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STEAM EDUCATION FOR SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL AWARENESS: IMPACT ON STUDENTS' BEHAVIOR AND ATTITUDES

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Abstract
This study examined the impact of STEAM Education for Sustainable Development on students' environmental awareness, environmental attitudes, environmental behavior, and climate awareness in the context of Sustainable Development Goal 13 (Climate Action). STEAM education integrates Science, Technology, Engineering, Arts, and Mathematics to promote creativity, critical thinking, collaboration, and sustainability-oriented problem-solving skills among learners. The study adopted a quantitative cross-sectional survey design and collected data from 200 students enrolled in secondary schools and higher education institutions through structured questionnaires. Descriptive statistics, correlation analysis, and regression analysis were employed to examine the relationships among the study variables. The findings revealed that sustainability-focused STEAM education significantly enhanced students' environmental awareness, positive environmental attitudes, climate consciousness, and environmentally responsible behavior. The results further indicated strong positive relationships between STEAM learning experiences and sustainable practices among students. The study supported Constructivist Learning Theory and Experiential Learning Theory by emphasizing the importance of active participation and practical learning experiences in promoting environmental responsibility. The study contributed to the growing literature on sustainability education and provided practical implications for educators, curriculum developers, and policymakers in integrating climate education and sustainability concepts into educational practices aligned with SDG 13.

Keywords: *STEAM Education, Sustainable Development, Environmental Awareness, Environmental Behavior, Climate Awareness, Sustainability Education, SDG 13, Climate Action*

Introduction
In recent years, STEAM learning, which combines the fields of Science, Technology, Engineering, Arts and Mathematics, has become an innovative educational method that encourages creativity, critical thinking, collaboration and problem-solving abilities among students. According to some studies, STEAM-based learning is beneficial for sustainable development because it allows students to learn in a way that focuses on solving real problems in the environment (Rosyida et al., 2024; Djam'an, 2024). Education for Sustainable Development (ESD) is an approach that focuses on providing students with the knowledge, values, and attitudes required to create a sustainable future and to effectively address global challenges like climate change and environmental degradation (Huang, 2024). Climate change is one of the greatest global challenges that are discussed under Sustainable Development Goal 13 (Climate Action) and consequently, environmental awareness and climate education are of growing importance. Integrating SDG 13 into educational systems helps students develop environmental responsibility and sustainable behavior. The study reveals that STEAM education with ESD principles has a significant effect in improving students' environmental awareness and pro-environmental attitudes. Therefore, STEAM education plays an important role in promoting environmental responsibility and climate consciousness among learners.

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Although the environment is experiencing increasing challenges, the students show low level of environmental awareness and also low level of sustainable behaviour. Many educational institutions do not have sustainability-related pedagogies which are well anchored in real-world environmental issues (Parry & Metzger, 2023; Agbor et al., 2024). Climate action and environmental responsibility are often not addressed with students in traditional teaching and learning approaches. Thus, there is a pressing requirement for innovative educational approaches and methods, like STEAM education, to build students' environmental attitudes, climate literacy, and sustainable practices.

Research Objectives

1. To examine the impact of STEAM education on students' environmental awareness and attitudes.
2. To analyze the relationship between sustainability-focused STEAM learning and students' environmental behavior.
3. To evaluate the effectiveness of STEAM education in promoting sustainable development and climate awareness among students.

Research Questions

1. What is the impact of STEAM education on students' environmental awareness and attitudes?
2. What relationship exists between sustainability-focused STEAM learning and students' environmental behavior?
3. How effective is STEAM education in promoting sustainable development and climate awareness among students?

Research Hypotheses

H1 STEAM education significantly influences students' environmental awareness and attitudes.

H2 Sustainability-focused STEAM learning has a positive relationship with students' environmental behavior.

H3 STEAM education significantly promotes sustainable development and climate awareness among students.

This study is significant for educators because it highlights effective teaching strategies that improve environmental awareness and responsible behavior among students (Aldawsari et al., 2024; Torabi et al., 2021). It is useful for curriculum developers in creating a learning programs of sustainability oriented and interdisciplinary learning that are related with SDG 13. The results could be leveraged by policymakers to improve climate education policies and to encourage sustainable educational reforms. In addition, the study helps in fulfilling SDG 13 Climate Action by promoting environmentally responsible actions through educating people (Priatna & Khan 2024). Furthermore, it enriches the literature on sustainability education by analyzing the effect of STEAM education on students' attitudes and behaviors toward the environment.

Literature Review

Concept of STEAM Education

STEAM education is the result of a combination between Science, Technology, Engineering, Arts and Mathematics, with the aim of using this combination in an integrated way that promotes the development of critical thinking, creativity, collaboration and innovation. STEAM focuses on interdisciplinary learning, which embodies the knowledge gained in several fields to solve real world problems, rather than learning based on specific subjects (Perignat & Katz-Buonincontro, 2019). Educational reforms in recent years have focused on

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STEAM as it helps to strengthen students' creative thinking, analytical, and 21st-century problem-solving skills (Yakman & Lee, 2012). Incorporating arts into STEM subjects enhances imagination, communication, and innovation, allowing students to develop their imagination to tackle scientific and environmental challenges. This comprehensive concept of STEAM education is a way to make education meaningful, as it combines theory with application and social issues such as sustainability and climate change education (Auh et al., 2024).

Sustainable Development in Education

Sustainable development in education is about imparting knowledge, values, and competencies to make a sustainable society. Education for Sustainable Development (ESD) invites children and young people to learn about the three facets of sustainability (environment, economy, society), and to be citizens with a sense of responsibility (UNESCO, 2020). The significance of ESD has grown over time as the world faces environmental issues like climate change, pollution and biodiversity loss, and it is important for students to be educated on this so that they have the ability to act responsibly. One of the Sustainable Development Goals has a particular focus on Education and awareness raising on climate mitigation and adaptation (plus SDG13), as stated by Babacan (2024). Therefore, educational institutions are encouraged to incorporate concepts of sustainability in education programs and practices. Kopnina (2020) notes that sustainability education fosters students' environmental ethics and motivates them to take action in climate action efforts. Incorporating sustainability into STEAM education offers students a chance to engage in creative innovation, scientific inquiry, and technology to solve environmental problems.

Environmental Awareness and Environmental Attitudes

Environmental awareness refers to individuals' understanding of environmental issues and their willingness to protect natural resources. Environmental literacy entails knowledge, attitudes, values and behaviors, concerning environmental protection (Ardoin et al., 2020). High environmental awareness is a key factor in enabling students to adopt sustainable lifestyles and engage in environmental conservation activities. Educational experiences, social values, media exposure and environmental policies are all factors that shape environmental attitudes (Collado et al., 2020; Otto & Pensini, 2017). The importance of climate education in raising students' awareness of the environment is because it will help to increase awareness of the problems related to climate change and the effects of climate change on society. There is some evidence that a more experiential/activity based method of learning is more effective at enhancing environmental attitudes than a lecture approach (Trott, 2019). As a result, more and more schools and universities are implementing sustainability programs to improve environmental education and climate awareness among students.

STEAM Education and Environmental Sustainability

STEAM education has become known as an effective pathway to promote environmental sustainability and climate awareness. In STEAM learning, students can deepen their understanding of the environment by immersing themselves in the process of solving problems, which not only helps them gain knowledge, but also fosters creativity and innovation (Zhao & Abdullah, 2024). Education that focuses on sustainability, including project-based learning, design challenges focused on the environment, green innovation activities, etc., promotes students in the process of finding solutions to environmental issues. Students can create renewable energy projects, recycling systems, eco-friendly products, etc. in interdisciplinary STEAM projects. Sousa and Pilecki (2018) argue that STEAM education increases climate awareness as students are directly involved in real-world issues concerning climate and use

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knowledge to make decisions for sustainable practices. These methods foster environmental awareness and contribute to the knowledge of students in relation to sustainable development goals.

Students' Environmental Behavior

Environmental Behavior is something that is associated with actions and practices that help to make the environment sustainable and conserved. Some of the students' sustainable behaviours are: recycling, conserving energy, reducing waste and participating in campaigns for the environment. The role of educational institutions is crucial in influencing students' environmental behavior, as they can foster eco-friendly practices and initiatives (Altassan, 2023). Environmental awareness, attitudes and education experiences can often affect behavioral intention to protect the environment. Research studies have shown that students who engage in education relating to sustainability are more likely to exhibit positive environmental behaviors and climate conscious actions (Al-Naqbi & Alshannag, 2018; Badea et al., 2020). Environmental projects based on the STEAM strand further promote students' sustainable practices in everyday life, and foster a long-term environmental responsibility.

Empirical Review of Previous Studies

The correlations between STEAM education, environmental awareness, and sustainability behavior have been investigated in several studies. The result of Zhao and Abdullah's (2024) study showed that project learning with STEAM approach increased students' critical thinking and environmental problem solving skills. Similarly, Auh et al. (2024) showed that interdisciplinary STEAM activities facilitated students to become more creative, and more conscious of sustainability. Psycho-social studies on EE have also shown positive outcomes with regard to environmental attitudes and behaviour. Experiential climate education was found to have a profound influence on enhancing participants' environmental consciousness by Trott (2019). Ardoin et al. (2020) also noted that environmental literacy initiatives have a positive impact on the sustainability behaviour of students and their environmental responsibility. Recent research on the importance of STEAM learning and sustainability awareness suggests that the presence of environmental themes in STEAM syllabuses enhances the knowledge of climate change, sustainable attitudes and behaviors among students (Sousa & Pilecki, 2018).

Theoretical Framework

The principles of Constructivist Learning Theory focus on learning as a process of building knowledge by engaging in real-life experiences and collaboration. In STEAM education, students engage in hands-on environmental projects, investigations, and problem-solving activities that enhance understanding of sustainability concepts (Piaget, 1972). The theory is reinforced and strengthened by the conviction that learning is an active process: this increases the awareness of the surrounding and acts as a motivator for responsible behavior.

According to Kolb (2014) in his work of Experiential Learning Theory, learning is a process of doing, experiencing and reflecting. Environmental education programs make use of fieldwork, experiments and sustainability projects to facilitate students' learning by interacting with environmental issues. The experiential learning model is the one that involves the link between what is learned in the classroom and environmental issues in real life to increase environmental attitudes and climate awareness.

Conceptual Framework

STEAM Education for Sustainable Development is identified as the independent variable that affects students' environmental outcomes in this conceptual framework. According to the framework, STEAM education imbued with sustainability awareness helps to cultivate

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students' environmental awareness, climate awareness, and responsible attitude toward environmental protection. The combination of science, technology, engineering, arts and mathematics with the concepts of sustainability allows students to acquire inter-disciplinary knowledge and hands-on experience in addressing environmental issues and finding solutions to sustainability (Huang, 2024; Setiawan et al., 2024). Additionally, previous research showed that STEAM education improved students' critical thinking skills and encouraged the adoption of sustainable learning practices in education (Rosyida et al., 2024).

The dependent variables in the present study are Environmental Awareness, Environmental Attitudes, Environmental Behavior, and Climate Awareness. Environmental Awareness is students' knowledge and understanding of environmental problems and environmental sustainability practices. Environmental Attitudes are students' values, perceptions and positive feelings about environmental conservation and climate action. Environmental Behavior and Climate Awareness are concerned with students' environmentally responsible participation and behavior in daily life, and their understanding of causes, impacts and prevention strategies to climate change, respectively. The study revealed that environmental education had a significant impact on the students' environmental responsibility and awareness of sustainability (Aldawsari et al., 2024). In the same way, educational institutions are one of the important actors in climate change mitigation by carrying out environmental education activities and in fostering Sustainable Development Goal 13 (SDG 13) (Priatna & Khan, 2024).

The framework is based on the premise that incorporation of STEAM education with sustainability has a positive impact on students' comprehension of environmental concern, attitudes towards climate change action and environmentally responsible behaviours. Research that investigated the environmental education in STEAM education showed positive impacts for learners' attitudes of sustainability and involvement with the environment (Djam'an, 2024). Moreover, good environmental teaching methods improved environmental knowledge and sustainable practices of the students (Agbor et al., 2024). Innovative teaching methods also proved to have a positive impact on environmentally responsible behaviors and attitudes of learners (Torabi et al., 2021). However, barriers to sustainability learning still existed in educational institutions, highlighting the need for stronger sustainability-focused instructional practices and effective teacher support systems (Parry & Metzger, 2023). The conceptual framework in Figure 1 displays the relationship between STEAM education for sustainable development and student environmental awareness, attitudes, behavior and environmental climate awareness.

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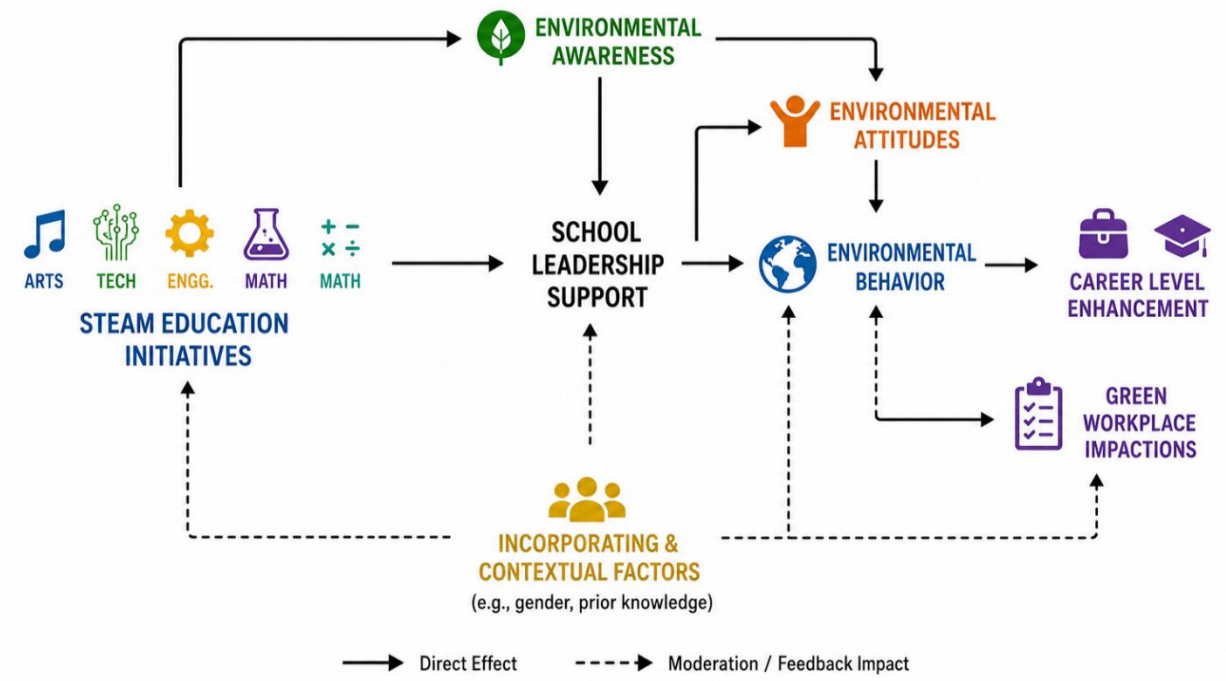

Figure 1. Conceptual Framework of STEAM Education for Sustainable Development and Environmental Outcomes

Research Methodology

The quantitative research was used in this study to delve into the relationship between STEAM Education for Sustainable Development and students' environmental awareness, attitudes, behavior, and climate awareness pertaining to SDG 13 (Climate Action). The quantitative method was deemed appropriate as it would allow the researcher to gather numerical data, analyze the relationships between the study variables, and use statistical methods (Creswell & Creswell, 2017). The study utilized a cross sectional survey design because data were gathered at one time. This design facilitated an efficient and systematic understanding of students' perceptions, experiences and environmental behaviors.

Population of the Study

The population was students from secondary schools and higher education institutions. These students were chosen as they are the learners who were exposed to science, technology and sustainability related educational activities. The study aimed at investigating the effect of STEAM learning experiences on environmental awareness, attitude and sustainable behavior of students (Taherdoost, 2016).

Sample Size and Sampling Technique

The number of students involved in the study was 200 students. The sample size was deemed to be sufficient for statistical analysis and for accurate results about the effects of STEAM education on students' environmental awareness and behavior. A stratified random sampling was used in the study. The participants were divided into different strata according to their education and institutions. The stratification was followed by random sampling within each stratum to ensure equal representation of respondents and to reduce sampling bias. This method gave better results in terms of accuracy and reliability of the data collected.

Data Collection Instruments

A structured questionnaire was used for collecting data, which was developed by the researcher. The questionnaire provided the data for this study on the experiences of students in

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STEAM education, environmental awareness, environmental attitudes, environmental behavior, and climate consciousness. The questionnaire included demographic data, STEAM learning experiences, environmental awareness, environmental attitudes, environmental behaviors and climate awareness. These sections allowed the researcher to explore students' perception of environmental sustainability and how STEAM-based learning can impact students' attitudes and actions towards climate issues. The questionnaire items were measured on a five-point Likert scale which spanned from strongly disagree to strongly agree. The use of a likert scale helped the researcher gather quantitative information and to systematically analyze what participants responded. The structured questionnaire was found suitable as it would enable data collection from a large number of participants in a structured, reliable and efficient manner.

Validity and Reliability

The research instrument was reviewed with subject experts for content validity in order to guarantee the validity of the research instrument. They made suggestions and recommendations which were included prior to the completion of the instrument (Taber, 2017). A small number of students were also involved in a pilot test to check for any confusion or difficulty in the items in the questionnaire. In addition, reliability test (Cronbach's Alpha) was conducted to analyse the instrument's internal consistency. The reliability results showed moderate values, thus confirming the reliability of the questionnaire used in collecting the data.

Data Collection Procedure

The initial stage in the data collection process was to get permission from the chosen educational institutions. The questionnaires were distributed to all participants, once approved. Before participation the respondents were provided with information about the objectives and the significance of the study. Great care was taken to ensure that ethical issues were respected in the data-gathering process. Confidentiality and anonymity of participants was maintained and all data collected was utilized only for academic purposes.

Data Analysis Techniques

Data collected was analyzed using different statistical methods. The respondents' demographic characteristics were summarized using descriptive statistics. In order to measure the students' responses to the questions related to environmental awareness, attitude, behavior and climate awareness, the mean and the standard deviation were calculated. Correlation analysis was performed to investigate the correlation between the variables, and regression analysis was performed to identify the influence of STEAM education on students' environmental outcomes.

Results and Data Analysis

Demographic Analysis

Table 1: *Gender Distribution of Respondents*

Gender	Frequency	Percentage
Male	92	46.0
Female	108	54.0
Total	**200**	**100.0**

Table 1 showed the gender distribution of the respondents of the study. Out of 200 students, 108 (54%) were female, while 92 (46%) were male. The results showed that the sample of the study was slightly dominated by female respondents. The inclusion of both genders in the study

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in a balanced manner made the study more representative and gave different opinions about the subject of STEAM education and environmental sustainability.

Table 2: *Age Distribution of Respondents*

Age Group	Frequency	Percentage
15–18 Years	78	39.0
19–22 Years	94	47.0
23 Years and Above	28	14.0
Total	**200**	**100.0**

Table 2 showed the distribution of the respondents according to age. The age group of the most respondents was 19-22 years, accounting for 47% of the total respondents. 39% of students were between the ages of 15 and 18 and 14% were 23 years old and older. The results showed that most of the respondents were young learners who are involved in educational activities related to STEAM and sustainability.

Table 3: *Educational Level of Respondents*

Educational Level	Frequency	Percentage
Secondary School	86	43.0
Undergraduate	96	48.0
Postgraduate	18	9.0
Total	**200**	**100.0**

Table 3 indicated the educational levels of the respondents. The highest proportion of participants was made up of undergraduate students (48%) while the secondary school students made up 43%. The postgraduate student sample made up 9% of the sample. The results indicated that the study achieved the achievement of collecting responses from the learners from various educational levels, which would lead towards diversity and reliability of the data.

Descriptive Statistics

Table 4: *Descriptive Statistics of Study Variables*

Variables	N	M	SD
STEAM Education	200	4.12	0.61
Environmental Awareness	200	4.25	0.57
Environmental Attitudes	200	4.18	0.63
Environmental Behavior	200	4.05	0.66
Climate Awareness	200	4.21	0.59

Table 4 presented the descriptive statistics of the study variables. The findings revealed that there is high agreement among the students on the variables of STEAM education and environmental sustainability. The mean score of Environmental Awareness was the highest (M = 4.25, SD = 0.57), reflecting good understanding of the students in relation to environmental issues and sustainability practices. The respondents were also aware of climate change and environmental protection as evidenced by the high mean value (M = 4.21, SD = 0.59) that was

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obtained for Climate Awareness. Also, Environmental Attitudes (M = 4.18, SD = 0.63) and Environmental Behavior (M = 4.05, SD = 0.66) showed positive sustainable attitudes and environmentally responsible actions of students. It was found that training students in STEAM with sustainability had a positive impact on their environmental perceptions and climate consciousness.

Table 5: *Environmental Awareness Levels*

Response Category	Frequency	Percentage
Low	18	9.0
Moderate	52	26.0
High	130	65.0
Total	**200**	**100.0**

Table 5 showed the level of awareness of students on environment. Most of the respondents (65%) were high environmental awareness, 26% moderate environmental awareness. 9% indicated that they were low on environmental awareness. The results of these findings suggested that students who were exposed to STEAM education had rich knowledge and understanding about environmental sustainability and climate-related issues.

Table 6: *Environmental Attitude and Behavior Analysis*

Variables	M	SD	Interpretation
Environmental Attitudes	4.18	0.63	Positive
Environmental Behavior	4.05	0.66	Responsible

Table 6 showed students' environmental attitudes and behaviors. High scores (M = 4.18, SD = 0.63) were obtained in the Environmental Attitudes domain, reflecting positive attitudes and perceptions of respondents towards the conservation of the environment and climate action. In the same way, the mean score of Environmental Behavior was 4.05 (SD = 0.66) showing the students' practice of being environmentally responsible. The results indicated that the learning outcomes of STEAM sustainability education made learners feel and act sustainably.

Reliability Analysis

Table 7: *Cronbach's Alpha Reliability Results*

Variables	Number of Items	Cronbach's α
STEAM Education	6	0.86
Environmental Awareness	5	0.84
Environmental Attitudes	5	0.82
Environmental Behavior	5	0.88
Climate Awareness	4	0.81
Overall Reliability	**25**	**0.87**

Table 7 presented the Cronbach's Alpha reliability analysis results for the study instrument. The reliability values were from 0.81 to 0.88, higher than the acceptable value of 0.70

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recommended by researchers. The internal consistency of the items in the questionnaire was high with an overall reliability value of 0.87. Hence it can be stated that the instrument was reliable and appropriate for data collection and statistical analysis.

Correlation Analysis

Table 8: *Correlation Analysis Among Study Variables*

Variables	1	2	3	4	5
1. STEAM Education	1				
2. Environmental Awareness	.691**	1			
3. Environmental Attitudes	.648**	.721**	1		
4. Environmental Behavior	.603**	.674**	.702**	1	
5. Climate Awareness	.657**	.738**	.689**	.641**	1

Note. Correlation is significant at the 0.01 level (2-tailed).

Table 8 presented the correlation analysis among the study variables. The results showed that there were significant positive correlation between STEAM Education and Environmental Awareness ($r = .691$, $p < .01$), Environmental Attitudes ($r = .648$, $p < .01$), Environmental Behavior ($r = .603$, $p < .01$), and Climate Awareness ($r = .657$, $p < .01$). The findings showed that the application of sustainability-focused STEAM learning was able to positively impact students' awareness, attitudes and sustainable practices. Further, high positive correlation among the environmental variables indicated that an enhanced environmental awareness led to positive changes in attitude and environmentally responsible behavior.

Regression Analysis

Table 9: *Regression Analysis: Impact of STEAM Education on Environmental Awareness*

Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.691	.477	.472	0.421

ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	31.846	1	31.846	179.420	.000
Residual	34.947	198	0.176		
Total	66.793	199			

Coefficients

Variables	B	Std. Error	β	t	Sig.
Constant	1.284	0.214		5.999	.000

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STEAM Education	0.721	0.054	.691	13.395	.000

The regression results showed that students' Environmental Awareness was significantly predicted by STEAM Education (β = .691, p < .001). The R^2 value of 0.477 indicated that 47.7% of the students' environmental awareness is accounted for by STEAM education. The results from ANOVA also verified that the regression model was statistically significant, F(1, 198) = 179.420, p < .001. Based on these results, it was concluded that STEAM-based sustainability education had a positive impact on learners' environmental understanding and awareness.

Table 10: *Regression Analysis: Impact of STEAM Education on Environmental Behavior*

Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.603	.364	.359	0.468

ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	24.281	1	24.281	113.627	.000
Residual	42.312	198	0.214		
Total	66.593	199			

Coefficients

Variables	B	Std. Error	β	t	Sig.
Constant	1.462	0.237		6.168	.000
STEAM Education	0.629	0.059	.603	10.659	.000

The regression results showed that students' Environmental Behavior (EB) was significantly influenced by STEAM Education (β = .603, p < .001). The R^2 result was 0.364, which meant that the variance of environmental behavior accounted for 36.4% due to STEAM education. The results of statistically significant ANOVA, F(1,198) = 113.627, p < .001, showed that the regression model was suitable. The results indicated that STEAM learning that focused on sustainability was able to motivate students to act in an environmentally responsible way and adopt sustainable practices.

Hypotheses Testing

Table 11: *Summary of Hypotheses Testing*

Hypotheses	Statement	Decision
H1	STEAM education significantly influences students' environmental awareness and attitudes.	Accepted
H2	Sustainability-focused STEAM learning has a positive relationship with students' environmental behavior.	Accepted

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H3	STEAM education significantly promotes sustainable development and climate awareness among students.	Accepted

Table 11 summarized the hypotheses testing results of the study. All hypotheses were accepted as the results of the statistical analysis indicated that all study variables have significant positive relationships and impacts. The results showed that STEAM Education had a positive effect on students' environmental awareness, environmental attitudes, environmental behavior, and climate awareness. Thus, sustainability-oriented STEAM learning was determined to be an effective learning approach to foster environmental responsibility and to contribute to Sustainable Development Goal 13 (Climate Action).

Discussion

The results of this study showed that STEAM Education for Sustainable Development had a great effect on increasing the awareness of students about the environment, environmental attitude, environmental behavior and awareness about climate change. Results from descriptive and regression analysis indicated that the students who engaged in the STEAM approach to sustainability had high scores for their environmental understandings and environmentally responsible behaviors. The correlation analysis also revealed positive correlations between the variables of STEAM education and environmental sustainability. The results confirmed the hypotheses of this study and suggested that the learning model of interdisciplinary STEAM was able to positively affect students' climate consciousness and sustainable practices. The findings were similar to previous research that found the use of STEAM-based learning increased students' environmental literacy, creativity and awareness of sustainability (Rosyida et al., 2024; Zhao & Abdullah, 2024). Likewise, Setiawan et al. (2024) revealed that STEAM learning with the principles of Education for Sustainable Development greatly enhanced students' environmental awareness and positive environmental attitudes. The results also supported the conclusions of Trott (2019), who argued that experiential climate education increased students' involvement in the environment and their responsible actions. Moreover, the study was congruent with the theory of Constructivist Learning Theory and Experiential Learning Theory as the students acquired knowledge about the environment by engaging in active learning, interaction, and sustainability experiences (Piaget, 1972; Kolb, 2014). These theories were used to account for the process of meaningful learning by directly experiencing the challenges of the environment around them and reflecting on the experiences.

STEAM Education and Environmental Awareness

The results showed that STEAM education had a positive impact on the environmental awareness and understanding of climate change among students. The interdisciplinary learning approach helped Students Bridge the gap between scientific knowledge, creativity, and problem-solving while addressing environmental sustainability concerns. The students were able to gain knowledge about climate change, environmental conservation, and sustainable development practices through the sustainability-focused projects and hands-on tasks. Huang (2024) found that education for sustainable development positively contributed to the students' knowledge of sustainable development and their environmental responsibility. Likewise, Djam'an (2024) noted that EE in the context of STEAM approaches had a positive effect on enhancing sustainability consciousness and environmental involvement of learners.

STEAM Learning and Sustainable Behavior

The study showed that the STEAM learning had a positive effect on the students' environmentally responsible behaviors and sustainable attitudes. Students who were exposed to STEAM sustainability education showed their eco-friendly attitude towards recycling, energy saving, and participating in environmental activities. The results aligned with the

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Ardoin et al. (2020) who found that EE programs had positive effects on sustainable behaviour and environmental responsibility. Similarly, Torabi et al. (2021) revealed that innovative and activity based teaching methods have a positive effect on the improvement of students' environmentally responsible behavior. In this experiential and collaborative approach to STEAM learning, students engaged with sustainable practices in their lives and were cultivating long-term environmental ethics.

Contribution to SDG 13

The study is a significant contribution to Sustainable Development Goal 13 (Climate Action) by underlining the need for sustainability education to foster climate awareness and eco-responsible actions among learners. The results indicated that incorporating STEAM education into the environmental sustainability discourse helped improve the students' awareness about climate change topics and promoted active engagement in climate change action projects. Interdisciplinary sustainability education and climate literacy programs in education were thus found to be crucial to realizing SDG 13 (Priatna & Khan, 2024). The study also complemented UNESCO's (2020) focus on incorporating the principle of Education for Sustainable Development into the education system to equip learners for environmental issues and sustainable futures.

Conclusion and Recommendations

Conclusion

This study examined the impact of STEAM Education for Sustainable Development on students' environmental awareness, environmental attitudes, environmental behavior, and climate awareness in relation to Sustainable Development Goal 13 (Climate Action). The results showed that STEAM education with sustainability concepts had a positive impact on improving students' understanding of environmental problems and creating environmental responsibility. The descriptive, correlation and regression analyses results have verified the positive effect of STEAM education on environmental awareness, climate consciousness and sustainable practices of students. Interdisciplinary STEAM education was found to positively influence students' attitudes towards the environment and their involvement in taking care of the environment, including recycling, saving energy, and participating in climate related practices.

The results also revealed that STEAM education provided meaningful learning experiences by combining STEAM with concepts and challenges related to sustainability. The study also reinforced Constructivist Learning Theory and Experiential Learning Theory, which posited that students' understanding and behavior towards environmental sustainability can be enhanced through active involvement and hands-on learning experiences. The findings were also similar with previous studies that showed that STEAM sustainability education is effective in increasing environmental literacy and climate awareness in students (Setiawan et al., 2024; Djam'an, 2024).

Overall, the study concluded that STEAM education served as an effective educational strategy for promoting environmental responsibility and sustainability awareness among students. Sustainability concepts' embedding in interdisciplinary education is a significant contribution to climate education and helped to implement SDG 13 by adopting sustainable education approaches and processes.

Recommendations

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The study's results were used to recommend that the incorporation of sustainability-related STEAM curricula in educational processes should foster students' environmental awareness and climate literacy. Additionally, teachers need professional development on climate education and the teaching of sustainability and interdisciplinary teaching to enhance the effectiveness of the STEAM learning environments. Schools and universities should continue to arrange environmental projects, green innovation activities and practical experiences based on sustainability to provide opportunities for active involvement of students in environmental protection and climate action projects. Policymakers were also urged to support sustainability education through institutional and policy measures with the inclusion of SDG 13 goals in the national educational systems and curriculum changes.

Implications of the Study

Educational Implications

The study highlighted the importance of improving sustainability-oriented teaching practices through STEAM education. The results can be applied in educational environments to create innovative teaching methods that improve environmental education, climate awareness and fostering students' problem-solving skills regarding sustainability issues.

Policy Implications

The findings highlighted the significance of the education policies required for SDG 13 Climate Action. The results can be utilized by the policy makers on supporting sustainability-related curriculum development, climate education programs, and environmental awareness education in educational institutions.

Practical Implications

The study was practically significant in promoting responsible student behavior towards the environment through interdisciplinary and experiential learning activities. Through sustainability STEAM education, students were encouraged to develop a habit of green behavior and actively engage in environmental protection work.

Suggestions for Future Research

Future researchers are encouraged to carry out comparative studies over various regions and educational context to investigate the differences in the effectiveness of STEAM education for sustainability. In addition, researchers can use mixed method research approaches to get a more comprehensive understanding of students' experiences and perceptions of sustainability-focused STEAM learning. In addition, the use of longitudinal studies is recommended to investigate over time the effects of STEAM learning on students' attitudes toward the environment, climate awareness and sustainable behavior.

References

Agbor, C. N., Etan, M. O., Akuji, R. T., & Ogbor, C. O. (2024). Methods of teaching environmental education for sustainability. *International Journal of Economics, Environmental Development and Society*, *6*(2), 209-233.

Aldawsari, N. D., Nemt-Allah, M. A., & Abdellatif, M. S. (2024). Environmental Education Awareness in Light of Sustainable Development Goals and Its Relationship with Environmental Responsibility Among University Students. Sustainability, 17(21), 9393. https://doi.org/10.3390/su17219393

Al-Naqbi, A. K., & Alshannag, Q. (2018). The status of education for sustainable development and sustainability knowledge, attitudes, and behaviors of UAE University students. International Journal of Sustainability in Higher Education, 19(3), 566–588. https://doi.org/10.1108/ijshe-06-2017-0091

ISSN Online: 3006-4686, ISSN Print: 3006-4678
Volume No: 01 Issue No: 04 (2024)

Altassan, A. (2023). Sustainable integration of solar energy, behavior change, and recycling practices in educational institutions: A Holistic Framework for environmental conservation and quality Education. Sustainability, 15(20), 15157. https://doi.org/10.3390/su152015157

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation, 241*, 108224. https://doi.org/10.1016/j.biocon.2019.108224

Auh, Y., Hwang, S., & Cho, M. (2024). STEAM education for sustainable futures: A pedagogical framework for education for sustainable development. Pedagogical Research, 11(1), em0259. https://doi.org/10.29333/pr/18125

Babacan, H. (2024). From crisis to policy action: Tackling climate change through SDG 13. The International Journal of Community and Social Development, 7(2), 205–221. https://doi.org/10.1177/25166026251351370

Badea, L., Șerban-Oprescu, G. L., Dedu, S., & Piroșcă, G. I. (2020). The impact of education for Sustainable Development on Romanian economics and business students' behavior. Sustainability, 12(19), 8169. https://doi.org/10.3390/su12198169

Collado, S., Rosa, C. D., & Corraliza, J. A. (2020). The Effect of a Nature-Based Environmental Education Program on Children's Environmental Attitudes and Behaviors: A Randomized Experiment with Primary Schools. Sustainability, 12(17), 6817. https://doi.org/10.3390/su12176817

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Djam'an, N. (2024). Examining the implementation of environmental education in the STEAM approach for sustainability. Discover Education, 4(1). https://doi.org/10.1007/s44217-025-00837-4

Huang, D. (2024). From MDGs to the concept of education for UN in 2024: How can the concept of Education for Sustainable Development (ESD) be practically linked to education? International Journal of Research Studies in Education, 14(3). https://doi.org/10.5861/ijrse.2024.25825

Kolb, A. Y., Kolb, D. A., Passarelli, A., & Sharma, G. (2014). On becoming an experiential educator: The educator role profile. *Simulation & gaming*, *45*(2), 204-234.

Kolb, D. A. (2014). Experiential learning: Experience as the source of learning and development. FT press.

Kopnina, H. (2020). Education for the future? Critical evaluation of education for sustainable development goals. The Journal of Environmental Education, 51(4), 280–291. https://doi.org/10.1080/00958964.2019.1710444

Otto, S., & Pensini, P. (2017). Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behaviour. *Global Environmental Change, 47*, 88–94. https://doi.org/10.1016/j.gloenvcha.2017.09.009

Parry, S., & Metzger, E. (2023). Barriers to learning for sustainability: a teacher perspective. Sustainable Earth Reviews, 6(1). https://doi.org/10.1186/s42055-022-00050-3

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. Thinking skills and creativity, 31, 31-43.

Piaget, J. (1972). Development and learning. *Reading in child behavior and development*, 38-46.

ISSN Online: 3006-4686, ISSN Print: 3006-4678
Volume No: 01 Issue No: 04 (2024)

Priatna, D., & Khan, S. M. (2024). The importance of education and role of educational institutions in climate change mitigation and achieving UN SDG 13 Climate Action. Indonesian Journal of Applied Environmental Studies, 5(1), 1–5. https://doi.org/10.33751/injast.v5i1.10559

Rosyida, K. M. I., Prahani, B. K., & Kurtuluş, M. A. (2024). Analysis of the Role of STEAM Education in improving critical thinking skills for sustainable development. *Journal of Current Studies in SDGs*, *1*(1), 20-32.

Setiawan, B., Barokah, A., Hafifah, D. N., & Iasha, V. (2024). Enhancing Environmental Awareness through STEAM-Based Learning with ESD Principles in Elementary Education. International Journal of Education and Learning Studies, 1(1), 1–12. https://doi.org/10.64421/ijels.v1i1.1

Sousa, D. A., Pilecki, T., & Pilecki, T. (2018). From STEM to STEAM: Brain-compatible strategies and lessons that integrate the arts. Corwin Press.

Taber, K. S. (2017). The use of Cronbach's Alpha when developing and reporting research instruments in science education. Research in Science Education, 48(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Taherdoost, H. (2016). Sampling methods in research methodology; how to choose a sampling technique for research. How to choose a sampling technique for research (April 10, 2016).

Torabi, Z., Rezvani, M. R., & Palouj, M. (2021). Comparing the effect of lecture and jigsaw teaching strategies on attitude and environmentally responsible behavior: A Mixed-methods approach. Journal of Quality Assurance in Hospitality & Tourism, 23(4), 1064–1087. https://doi.org/10.1080/1528008x.2021.1955235

Trott, C. D. (2019). Children's constructive climate change engagement: Empowering awareness, agency, and action. Environmental Education Research, 26(4), 532–554. https://doi.org/10.1080/13504622.2019.1675594.

UNESCO. (2020). *Education for sustainable development: A roadmap*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000374802

Yakman, G., & Lee, H. (2012). Exploring the exemplary STEAM education in the US as a practical educational framework for Korea. Journal of the korean Association for Science Education, 32(6), 1072-1086.

Zhao, S., & Abdullah, A. H. (2024). Integrated STEAM and Problem-Based Learning: A teaching framework to enhance undergraduates' creative thinking. International Journal of Academic Research in Progressive Education and Development, 14(1). https://doi.org/10.6007/ijarped/v14-i1/24490.