the percentage of students in the high category increased from 60.87% to 82.61%, while the percentage of students in the medium category decreased from 39.13% to 17.39%. This increase indicates that the implementation of the Science Technology Society learning model was able to optimally improve 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 results of the study showed an increase in students' environmental awareness in each cycle of action. The average score increased from 83.13 in the pre-action stage to 93.35 in Cycle I, then increased to 95.65 in Cycle II, and reached 103.13 in Cycle III. The percentage of achievement also increased successively from 69.28%, 77.79%, 79.71%, to 85.94%. These findings indicate that the implementation of the Science Technology Society learning model is effective in improving elementary school students' environmental awareness. Based on these data, the results of observations of students' environmental awareness in Cycle III can be depicted in the pie chart presented to Figure 4.

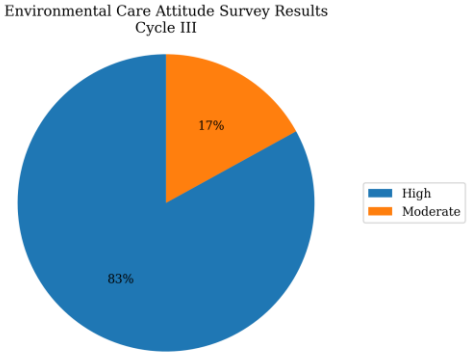

Figure 4. Pie chart of the results of the Environmental Attitude Questionnaire Cycle III

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.

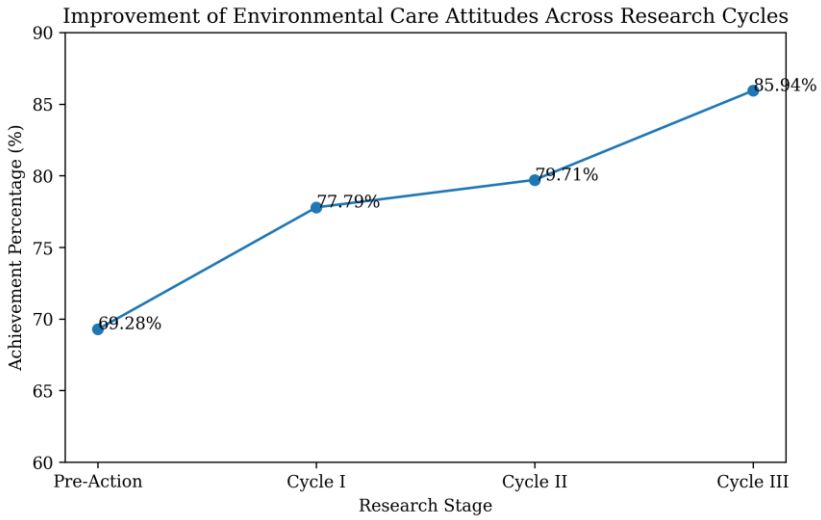

Figure 5. Increase in Students' Environmental Awareness Attitudes Across the Research Cycle

Figure 5 shows a continuous increase in students' environmental awareness attitudes throughout the research cycle. The percentage of achievement increased from 69.28% in the pre-action stage to 77.79% in Cycle I, followed by 79.71% in Cycle II and 85.94% in Cycle III. The largest increase occurred between the pre-action stage and Cycle I, indicating that the initial implementation of the Science-Technology-Society learning model had a substantial impact on students' environmental awareness and behavior. The results showed that repeated exposure to contextual environmental learning activities contributed to the gradual development of positive environmental attitudes among students.

The implementation of the Community Science and Technology learning model has been proven to be able to strengthen students' environmental care attitudes through learning experiences that are contextual and oriented towards solving real problems. In this model, students not only learn scientific concepts theoretically, but also understand their relationship to technological developments and various environmental problems faced by society. The involvement of students in activities that are directly related to the environment allows the formation of meaningful learning experiences so that the values of environmental care are more easily internalized [61], [62]. This finding is in line with constructivism theory which emphasizes that knowledge and attitudes will develop more effectively when students interact directly with the environment and problems that are relevant to their lives.

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 research have strong relevance to achieving the Sustainable Development Goals. From an educational perspective, the research results support the achievement of Goal 4 on quality education, especially targets that emphasize the importance of education for sustainable development and sustainable lifestyles. Through the integration of environmental issues into learning, students gain the competencies needed to understand and face environmental challenges in the future. In addition, increasing awareness regarding waste management, environmental cleanliness and responsible use of resources also contributes to Goal 12 on responsible consumption and production [9], [65]. At the same time, the development of concern for environmental conservation from an early age can be an important foundation in supporting Goal 13 regarding handling climate change through the formation of sustainable environmentally friendly behavior.

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 results of this study are also supported by research by Ardoin et al. [67] which found that environmental education for school-age children can improve affective and cognitive development, as well as students' connection to their surroundings. The study emphasized that learning experiences involving direct interaction with the environment have a significant influence on the development of positive attitudes toward it. These findings are consistent with the results of this study, where students demonstrated increased concern for environmental cleanliness, waste management, and plant care after participating in Science and Technology-Community-based learning.

In addition, research conducted by Otto and Pensini [68] showed that environmental knowledge combined with a connection to nature was positively related to students' ecological behavior. They found that learning experiences that allowed students to interact directly with the environment increased their propensity to engage in environmentally friendly behavior. These results reinforce the study's finding that student involvement in real-world activities, such as waste management, plant care, and environmental hygiene practices, contributes to increased environmental awareness.

The findings of this study are also supported by research by Maurer and Bogner [69] Research on environmental literacy shows that environmental attitudes have a stronger relationship with environmental behavior than knowledge alone. In other words, learning that focuses not only on mastering concepts but also on developing attitudes and values will be more effective in fostering pro-environmental behavior. This is evident in this study, where students not only understand the importance of environmental protection but also begin to apply it through concrete actions in their daily school lives.

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 practical implications for teachers, schools, and educational policymakers. The Science-Technology-Society learning model can serve as an effective approach for integrating environmental education into science learning without requiring sophisticated facilities or advanced technology [19], [72]. Because the model utilizes local environmental issues as learning resources, it is particularly suitable for schools in developing countries where educational resources may be limited. Therefore, wider adoption of this model could support sustainability-oriented education in diverse educational settings.

Several limitations should be acknowledged. First, the study involved participants from a single elementary school, which may limit the generalizability of the findings. Second, environmental care attitudes were assessed through observation and self-report questionnaires, which may not fully capture long-term behavioral changes. Third, the classroom action research design focuses on instructional improvement rather than establishing causal relationships. Future research should involve larger samples, different educational levels, and more rigorous research designs, such as quasi-experimental or longitudinal studies, to examine the long-term effectiveness of the Science-Technology-Society learning model in promoting 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 demonstrates that the implementation of the Science-Technology-Society learning model effectively enhances environmental care attitudes among elementary school students. By connecting scientific concepts with technological developments and environmental issues encountered in daily life, the model encourages students to develop environmental awareness, responsibility, and active participation in environmental conservation activities. The findings suggest that contextual and sustainability-oriented learning experiences play an important role in fostering pro-environmental attitudes among young learners. Furthermore, this study contributes to the achievement of Sustainable Development Goals, particularly Goal 4 (Quality Education), Goal 12 (Responsible Consumption and Production), and Goal 13 (Climate Action). The findings highlight the potential of the Science-Technology-Society learning model as a practical and scalable approach for integrating environmental education into elementary science learning. Future studies should investigate the long-term effects of this learning model across different educational contexts and explore its integration with digital learning technologies and broader sustainability education frameworks.

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AUTHOR CONTRIBUTIONS

Conceptualization, G.A., H.J., and P.K.S.; Methodology, G.A. and H.J.; Software, H.J.; Validation, G.A., H.J., and P.K.S.; Formal Analysis, G.A. and H.J.; Investigation, G.A.; Resources, P.K.S.; Data Curation, G.A.; Writing – Original Draft Preparation, G.A.; Writing – Review & 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 read and agreed to the published 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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