Fostering Environmental Awareness and Social Attitudes in Early Childhood through Green-Tech Project-Based Learning and Teacher Guidance

Choirun Nisak Aulina[1,*], Fajar Arianto[2], Agus Salim[1], and Fitri Mar'atus Sholihah[1]

[1]Early Childhood Teacher Education, Faculty of Psychology and Educational Sciences, Muhammadiyah University of Sidoarjo, Sidoarjo, Indonesia
[2]Educational Technology, Faculty of Educational Sciences, State University of Surabaya, Surabaya, Indonesia
Email: lina@umsida.ac.id (C.N.A.); fajararianto@unesa.ac.id (F.A.); agussalim@umsida.ac.id (A.S.); fitriekonomi12@gmail.com (F.M.S.)
*Corresponding author
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***Abstract*—The purpose of this study is to analyze the effectiveness of the Green Technology Project-Based Learning (GTPBL) model in improving environmental awareness and social attitudes in early childhood, with teacher guidance as a moderating factor that strengthens the impact of learning. This study used quasi-experimental method with pretest-posttest control group design. The study involved 3 kindergarten schools totaling 60 students and was selected by purposive sampling technique, then divided into experimental control group and experimental group. The results showed a significant improvement in students' environmental awareness and social attitudes after participating in this project-based learning, with teacher guidance playing an important role in moderating the improvement. Teacher guidance helped students to better understand the environmental impact of technology and encouraged them to be more empathetic towards social issues. These findings suggest that integrating GTPBL with structured teacher support can be an effective approach in early childhood education to nurture pro-environmental behavior and social responsibility. In practical terms, this model has the potential to enrich the early childhood education curriculum by providing meaningful, hands-on learning experiences that build character and ecological awareness from an early age. Educators and curriculum developers are encouraged to adopt and adapt this model to promote sustainability values in schools.**

***Keywords*—Green-Tech Project-Based Learning (GTPBL), environmental awareness, social attitudes, teacher guidance**

I. Introduction

The early years represent a crucial period in a child's development, during which character, values, environmental awareness, and social attitudes begin to take shape [1]. Regarding early childhood education, environmental awareness involves children comprehension of the importance of protecting nature and natural resources, while social attitudes include children's ability to interact with others in a positive way, such as cooperating and sharing. In early childhood education, these two aspects contribute to children's better social-emotional development. These two aspects play an important role in fostering children's social-emotional development. Theories relevant to these domains include Albert Bandura's socio-cognitive development theory, which posits that children learn through observation and social interaction, and Urie Bronfenbrenner's ecological systems theory, which underscores the influence of social and physical environments on children's development [2]. Previous studies indicate that Project-Based Learning (PBL) programs featuring environmental activities can enhance children's environmental awareness and encourage the development of positive social attitudes, especially when accompanied by appropriate teacher guidance [3].

Global issues pertaining to environmental awareness and social attitudes have become increasingly significant amid rising social inequality, environmental deterioration, and climate change in various parts of the world [4]. Low environmental awareness drives the overexploitation of natural resources, pollution, and climate change, adversely affecting both human life and other living organisms. In addition, a lack of positive social attitudes such as self-centeredness or indifference to others compounds social problems, including economic inequality, poverty, and social conflict. Data from the World Economic Forum shows that 69% of young people around the world believe that environmental issues are a major challenge that needs to be faced, yet only 38% feel that they are involved in real sustainability efforts [5]. Meanwhile, United Nations Children's Fund (UNICEF) research indicates that around 30% of children globally live in poverty, highlighting insufficient social concern regarding equality and social welfare [6]. In Indonesia, the Ministry of Environment and Forestry notes that early childhood environmental awareness is still low due to the lack of integration of sustainability education in PAUD learning [7]. This shows a gap between awareness and action, especially in the context of early childhood education, which should be the foundation for the formation of environmental and social awareness.

In early childhood, issues relating to environmental awareness and social attitudes continue to pose significant challenges in education, especially in developing countries. Although global recognition of environmental problems is rising, the integration of these topics into early childhood education remains limited [8]. Data indicate that only 15% of educational curricula in developing countries effectively incorporate environmental education into teaching and learning activities. In Indonesia, for instance, a report from the Ministry of Education and Culture shows that 45% of early childhood teachers have not received training on teaching social attitudes and environmental awareness, contributing to children's limited understanding of environmental issues and their capacity for positive social interaction. Furthermore, a survey conducted by the Indonesian Ministry of Environment and Forestry found that around 60% of young children in Indonesia do not possess an

adequate awareness of the importance of cleanliness, waste management, and environmental conservation. The limited use of education approaches based on environmental projects and social interactions that actively engage children contributes to gaps in their development of social attitudes and environmental awareness [9].

Failure to address issues of environmental awareness and social attitudes in early childhood can have detrimental effects on both individuals and society. Children who are not taught to value environmental stewardship may overlook the importance of nature conservation, thereby intensifying environmental damage, pollution, and climate change [10, 11]. Furthermore, inadequate education on social attitudes can lead to self-centeredness and a lack of empathy, which may exacerbate social inequalities and conflicts. This topic is particularly compelling to investigate, as it presents an opportunity to cultivate a younger generation that is both environmentally conscious and adept at positive social interaction. Research and solutions in this area can produce significant long-term benefits, including the formation of a more inclusive, harmonious, and sustainable society, while also engaging younger generations in initiatives to protect the environment and enhance social relations [12].

However, despite growing evidence supporting the effectiveness of PBL in fostering environmental and social competencies, previous studies rarely focus on its implementation in early childhood settings. More importantly, there is limited research exploring the role of teacher guidance as a moderating factor in enhancing the success of PBL models, particularly those incorporating green technology themes. Most existing studies focus on primary or secondary education, with little attention given to how young children engage with sustainability themes through structured projects. This gap calls for an in-depth investigation of how early learners respond to environmental PBL interventions and how teacher facilitation can maximize learning outcomes. To address the aforementioned issues, the Green Technology Project-Based Learning (GTPBL) model offers an effective solution for enhancing environmental awareness and social attitudes in early childhood. The effectiveness of this approach is supported by previous research showing that PBL combined with environmental issues can improve children's understanding of sustainability and strengthen their social interactions from an early age [13, 14]. One possible solution is to engage children in environmental conservation projects, such as establishing a school garden or implementing waste recycling initiatives, thereby providing them with hands-on experience in sustainability and social cooperation [15]. Through this project-based approach, children actively acquire knowledge rather than passively absorbing information, thereby enhancing their comprehension of environmental concerns and social skills [16]. Additionally, the GTPBL model can be integrated with green technologies, such as the use of renewable energy or apps that teach children about efficient natural resource management.

The choice of the GTPBL model as a suitable solution stems from its capacity to offer hands-on learning experiences, which can deepen children's understanding of environmental and social concepts. According to Piaget and Vygotsky's constructivist theories, experiential learning facilitates enhanced cognitive and social development. Empirical evidence, including a study by Zhang *et al.* [17], suggests that the integration of green technology within PBL effectively boosts children's environmental awareness and collaborative abilities. The strength of the GTPBL model lies in its capacity to merge sustainability principles with engaging, participatory learning, making it particularly well-suited for fostering social character and environmental consciousness in early childhood.

Teacher guidance plays a crucial role in project-based learning approaches such as the GTPBL model. By providing direction, support, and motivation, teachers help children more fully grasp concepts related to environmental awareness and social attitudes [18]. Acting as facilitators and mentors, teachers strengthen the learning process by offering deeper explanations, assisting children with project-related challenges, and delivering constructive feedback. In addition, teacher guidance not only fosters knowledge acquisition but also encourages the development of children's social character, including traits like cooperation, empathy, and environmental responsibility [19]. Acting as facilitators and mentors, teachers strengthen the learning process by offering deeper explanations, assisting children with project-related challenges, and delivering constructive feedback. In addition, teacher guidance not only fosters knowledge acquisition but also encourages the development of children's social character, including traits like cooperation, empathy, and environmental responsibility [20]. With such guidance, children become better able to adapt to new concepts and more willing to participate in project activities that support the development of environmental awareness and social attitudes [21].

Recent studies have investigated the effects of PBL and green technology practices on environmental awareness and attitudes in educational contexts. Findings indicate that PBL positively affects students' environmental attitudes and cognitive learning outcomes [22, 23]. Specifically, PBL fosters creativity and supports deeper, more enduring learning, helping students better understand environmental issues [23]. The incorporation of green technology practices in education has also garnered attention, with teachers' awareness and motivation strongly linked to their acceptance of such practices [24]. Furthermore, integrating PBL with green technology-based learning has been shown to enhance both students' conceptual understanding and their environmentally responsible attitudes in science and technology approaches [25]. These findings suggest that merging PBL with green technology in educational settings can effectively boost environmental awareness and promote positive attitudes toward environmental conservation among students.

This research is critically important in light of increasingly urgent environmental issues, such as pollution, climate change, and ecological degradation, which require attention from an early age. Children's environmental awareness and social attitudes serve as the foundation for nurturing a generation committed to preserving the Earth and caring for others. Despite growing global concern about environmental issues, our understanding of how to cultivate environmental awareness in early childhood through contextual and applicable learning approaches—like the GTPBL

model—remains limited, particularly in the Indonesian context. By emphasizing teacher guidance in this process, this research also addresses the need to strengthen the role of teachers in guiding children to understand and internalize values of sustainability and social attitudes essential for daily life.

The purpose of this study is to analyze the effectiveness of the Green Technology Project-Based Learning (GTPBL) model in improving environmental awareness and social attitudes in early childhood, with teacher guidance as a moderating factor that amplifies the impact of learning.

II. Literature Review

A. Green Technology Project Based Learning (GTPBL) Model

The GTPBL model is an instructional approach that integrates sustainability and green technology-based projects to enhance students' environmental awareness and social skills. Through this model, students actively engage in projects that emphasize eco-friendly principles, such as the use of renewable energy, waste management, and the protection of ecosystems [26]. The collaborative nature of these projects enables students to develop positive social attitudes, including cooperation, empathy, and responsibility for the environment.

Previous research on PBL has demonstrated its effectiveness in improving students' critical thinking, problem-solving and collaborative skills [27]. However, these studies were conducted at the high school level and focused on academic subjects. In contrast, the GTPBL model adapts PBL specifically for early childhood education and incorporates a green technology perspective, which remains limited in the current literature. The model addresses the gap by providing concrete, age-appropriate environmental projects that engage learners through hands-on and meaningful activities [28] Thus, GTPBL contributes a more holistic and sustainability-oriented dimension to PBL in early childhood education [29]. Table 1 shows the syntax of GTPBL learning.

Table 1. Syntax of Green Technology Project Based Learning (GTPBL) model

Steps	Learning Activities	Learning Objective	Tools and Materials
Problem Identification	Teachers and students identify environmental issues such as pollution or climate change.	To help students recognize environmental issues that need to be addressed with green technology.	Concept cards, posters, environmental issue images, world map, reading materials
Project Planning	Students, along with the teacher, plan a green technology-based project such as creating a renewable energy system or waste management.	To develop planning and collaboration skills, and to provide understanding of green technology solutions.	Paper, pencils, whiteboard, stationery, project reference materials (books, internet)
Research and Exploration	Students conduct research on relevant green technologies for the selected project, including exploring eco-friendly resources.	To deepen students' knowledge of green technologies and sustainability.	Computers, internet, reference books, scientific articles, ecological materials
Project Implementation	Students carry out the project using selected green technology, such as creating a solar panel model or composting.	To apply knowledge through real-life actions and build environmental awareness via hands-on experience.	Mini solar panels, compost bins, plastic bottles, recyclable materials, soil, plant seeds, tools (scissors, glue)
Presentation and Discussion	Students present their project results to the class, followed by a discussion about the environmental and social impacts of the project.	To develop communication skills and increase understanding of the social and environmental impacts of the project.	Projector, computer, project posters, whiteboard, presentation tools (pointer, microphone)
Reflection and Evaluation	Teachers and students reflect together on the learning process and project results, discussing challenges and achievements.	To enhance self-awareness and evaluate the learning process, identifying areas for improvement in future projects.	Notebooks, evaluation forms, whiteboard, paper for group discussions
Strengthening Social Attitudes	The teacher provides further guidance on social values such as social responsibility, empathy, and cooperation during the project.	To enhance students' social attitudes, such as care for others and the environment, and promote proactive behaviors toward sustainability.	Books on sustainability, social values cards, inspirational videos, teaching aids

B. Environmental Awareness

Environmental awareness involves an individual's understanding of, and concern for, the importance of environmental conservation and the effects of human activities on ecosystems. Research indicates that individuals with high environmental awareness are more likely to engage in environmentally responsible behaviors, such as recycling and reducing energy consumption [30]. Many studies have highlighted the effectiveness of environmental education in improving children's ecological knowledge and attitudes [31, 32]. However, these programs often focus on information transmission rather than experiential learning. In contrast, recent studies advocate for hands-on activities, such as gardening and waste separation, which significantly enhance young learners' pro-environmental behaviors [33]. PBL related to environmental issues has also proven effective in encouraging ecological responsibility [34], yet its application in early childhood settings remains underexplored. The current study advances this field by incorporating environmental awareness into a project-based model tailored to early learners, supporting the development of sustainable habits from a young age. Table 2 presents the dimensions and indicators of environmental awareness.

C. Social Attitudes

Social attitudes represent individuals' judgments or evaluations of social objects, people, or groups, which shape their interactions and behavior within society. In early childhood, nurturing social attitudes is vital for fostering positive behaviors such as empathy, cooperation, and respect [35]. Previous research has established that positive role models, family dynamics, and social norms significantly impact children's social development [36]. Studies by Silvia *et al* [37] and Perez [38], emphasized the importance of emotional support and cooperative learning environments in cultivating social competence. According to research, children who are raised in welcoming and encouraging surroundings are more likely to acquire positive social skills like empathy and cooperation [39]. What distinguishes the

present study is its integration of social attitude development within the GTPBL framework, embedding values like cooperation and empathy directly into environmentally themed projects. This approach contrasts with earlier programs that treated social learning as a separate domain, offering a more integrated and applied method of social-emotional development. Table 3 shows the dimensions and indicators of social attitudes.

Table 2. Dimensions and indicators of environmental awareness

No	Dimension	Indicator
1.	Information/Knowledge	1. Knowing environmental issue. 2. Understanding the impact of environmental damage and possible solutions. 3. Knowing the individual's role in preserving the environment.
2.	Personal Attitides	1. Having a caring attitude towards the environment. 2. Adopting an environmentally friendly lifestyle, such as reducing waste. 3. Practicing resource conservation habits.
3.	General Belief/Values	1. Having values of sustainability and nature preservation. 2. Believing that protecting the environment is a collective responsibility. 3. Considering the importance of maintaining ecological balance for the future.

Source: Sánchez & Lafuente (2010) [34]

Table 3. Dimensions and indicators of social attitude

No	Dimension	Indicator
1.	Honest	1. Telling the truth and avoiding lies. 2. Being transparent and trustworthy in all actions.
2.	Discipline	1. Following rules and regulations. 2. Maintaining punctuality and adhering to schedules.
3.	Polite	1. Showing respect to others and using polite language. 2. Being courteous in both verbal and non-verbal communication.
4.	Confident	1. Demonstrating self-assurance in expressing ideas and interacting with others. 2. Believing in one's own abilities and decisions.
5.	Caring	1. Showing empathy and concern for the well-being of others. 2. Helping and supporting others in need.
6.	Responsible	1. Taking ownership of personal actions and fulfilling obligations. 2. Being accountable for tasks and commitments.

Source: Curiculum 2013

D. Teacher Guidance

Table 4. Dimensions and indicators of teacher guidance

No	Dimension	Indicator
1.	Providing learning guidance	1. Assisting children in understanding learning materials in an easy-to-grasp manner. 2. Providing direction in completing tasks or learning activities. 3. Motivating children to enhance their enthusiasm for learning.
2.	Providing problem-solving guidance	1. Guiding children to solve academic or non-academic challenges. 2. Helping children find appropriate solutions when facing learning difficulties. 3. Encouraging children to think creatively and critically to solve problems.
3.	Providing social and personal guidance	1. Supporting the development of children's self-confidence. 2. Guiding children to build positive social relationships with peers and their environment. 3. Providing advice on behavior and character development.

Teacher guidance refers to the support, direction, and attention provided by teachers to students, aimed at helping them realize their academic, social, emotional, and moral potential to the fullest. It involves constructive interactions in which teachers facilitate both the acquisition of subject matter and the development of personal growth [40]. Past studies have consistently shown that effective teacher guidance boosts students' self-confidence and supports their socio-emotional development [41]. However, most research tends to focus on the role of guidance in general classroom settings, often at higher education levels. The unique contribution of the current study lies in highlighting how teacher guidance functions within the GTPBL context, especially in early childhood education [42]. Unlike earlier research that primarily viewed teacher guidance as a cognitive scaffold, this study frames it as a holistic support system, encompassing environmental mentorship and value formation. Teachers guide children through real-world environmental projects, facilitating both technical skills and ethical behavior, thus reinforcing the learning objectives in a contextualized and supportive manner [43]. Table 4 shows the dimensions and indicators of teacher guidance.

III. Materials and Methods

A. Research Design

This study employed a quantitative approach with a quasi-experimental, control group pretest-posttest design. Two groups were involved: an experimental group that received the GTPBL model intervention, and a control group that did not receive any comparable treatment. The objective was to determine the effect of the GTPBL model, implemented under teacher supervision, on children's social and environmental attitudes. Table 5 presents the research design.

Table 5. Research design control group pretest posttest

Group	Pretest	Treatment	Posttest
Control	O1	X	O2
Experiment	O3	Xc	O4

B. Population, Sample, and Sampling Technique

The study sample consisted of children aged 5–6 years enrolled in Class B from three early childhood education institutions: KB TK Aisyiyah Bustanul Athfal 7, RA Aisyiyah 5 Kalitengah, and TK Dharma Wanita Persatuan Ngaban. These are private early childhood education schools that emphasize character development and social values. The sample was selected using purposive sampling based on specific criteria: (1) children aged 5–6 years, (2) actively participating in classroom learning activities, (3) having basic communication skills appropriate to early childhood development, and (4) receiving parental or guardian consent to participate in the research. A total of 60 students were selected and divided into two groups: the experimental group, which received treatment through the GTPBL learning model,

and the control group, which did not receive any equivalent treatment. The GTPBL strategy was implemented in Class B as an effort to improve children's social attitudes and environmental awareness.

C. Data Collection Technique

Data collection for this study involved administering a questionnaire designed around social attitudes and environmental awareness variables. Teachers facilitated the process to ensure that children clearly understood each statement, and the questionnaire items were presented in a Likert scale format calibrated to young learners' comprehension levels. Questionnaires were distributed before the intervention (pretest) to establish the baseline of students' environmental awareness and social attitudes, and then after the intervention (posttest) to assess any changes following the implementation of the GTPBL model. The effectiveness of this learning model was objectively evaluated by comparing the experimental group's posttest results with those of the control group.

In addition, teacher guidance as a moderating variable was measured using structured observation sheets completed by trained observers during the learning process. The observation instrument covers three dimensions: learning guidance, problem-solving guidance, and socio-personal guidance, each of which consists of indicators related to academic support, character development, and problem solving. This observation was used to assess the consistency of the teacher's role in supporting GTPBL learning.

D. Data Analysis Technique

The data analysis in this study uses descriptive analysis to describe or describe the characteristics of data derived from a sample (using mean and gain) and statistical analysis, namely using 1) Validity test, 2) Normality test with Kolmogorov-Smirnov, 3) Homogeneity test using Levine statistics, and 4) Hypothesis testing using Two-Way Analysis of Variance (ANOVA). The test in this study used the SPSS Program.

IV. Result and Discussion

A. Result

1) Validity test

At a 5% significance level (0.254), the calculated r-value from the test results is compared to the r-table value to determine an item's validity. An item is considered valid if its r-value exceeds the r-table value. Table 6 presents the validity test outcomes for the environmental awareness instrument, Table 7 for the social attitude instrument, and Table 8 for the teacher guidance instrument.

Table 6. Environmental awareness validity test results

Dimension	Parameter	r-tabel	r-hitung	Description
Information / Knowledge	Y1.1	0.254	0.883	Valid
	Y1.2	0.254	0.854	Valid
	Y1.3	0.254	0.779	Valid
Personal Attitides	Y1.4	0.254	0.612	Valid
	Y1.5	0.254	0.645	Valid
	Y1.6	0.254	0.771	Valid
General Belief/Values	Y1.7	0.254	0.725	Valid
	Y1.8	0.254	0.637	Valid
	Y1.9	0.254	0.812	Valid

Based on Table 6, all statement items in the dimensions of Environmental Awareness (Information/Knowledge, Personal Attitudes, and General Beliefs/Values) show r-count values greater than r-table (0.254), thus all items are declared valid. This indicates that the instrument used has good validity and is appropriate for measuring students' environmental awareness.

Table 7. Social attitude validity test results

Dimension	Parameter	r-tabel	r-hitung	Description
Honest	Y2.1	0.254	0.832	Valid
	Y2.2	0.254	0.854	Valid
Discipline	Y2.3	0.254	0.758	Valid
	Y2.4	0.254	0.725	Valid
Polite	Y2.5	0.254	0.721	Valid
	Y2.6	0.254	0.767	Valid
Confident	Y2.7	0.254	0.788	Valid
	Y2.8	0.254	0.771	Valid
Caring	Y2.9	0.254	0.638	Valid
	Y2.10	0.254	0.698	Valid
Responsible	Y2.11	0.254	0.821	Valid
	Y2.12	0.254	0.864	Valid

Based on Table 7, all statement items in the Social Attitude dimension also show r-count > r-table (0.254), meaning all items are valid. This implies that the instrument is legitimately usable to assess students' social attitudes such as honesty, discipline, politeness, self-confidence, care, and responsibility.

Table 8. Teacher guidance validity test results

Dimension	Parameter	r-tabel	r-hitung	Description
Providing Learning Guidance	M1.1	0.194	0.729	Valid
	M1.2	0.194	0.634	Valid
	M1.3	0.194	0.687	Valid
Providing Problem-Solving Guidance	M1.4	0.194	0.741	Valid
	M1.5	0.194	0.632	Valid
	M1.6	0.194	0.783	Valid
Providing Social and Personal Guidance	M1.7	0.194	0.725	Valid
	M1.8	0.194	0.692	Valid
	M1.9	0.194	0.637	Valid

According to Table 8, all items in the Teacher Guidance dimension (Learning Guidance, Problem Solving, and Social-Personal Guidance) show r-count > r-table (0.194), and are therefore considered valid. This demonstrates that the teacher guidance instrument has a high level of reliability in measuring the teacher's role in the learning process.

2) Normality test

Table 9. Normality test results

Variable	Kolmogorov-Smirnov	Sig	Description
Environmental Awareness-GTPBL	0.947	0.521	Normal
(Environmental Awareness-Social Attitude)-GTPBL	0.728	0.771	Normal
Environmental Awareness-PLG	0.836	0.671	Normal
Environmental Awarness-PPSG	0.664	0.879	Normal
Environmental Awarness-PSPG	0.896	0.671	Normal
(Environmental Awareness-Social Attitude)-PLG	0.624	0.842	Normal
(Environmental Awareness-Social Attitude)-PPSG	0.821	0.671	Normal
(Environmental Awareness-Social Attitude)-PLG	0.643	0.874	Normal

The aim of the normality test was to ascertain that the study's data followed a normal distribution, a prerequisite for parametric statistical analysis. The Kolmogorov-Smirnov test was used to evaluate whether each variable in this study was

normally distributed. A significance (Sig.) value above 0.05 implies that the data for all variables are normally distributed. The results of the normality test are presented in Table 9.

Based on Table 9, all variables show significance values greater than 0.05, indicating that the data are normally distributed. Therefore, the assumption for conducting parametric statistical analysis is met.

3) Homogeneity test

The homogeneity test was performed to determine whether the variances between the groups in this study were similar, ensuring that the groups being compared had comparable characteristics. The homogeneity test was conducted using Levene's Statistic and significance (Sig). All Sig values were greater than 0.05, indicating no significant differences in variance between the groups. The results of the homogeneity test are presented in Table 10.

All of the variables that were examined had homogeneous variances, according to the findings of the homogeneity test in Table 10. For each combination of factors, the sig-value is more than 0.05, as shown by the values of 0.637 for GTPBL (Green Thinking Project-Based Learning), 0.621 for PLG (Project Learning Group), 0.693 for PPSSG (Pretest–Posttest Social Skills Group), and 0.681 for PSPG (Pretest Social Participation Group). Consequently, it may be said that the variation among the groups is uniform.

Table 10. Homogenity test results

Variable	Levene Statistic	Sig	Description
(Environmental Awareness) * (Environmental Awareness-Social Attitude) GTPBL	7.824	0.637	Homogen
(Environmental Awareness) * (Environmental Awareness-Social Attitude) PLG	6.469	0.621	Homogen
(Environmental Awareness) * (Environmental Awareness-Social Attitude) PPSSG	7.283	0.693	Homogen
(Environmental Awareness) * (Environmental Awareness-Social Attitude) PSPG	6.791	0.681	Homogen

4) Test between two subjects

The purpose of the between-subjects test is to compare the outcomes of the experimental group and the control group following different interventions. In this study, the experimental group was taught using the GTPBL approach with teacher supervision, while the control group received traditional instruction. This test was conducted to determine whether there were significant differences between the pretest, posttest, and gain scores of the two groups, helping to assess how effectively each learning model contributed to improving students' environmental awareness and social attitudes.

Table 11. Two-subject test results

Group	N	Pretest		Postest		Gain	
		Mean	Stdev	Mean	Stdev	Mean	Stdev
Control (Conventional)	30	45.30	6.10	80.00	7.10	34.70	4.20
Experiment (GTPBL)	30	50.10	5.90	83.20	6.80	33.10	4.50

Table 12. Control group test results

Control Group	N	Pretest		Postest		Gain	
		Mean	Stdev	Mean	Stdev	Mean	Stdev
Providing Learning Guidance	18	50.12	7.23	73.45	7.01	23.33	3.24
Providing Problem-Solving Guidance	20	48.94	6.04	74.21	7.11	25.27	3.36
Providing Social and Personal Guidance	22	47.72	5.89	79.34	7.02	31.62	4.12

Table 13. Experiment group test results

Experiment Group	N	Pretest		Postest		Gain	
		Mean	Stdev	Mean	Stdev	Mean	Stdev
Providing Learning Guidance	18	46.58	6.12	85.12	7.34	38.54	3.78
Providing Problem-Solving Guidance	20	47.11	5.98	82.52	6.91	35.41	3.54
Providing Social and Personal Guidance	22	45.76	5.59	84.76	7.45	39.00	3.94

Based on Table 11, Table 12, and Table 13, the results of the test between the two subjects show that the experimental group (Environmental Awareness–Social Attitude) had a higher mean posttest and gain scores than the control group (Environmental Awareness) in all subcategories. The highest gain was recorded in the experimental group in the Providing Social and Personal Guidance subcategory. Overall, the experimental group showed better improvement after the treatment, with consistently higher gains across all subcategories.

5) Two way ANOVA test

The two-way ANOVA test is used to analyze mean differences across multiple groups based on two factors that may influence the dependent variable. In this study, the two-way ANOVA test was applied to examine the effects of the Environmental Awareness and Social Attitude variables, moderated by Teacher Guidance, on post-test results, as well as the interaction between these two variables. This test aims to determine whether these factors significantly affect improvements in learning outcomes and to assess whether the interaction between the two variables has different impacts on the control and experimental groups. The results of the two-way ANOVA test are presented in Table 14 below.

Based on Table 14, the variable Environmental Awareness and Social Attitude significantly affects post-test scores (F = 4.87, $Sig.$ = 0.007 < 0.05), where students in the control group scored an average of 34.70, while those in the GTBEL experimental group scored lower at 33.10. Although statistically significant, this result suggests the need for further examination of contextual or instructional factors that may have influenced the experimental group's performance.

In terms of Teacher Guidance, the ANOVA results also show a significant effect (F = 3.98, $Sig.$ = 0.005 < 0.05). Students who received social and personal guidance achieved the highest post-test mean score (31.62), compared to those who received only learning guidance (23.33) or

problem-solving guidance (25.27). This indicates that teacher involvement in socio-emotional support is a crucial contributor to improved learning outcomes.

Furthermore, the interaction effect between Environmental Awareness–Social Attitude and Teacher Guidance is also statistically significant ($F = 5.12$, $Sig. = 0.009 < 0.05$). The highest mean score (35.41) was achieved by students who were exposed to the GTBEL model combined with social and personal guidance, suggesting that the effectiveness of environmental and social learning is significantly amplified when paired with appropriate teacher support.

Nevertheless, the practical significance of these findings is evident: integrating environmental and social attitude development into learning, especially when supported by comprehensive teacher guidance, has a meaningful and positive impact on student achievement. This emphasizes the importance of holistic teaching strategies that blend cognitive content with socio-emotional scaffolding.

Table 14. Two way ANOVA test results

Dependent Variable: Post Test	**Mean**	**F**	**Sig.**
Enviromental Awarness-Social Attitude			
Control (Conventional)	34.70	4.87	0.007
Experiment (GTPBL)	33.10		
Teacher Guidance			
Providing Learning Guidance	23.33	3.98	0.005
Providing Problem-Solving Guidance	25.27		
Providing Social and Personal Guidance	31.62		
Enviromental Awarness-Social Attitude * Teacher Guidance			
Environmental Awareness * PLG	23.33	5.12	0.009
Environmental Awarness * PPSG	25.27		
Environmental Awarness * PSPG	31.62		
Environmental Awareness-Social Attitude * PLG	38.54		
Environmental Awareness-Social Attitude * PPSG	35.41		
Environmental Awareness-Social Attitude * PLG	39.00		

B. Discussion

1) Effect of GTPBL model on environmental awareness before and after intervention

The GTPBL model demonstrates significant potential in enhancing students' environmental awareness. Prior to the intervention, students had a limited understanding of environmental issues, particularly in terms of applying green technology in everyday life. However, after the implementation of GTPBL, noticeable improvements were observed in students' environmental awareness, both in their comprehension of environmental issues and in their adoption of stronger sustainability values. The results indicated that students who participated in the GTPBL learning model experienced a substantial increase in environmental awareness, as reflected by the rise in pretest and posttest scores. This study found a significant difference between the experimental group, which followed the GTPBL model, and the control group, which did not receive the same treatment. These findings suggest that the GTPBL model effectively transformed students' understanding of and engagement with environmental issues.

Research conducted by Lopez and Palacios [44] suggests that PBL, particularly when focused on sustainability issues, is effective in enhancing students' environmental awareness. Through such projects, students not only gain knowledge but also actively participate in activities that reinforce their understanding of environmental conservation. Another study by Doychinova [45] It was also found that a PBL model integrating green technology enhanced students' understanding of the importance of sustainable natural resource management. A green technology-based project encourages students to think critically about the environmental impact of the technologies they use and provides them with a deeper understanding of eco-friendly technological solutions. Learning through the application of such real-world projects offers invaluable hands-on experience, enriching students' comprehension of how they can contribute to environmental conservation by adopting greener technologies [46]. Overall, the GTPBL model proved to be effective in enhancing students' environmental awareness. This approach not only expanded their knowledge of environmental issues but also equipped them with the skills to apply technology-based solutions that are environmentally friendly.

2) Effect of GTPBL model on social attitudes before and after intervention

The impact of the GTPBL model on students' social attitudes, both before and after the intervention, is evident in the increase in social values, particularly in their attitudes toward cooperation, concern for the environment, and social responsibility. PBL that integrates green technology provides students with opportunities to collaborate on solving real-world problems related to environmental issues. This collaborative experience fosters positive social attitudes, such as empathy, a sense of responsibility towards society, and the ability to communicate effectively within teams. Prior to the intervention, students' social attitudes may have been limited to theoretical understanding, but after engaging in the GTPBL project, they showed improvements in social awareness and a heightened sense of responsibility towards both environmental issues and society.

Previous research conducted by Alves *et al.* [47] suggested that PBL has a positive impact on improving students' social skills. The GTPBL learning model, in particular, is effective in enhancing cooperation among students and reinforcing social values within groups. With its focus on environmental issues, GTPBL provides students with the opportunity to not only learn about green technology but also strengthen social values such as solidarity and collaboration in addressing broader social challenges. Research by Piliang and Asnewastri [48] further supports the idea that green technology-based projects can improve students' social attitudes through collaboration-based learning aimed at

solving shared social and environmental problems. This suggests that GTPBL not only promotes environmental awareness but also contributes to the development of more positive social attitudes among students.

3) Effectiveness of GTPBL model moderated by teacher guidance on environmental awareness

This learning model incorporates a project-based approach that enables students to learn through hands-on practice by engaging them in activities that promote environmental sustainability, such as designing and implementing green technology-based solutions. The results indicate that the implementation of GTPBL significantly enhances students' understanding of environmental issues and fosters a shift toward more pro-environmental attitudes. These findings suggest that the GTPBL approach may help increase students' environmental awareness by providing opportunities for them to engage with real-world issues in a meaningful learning context [49].

In addition, teacher guidance plays a crucial role in enhancing the effectiveness of the GTPBL model. Teachers serve not only as instructors but also as facilitators who assist students in overcoming challenges that may arise during project implementation [50]. Teacher guidance is particularly important in helping students understand the connection between green technology and environmental sustainability, thereby enriching their learning experience. Teachers who provide the right support can significantly enhance students' critical thinking skills, as well as their ability to plan and implement environmentally friendly solutions [51]. Previous research by Hugerat [52] supports these findings, showing that PBL models integrated with environmental issues are effective in increasing students' awareness of sustainability challenges. In addition, strengthening the role of teachers in PBL is suggests to deepen students' understanding and accelerate the learning process, the combination of PBL and effective teacher guidance proves to be highly beneficial. In line with previous research, the results of this study also demonstrate that PBL, when coupled with proper guidance, can significantly enhance students' learning outcomes and environmental awareness [51].

Furthermore, the GTPBL model promotes the development of ecological citizenship, which is the students' awareness and responsibility to care for their natural environment beyond the classroom. By involving students in concrete actions and environmental campaigns, such as clean-up movements or community green technology exhibitions, students not only learn to care, but also inspire their surroundings to adopt a similar awareness. This adds a multiplier effect to the impact of GTPBL implementation, particularly when supported by consistent teacher mentoring.

The application of GTPBL model moderated by teacher guidance is not only suggests to increase students' environmental awareness, but also able to encourage them to take real action in preserving the environment. Through the PBL model, students are given the opportunity to design and develop green technology-based solutions that address current environmental issues, such as waste management, renewable energy use, and carbon emission reduction [53]. This hands-on involvement allows students to better grasp the importance of sustainability and understand the impact of their actions on the environment. Teacher guidance plays a strategic role in this process, as it helps students connect theoretical knowledge with real-world applications. Teachers, acting as facilitators, provide direction in designing projects that are not only grounded in theory but also align with the principles of environmental sustainability and green technology [54]. With the appropriate guidance, teachers can inspire students to think critically, creatively, and innovatively, enabling them to develop practical solutions that can be applied in the real world. This is crucial because the success of the GTPBL model relies not only on a well-structured learning design but also on the active involvement of teachers in supporting and guiding students throughout the learning process.

4) Effectiveness of GTPBL model moderated by teacher guidance on social attitudes

The GTPBL model has been suggests to be effective in improving students' social attitudes through a student-centered learning approach that focuses on environmentally oriented projects. GTPBL combines technology-based learning with project activities that instill sustainability values, such as social responsibility and environmental stewardship. During the implementation, students are actively engaged in activities such as waste management, tree planting, or creating eco-friendly products. These activities promote meaningful social interactions among students, peers, and the broader community, thereby strengthening a sense of shared responsibility, tolerance, and empathy [55]. Research by Beisel [56] further supports this, suggest that PBL significantly enhances students' social skills by emphasizing collaboration and collective problem-solving.

Teacher guidance plays a crucial moderating role in the GTPBL model. In this approach, the teacher acts as a facilitator, guiding students to understand the social and environmental values they are expected to achieve through the project [57]. During the GTPBL implementation, teachers provide direction, feedback, and motivation to ensure that students can successfully complete their projects. Teachers also assist students in reflecting on their learning experiences, making the social values they have learned more meaningful and applicable [58]. Research by McKinney [59] suggests that the success of PBL depends largely on the quality of teacher guidance, which helps students connect their project experiences to the development of social skills and values. Further studies support these findings, with Llorent *et al.* [60] demonstrating that PBL enhances students' social skills, including cooperation, empathy, and communication. Students who participated in GTPBL with effective teacher guidance showed significant improvements in their social attitudes compared to those who did not follow this model [61]. For instance, students became more open to their peers' perspectives, more actively engaged in group activities, and more concerned about the social impact of their actions. Green technology-based projects create opportunities for students to learn how to solve problems collaboratively, value team members' contributions, and communicate effectively.

In addition, teacher guidance in the GTPBL model also shapes students' leadership capacity and civic responsibility. Students are given the opportunity to take on leadership roles within group projects, coordinate team actions, and interact

with stakeholders such as local communities or environmental organizations. These activities, guided by teachers, enhance students' confidence and develop their initiative-taking behavior, which are essential components of social development.

The success of GTPBL is further supported by the sustainability of the social values it instills, which students continue to apply in their daily lives. After engaging in this PBL approach, students demonstrate increased concern for the environment and heightened empathy towards social issues within their communities. A study by El Bakkali [62] found that PBL not only enhances students' understanding of concepts but also has a long-term impact on their social attitudes and pro-social behavior. Therefore, GTPBL, when guided effectively by teachers, not only improves students' social attitudes during the learning process but also contributes to their long-term character development as socially responsible and conscientious individuals.

V. Conclusion

The GTPBL model suggests significant effectiveness in improving students' environmental awareness and social attitudes. The implementation of this model, which combines project-based learning with green technology, provides students with hands-on experience to solve environmental problems through practical and innovative approaches. The results show an increase in students' understanding of environmental issues such as climate change, pollution, and sustainability, which is accompanied by an improvement in their social attitudes toward society and the surrounding environment.

One of the key success factors of this model is the role of the teacher as a facilitator who assists students in designing and implementing green technology-based projects. Teachers not only provide guidance in technical aspects, but also direct students to develop social values such as cooperation, care, and responsibility for the environment. In addition, this model introduces the concept of sustainability in a broader context, which involves understanding the interaction between humans, technology, and nature. Thus, GTPBL not only increases students' knowledge of environmental issues, but also shapes social characters who are more concerned about sustainability and society.

Therefore, it is strongly recommended that schools and educational policymakers adopt the GTPBL model as part of environmental and character education curricula. Teachers should be empowered through professional development programs that equip them to guide project-based environmental learning effectively. In addition, school administrators are encouraged to create collaborative learning environments and support the integration of green projects that connect theory with real-world practices. Such concrete steps will ensure that environmental education is not only informative but also transformative in building a socially responsible and environmentally aware generation.

A. Limitations, Implications and Suggestions

This study has several limitations that should be considered. First, it was conducted in only three kindergartens with a total of 60 children. This relatively small sample size means that the results cannot be generalized to all early childhood education settings. In other words, the findings may not apply to schools or regions with different characteristics. Therefore, readers are encouraged to interpret the results within the limited context of the schools involved in this study. Second, the research focused only on learning related to environmental awareness and social attitudes. This means it does not yet show the effectiveness of the GTPBL model in other types of early childhood learning.

Despite these limitations, the study found that the GTPBL model can help children become more environmentally conscious and improve their social interactions. This suggests that project-based learning with a green technology theme can be an engaging and meaningful approach for young children. For future research, it is recommended to involve a larger and more diverse sample from different schools and regions to make the findings more reliable and widely applicable. In addition, a follow-up study is needed to assess the long-term impact of this learning model on students' character and behavior and how teachers can continue to implement it effectively in the classroom. Future research could also expand the focus to other learning domains such as literacy, numeracy and creativity, and explore the influence of teacher training in supporting the continued successful implementation of GTPBL.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The contributions of the authors to this study are as follows: Choirun Nisak Aulina contributed to the research design and implementation, focusing on the development of the Green-Tech Project-Based Learning (GTPBL) model, theoretical review of GTPBL, environmental awareness, and children's social attitudes. She was responsible for data analysis and manuscript drafting to communicate the research findings. Fajar Arianto contributed to the design of the research methodology related to GTPBL implementation and teacher guidance. He assisted with statistical data analysis and highlighted the model's impact on children's behavior. Agus Salim played a role in data collection, particularly measuring the effectiveness of GTPBL and teacher guidance in improving social attitudes and environmental awareness. He also assisted in data analysis and the preparation of the results and discussion sections. Fitri Mar'atus Sholihah contributed by managing the data collection process, including administering pretests and posttests to evaluate changes in children's attitudes. All authors collaborated in data analysis, interpretation of results, and manuscript preparation. Each author critically revised the manuscript for important intellectual content and approved the final version for publication.

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