Science Education International
36(2),189-198
https://doi.org/10.33828/sei.v36.i2.6

International Council of Association for Science Education

RESEARCH ARTICLE

The Impact of Science Curriculum in Reducing Pollution: Evidence from a University in Saudi Arabia

Saad Z. Alshehri*

Department of Curriculum and Instruction, Faculty of Education, University of Jeddah, Jeddah, Saudi Arabia

***Corresponding Author:** szalshehri@uj.edu.sa.

ABSTRACT

This study seeks to explore, through practical means, the holistic impact of the science curriculum (SC) in heightening awareness about pollution-related issues. In addition, it aims to assess its role in motivating a particular behavior among higher education students in Saudi Arabia specifically, the actions they take to mitigate pollution. The study adopted a conclusive research design and used a survey to collect quantitative data. The rationale for using the survey method was applied to analyze the relationship between the study constructs and verify the hypothesis based on the responses. A total of 182 students studying in various science disciplines, randomly selected from a higher educational institution in Saudi Arabia, responded to a survey. The results provide strong evidence that SC can promote a greater level of awareness of the effects of pollution. The findings offer concrete evidence backing the idea that the SC plays a mediating role in pollution reduction. Furthermore, they imply that education has a comparatively weaker influence on the pro-environmental behaviors or actions of students. This study will have significant value for higher educational institutions as it provides empirical evidence that SC can increase awareness of the effects of pollution, stimulating pro-environmental behaviors and in reaching sustainable development.

KEY WORDS: Awareness, higher education, pro-environmental behaviors, science curriculum

INTRODUCTION

The issues that occur within our world are not only economic or political but also ecological, and in particular, it is environmental pollution. The introduction of pollutants into the natural environment causes environmental pollution. The surge in greenhouse gas emissions, air pollution, rising sea levels, global climate shifts, and desertification demands urgent consideration. Consequently, there is a pressing requirement for coordinated initiatives to address environmental challenges (Nakajima et al., 2020). The responsibility lies with us to craft a cleaner environment, one that can be passed down to both the present and future generations.

The main cause of air pollution and climate change is carbon emissions (Lelieveld et al., 2019). Air pollutants have an impact on the earth as some pollutants can increase heat while others produce a cooling effect (Manisalidis et al., 2020). Air pollution, driven by primary pollutants such as carbon monoxide, carbon dioxide, sulfur dioxide, nitric oxide, nitrogen dioxide, ammonia, volatile organic compounds, and particulates, as well as secondary pollutants such as ground-level ozone, black carbon, methane, hydrofluorocarbons, acid rain, and nutrient enrichment compounds, is linked to environmental damage and increased mortality rates globally (Nakajima et al., 2020; West et al., 2016; Manisalidis et al., 2020; D'Amato et al., 2016). These pollutants contribute significantly to the man-made global greenhouse effect, responsible for up to 45% of current global warming (Manisalidis et al., 2020; Nakajima et al., 2020). The resulting rise in the Earth's average temperature leads to the melting of ice, icebergs, and glaciers, establishing a close relationship between air pollution and global warming (Manisalidis et al., 2020; D'Amato et al., 2016). The health impacts, including mortality and longevity, are determined by exposure trends to these pollutants and the associated relative risks (Lelieveld et al., 2019; Olstrup et al., 2018).

Water pollution occurs when people introduce substances to water that changes its chemical structure, temperature, or bacteriological composition to the point where resident organisms or humans are harmed (Heath, 2018). When the quality or structure of water changes organically or as a result of human activities, it cannot be consumed or used for farming, in industries, for sports (Kiraz et al., 2020). It is caused by the daily activities of humans, such as sewage, fertilizer, pesticide, industrial waste spills, petroleum oil spillage, fuel, oil, plastic packaging, and food waste which affect groundwater quality. This has a very serious negative effect on bodies of water, such as rivers, reservoirs, lakes, and oceans (Kiraz et al., 2020). Contaminated water can result in oxygen depletion and can affect human health. Recent statistics show that water pollution affects nearly 1.5 billion people and causes at least 1.2 million deaths annually (Kiraz et al., 2020; Ritchie and Roser, 2021).

While much of the pollution, whether it is air or water, is largely caused by increased industrial activities, these problems can be tackled through mitigation and adaptation strategies which are largely determined by individual and collective human behavior (Lutz and Muttarak, 2017). This entails encouraging a sustainable way of life and consumption through behavioral changes which are significant for reducing human impact on the environment (Hoffmann and Muttarak, 2020). Effectively reducing and mitigating pollution, as well as addressing its impacts, requires the implementation of strategic actions. The successful execution of these strategies is contingent upon having an informed and knowledgeable populace. Education, which can increase awareness and participation in environmental activities, is considered relevant for maximizing opportunities to meet the critical targets and goals of climate change and environmental pollution (Manisalidis et al., 2020). Although education is important for responding to environmental pollution, the mitigation potential of quality science education is rarely discussed.

Importance of Science Curriculum (SC) in Increasing Awareness (Knowledge) of Pollution

A comprehensive understanding of the interactions and health effects of various pollutants and risks of air or water contaminants and source categories is required for making informed choices to protect our health and environment (Lelieveld et al., 2019; LaVeaux et al., 2018). Effective mitigation measures to deal with pollution critically depend on our understanding of the pollutants (Nakajima et al., 2020). Higher educational institutions are increasingly aiming to educate students so that they will be capable and motivated to think and act in a sustainable manner (Goldman et al., 2014). Science education is a unique discipline that lays emphasis on inquiry-based learning to investigate socio-scientific issues and sustainability (Hogan and O'Flaherty, 2021).

Science, a discourse-based pedagogy that uses scientific evidence to support environmental solutions (Robson and McCartan, 2016), is increasingly viewed as just another authority that tells people how to live their lives (Voulvoulis and Burgman, 2019). SC is important as it is concerned with discovering, comprehending, clarifying, and predicting patterns in natural phenomena to produce a factual description of how the environment operates (Robson and McCartan, 2016; Walls et al., 2014). Its goal is the quest for scientific knowledge or the increase in the level of awareness of environmental issues. SC can help achieve this understanding, better characterize different types of pollution, reflect upon sustainability issues, engage in socio-scientific debate, and apply available scientific knowledge to take necessary actions to mitigate the detrimental effects of greenhouse gases (Hogan and O'Flaherty, 2021; Voulvoulis and Burgman, 2019). Moreover, education through science plays a crucial role in preparing students for the type of knowledge required for being responsible individuals (Wan and Bi, 2019; Holbrook and Rannikmae, 2007).

Environmental Awareness, Environmental Literacy, and Pro-Environmental Behavior

Environmental awareness refers to the recognition of environmental issues, including understanding the causes and impacts of pollution and other ecological challenges (Cordero et al., 2020). It is a crucial first step in fostering concern for environmental sustainability. Environmental literacy, on the other hand, encompasses the knowledge and skills necessary to understand environmental issues, evaluate potential solutions, and make informed decisions (Goulgouti et al., 2019). It is a more comprehensive concept, extending beyond awareness to include the cognitive competencies required to engage with environmental challenges critically.

The role of science education in promoting environmental awareness and literacy is well documented. By increasing students' awareness of environmental issues, such as the harmful effects of pollution, science education plays a central role in fostering environmental literacy, which includes knowledge about the scientific principles that underpin environmental issues and potential solutions (Craig and Allen, 2015). Thus, SC aids in the development of both awareness and literacy, forming a foundation for informed decision-making and responsible environmental behavior.

Pro-environmental behavior refers to the actions individuals take to reduce their environmental impact, such as reducing waste, conserving energy, or supporting sustainable practices. This behavior is typically influenced by the level of environmental awareness and literacy an individual possesses. For instance, individuals who understand the causes and effects of pollution are more likely to engage in behaviors that help mitigate such problems, such as recycling or using public transport (Okumah and Ankomah-Hackman, 2020).

Science Education and Students' Pro-Environmental Behaviors for Reducing Pollution

The general purpose of science education is to build critical scientific literacy for sustainable development (Holbrook and Rannikmae, 2007). The SC, along with textbooks and research literature emphasizing environmental literacy (Kaya and Elster, 2019), offers a platform for comprehending concepts related to the natural environment. This engagement leads to the development of environmental awareness, literacy, and the acquisition of knowledge and skills, empowering individuals to make informed and responsible choices in their interactions with the environment (Goulgouti et al., 2019). Thus, it can be argued that science contributes to the development of environmental literacy, which equips individuals to recognize environmental hazards and adopt pro-environmental behaviors.

Numerous studies have shown that environmental awareness and literacy are linked to pro-environmental behaviors. For example, De Leeuw et al. (2015) and Gould et al. (2018) emphasize that raising awareness of environmental problems, such as pollution and climate change, can directly influence an individual's behaviors toward the environment. Education through science serves to foster both awareness and literacy, motivating individuals to take action to mitigate environmental issues (Hoffmann and Muttarak, 2020).

The connection between environmental awareness or literacy and pro-environmental behavior is further illustrated by

Cordero et al. (2020). Evidence suggests that the development of environmental literacy through education is critical in transforming awareness into meaningful pro-environmental actions (Goulgouti et al., 2019). Education, particularly science education, is foundational for nurturing individuals capable of recognizing pollution risks, improving behaviors, and expressing concern for environmental sustainability (Salvador et al., 2017).

Recent studies (Braun et al., 2018; Geiger et al., 2018) also support the notion that pro-environmental behaviors improve with an increase in environmental knowledge. The strongest link was found between awareness of pollution issues and the likelihood of engaging in pro-environmental actions, such as reducing plastic waste (Okumah et al., 2019; Okumah and Ankomah-Hackman, 2020). This suggests that individuals who are aware of environmental problems are more likely to take appropriate actions to address those issues.

Science-based practices involve both procedural knowledge (understanding how to take action) and effectiveness knowledge (knowing which actions are most effective in mitigating environmental harm). For instance, procedural knowledge includes understanding how practices like using public transportation or bicycles can help reduce pollution (Geiger et al., 2019). Effectiveness knowledge, meanwhile, relates to understanding the consequences of specific actions, such as whether smoking outdoors reduces indoor pollution more effectively than quitting altogether (Geiger et al., 2019).

While some researchers argue that knowledge alone cannot always lead to behavioral changes (Bray and Cridge, 2013), this study focuses on the relationship between science education, awareness of pollution issues, and pro-environmental behaviors in the context of higher education in Saudi Arabia. Moreover, studies have shown that individuals with greater educational backgrounds are generally more concerned about climate change and environmental issues than those with less education (Poortinga et al., 2019; Kabir et al., 2016). This increased concern often translates into more pro-environmental behaviors, suggesting that education plays a pivotal role in fostering sustainable actions (Chankrajang and Muttarak, 2017; Goulgouti et al., 2019; Goldman et al., 2014; Ortega-Egea et al., 2014; Muttarak and Chankrajang, 2016).

Research Problem

Empirical research examining the relationship between SC/education, student awareness of the problems caused by pollution and pro-environmental behaviors is very scarce in emerging economies and developing countries. There is only one study from Saudi Arabia that has examined students' perceptions regarding science learning environments (Kim and Hamdan Alghamdi, 2019). Most studies have linked environmental education and environmental quality, for example, water and air quality (Höfner and Schütze, 2021; Johnson et al., 2012) and education and energy reduction (Kubsch et al., 2021). Moreover, the studies are not related to a specific education domain (Ardoin et al., 2018; Cordero et al., 2020).

Previous research has not simultaneously considered the relationship between science education, the role of SC in generating awareness of the causes of pollution, and action taken by higher education students to reduce pollution. The objective of this study is to examine the relationship between science education, awareness of the causes of pollution and pro-environmental behavior in a higher education institution in Saudi Arabia. In doing so, this paper aims to provide empirical evidence concerning these effects. Furthermore, this study will fill the existing gap in the literature by achieving a greater understanding of the relationships in a developing country context.

Conceptual Model and Hypothesis Development

A conceptual framework was developed based on a thorough review of relevant literature (Figure 1). The conceptual model consists of two independent variables (exogenous constructs): Students' perceptions of the SC in its role in reducing pollution and students' awareness of the effects of pollution (AW). The dependent variable (endogenous construct) is students' pro-environmental behaviors aimed at reducing pollution (PB). All three constructs are treated as reflective, meaning the indicators (or items in the questionnaire) reflect the underlying theoretical constructs.

Rationale for Mediation Analysis

Mediation analysis is used to explore how an independent variable influences the relationship between two other variables through a third, intermediary variable. The study hypothesized that SC mediates the relationship between students' AW and their PB.

The SC is expected to act as a key mediator by enhancing students' understanding of environmental issues, which may lead to increased motivation to adopt PB. While awareness of pollution is a necessary first step, it does not automatically translate into behavior change. The curriculum provides the necessary knowledge and context, allowing students to apply their awareness in actionable ways, thereby fostering the adoption of sustainable behaviors.

Using mediation analysis allows for a deeper understanding of the pathways through which education (in the form of the SC) influences PB. By examining whether the SC is a significant mediator, this analysis will provide insights into

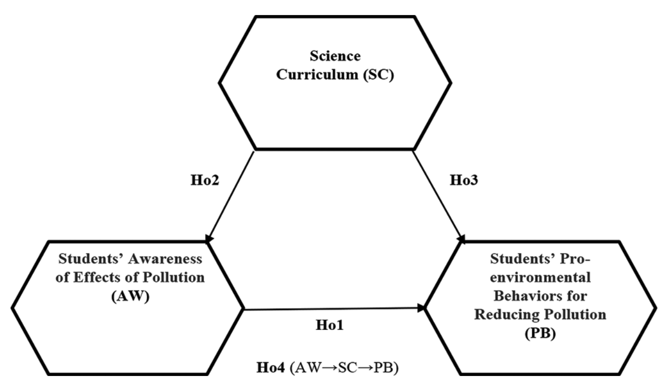

Figure 1: Conceptual model for reducing pollution and related hypothesis

how specific educational interventions can be designed to enhance sustainability efforts among students.

The hypothesis proposed are as follows:

- Hypothesis 1 (H_{01}): There is a significant relationship between students' awareness (AW) of the effects of pollution and students' pro-environmental behaviors for reducing pollution (PB).
- Hypothesis 2 (H_{02}): There is a significant relationship between SC and awareness of the effects of pollution (AW).
- Hypothesis 3 (H_{03}): There is a significant relationship between SC and students' pro-environmental behaviors (PB) for reducing pollution.
- Hypothesis 4 (H_{04}): SC mediates the relationship between students' awareness of the effects of pollution (AW) and students' pro-environmental behaviors (PB) for reducing pollution.

RESEARCH METHODOLOGY

The present study applies quantitative methods in order to meet the study's goals and test the hypothesis. A conclusive research design was adopted to test a priori hypothesis and predict the relationships between constructs of interest and their generalizability to the population (Malhotra, 2010). However, it is important to note that the study is based on data collected from a single university in Saudi Arabia, which introduces certain limitations regarding the broader applicability of the findings.

Given the cultural, socio-economic, and institutional differences across regions, the results of this study may not be directly transferable to other regions or educational contexts. Specifically, the perceptions of students in Saudi Arabia regarding the SC and their environmental awareness may differ significantly from those in other countries due to variations in educational systems, cultural values, and environmental policies. For instance, in countries with a strong emphasis on sustainability education or environmental activism, students may exhibit higher levels of environmental literacy and more proactive behaviors compared to those in regions where environmental concerns are less integrated into the curriculum. In addition, in some cultures, environmental issues may be perceived through different lenses based on local values, religious beliefs, or historical experiences with nature, which could influence how students relate to environmental topics.

Institutionally, the degree to which universities emphasize sustainability, environmental awareness, and the integration of these concepts into the curriculum can vary widely. In Saudi Arabia, for example, the SC's focus on environmental issues may be influenced by national policies, governmental priorities on resource management, and environmental conservation, which may not be the case in other regions. These institutional factors could significantly affect how students engage with environmental issues, as students in different educational settings might be exposed to varying levels of emphasis on environmental education and sustainability practices. Moreover, the level of governmental support for environmental education and public awareness campaigns may play a significant role. In regions where governments invest heavily in public awareness programs related to pollution and sustainability, students might be more likely to internalize pro-environmental behaviors, thus making the relationship between environmental awareness and behavior stronger. Conversely, in regions where such initiatives are less prevalent, the relationship between awareness and action may not be as robust. Therefore, the relationships studied in this research, specifically, the link between the SC, environmental awareness, and pro-environmental behaviors, may be influenced by factors such as cultural perceptions of environmental issues, educational priorities, and institutional practices. These factors may differ in other contexts, making it challenging to generalize the findings outside the specific setting of this study.

Research Instrument

The researcher's ontological position, rooted in a constructivist view of reality shaped by educational experiences, led to the development of a 17-item survey instrument designed to investigate the influence of science education in increasing awareness and reducing pollution. The instrument comprised three sections: the first 3 items focused on the SC, the next 8 items addressed the influence of science education on increasing awareness of pollution issues, and the final 6 items explored students' pro-environmental behaviors and actions they intend to take to reduce pollution.

These items were primarily developed based on a comprehensive review of relevant literature on science education's role in promoting environmental awareness (Hogan and O'Flaherty, 2021; Voulvoulis and Burgman, 2019), and on studies examining the relationship between environmental literacy and pro-environmental behaviors (Sharpe et al., 2021; Goulgouti et al., 2019; Holbrook and Rannikmae, 2007). While the instrument did not directly replicate items from existing validated tools, the wording and structure of several items were adapted and refined from previously validated instruments found in these studies to ensure content validity and relevance to the research context. Expert review and pilot testing were also conducted to further refine item clarity and alignment with constructs. The final questionnaire used a five-point Likert scale: Strongly Agree [5], Agree [4], Neutral [3], Disagree [2], and Strongly Disagree [1].

The questionnaires were administered online using Google Forms. Emails with online links and drop-off surveys were used to administer the questionnaires. To conduct the study in an ethical manner, confidentiality was maintained by using identifiers (numerals instead of participants' names) and informed consent was obtained. The questionnaires were accompanied by a participation information sheet which stated the purpose of the survey.

Data Analysis

The quantitative data were analyzed statistically using partial least squares structural equation modeling (PLS-SEM) (Ringle et al., 2015).

Response Rate

The questionnaire was accessed by 279 participants, but only 182 completed and usable questionnaires were received from respondents (Table 1). The response rate was 65.23%.

Table 1 shows that 97 respondents had shown interest but had exited or abandoned the questionnaire before completing.

Sample Size

The sample was composed of 182 students and composed of 109 females and 73 males (Table 2). Although this sample is small, PLS-SEM provides accurate estimates with small sample sizes (Hair et al., 2019). The thumb rule for calculating sample size when using PLS-SEM is 10 times of each question in the research instrument (Hair et al., 2022).

Data Preparation and Screening

Prior to analyzing the data, it was prepared for screening. Screening involves checking for missing data, which occurs when respondents purposefully or unintentionally fail to answer one or more survey questions. However, the respondents had answered all the questions and there were no missing data. To minimize the incidence of missing or needless data, the questionnaire responses were checked to ensure that participants could only select one response to each item (Hair et al., 2022). Next, response patterns were checked to identify patterns. This procedure was used to identify if a respondent had used the same response for a large number of the questions. However, the frequent use of a single pattern was not identified. The next step involved identifying outliers as they can lead to adverse outcomes in data analysis and distort the results of the study. There were no cases of outliers in this study.

Descriptive Statistics and Test of Multivariate Normality

A multivariate normality test was also carried out using Smart PLS 3.2.9 to assess data normality and to check if there is a normal distribution of data, namely skewness and kurtosis. Descriptive statistics (Table 3) shows the data normality assessment of the study. Values between 0.5 and 1 or −0.5 and −1 are considered to be fairly skewed and between −0.5 and 0.5 indicates symmetrical distribution. Therefore, it can be concluded that the distributions are normal (Hair et al., 2022). The mean scores were also in the normal range (M≥3.31).

Table 1: Sampling frame

Sampling frame	n/%
Sample (who accessed initially)	279
Respondents (those who completed the questionnaire)	182
Response rate	65.23

Table 2: Sample

Gender	Frequency	Percentage
Female	109	60
Male	73	40

Table 3: Descriptive statistics and data normality assessment

	Statements	M	SD	K	S
	Perceptions of science curriculum (SC)				
1	Science education is related to the main principles of sustainable development	3.41	1.22	−1.53	−0.61
2	The goal of science education is the pursuit of knowledge or the increase in the level of awareness of environmental issues	3.29	1.40	−1.16	−0.55
3	Science curricula lay the foundation for new approaches and solutions and helped me understand responsible and sustainable practices for addressing pollution-related issues	3.59	1.37	−1.06	−0.67
	Potential of science curriculum to reduce adverse effects of air pollution through generating awareness (AW) As a result of the science curriculum, programs, and activities.				
4	I have increased my awareness of the effects of pollution, for example, conserving nature's resources and maintaining ecological balance	3.36	1.43	−1.02	−0.51
5	I have increased my awareness of renewable energy technologies which have much lower life cycle emissions	3.65	1.23	−0.91	−0.57
6	I have learned that pollution is triggered by contamination and air pollution is caused by certain gases as well as solid and liquid particles.	3.64	1.43	−1.36	−0.55
7	I am now aware that I must take actions to reduce the amount of waste at home, for example recycling	3.90	1.30	−1.17	−0.54
8	I understand that I must reduce energy consumption at home, for example by using energy-saving appliances and solar energy	3.86	1.38	−1.15	−0.66
9	I understand that I have to make dietary and lifestyle choices to reduce carbon emissions	3.65	1.37	−1.23	0.72
10	I understand that I have to make changes to my transportation methods (for instance using public transportation or bicycle or hybrid vehicles more often)	3.92	1.45	−1.20	0.63
11	I understand I must use carbon offsets	3.31	1.23	−1.58	0.69
	Students' pro-environmental behaviors and potential actions toward reducing pollution (PB)				
12	Levying tariffs on fossil fuels (e.g., coal and oil)	4.25	0.99	1.36	−1.02

(Contd...)

Table 3: *(Continued)*

	Statements	M	SD	K	S
13	Subsidies for sustainable energy such as wind and solar energy	3.78	1.14	−0.93	0.62
14	Increasing the cost of energy during peak hours	3.79	1.08	−1.37	−0.91
15	Lowering the cost of energy during off-peak hours	4.31	0.99	−1.42	−0.63
16	Decreasing the cost of energy-saving devices	4.30	0.96	−1.07	−0.58
17	Subsidies to reduce the cost of renewable energy	3.79	1.08	0.94	−0.90

RESULTS

Assessment of the Reflective Measurement Model

The evaluation of the measurement model's appropriateness included assessing indicator reliability (outer loadings), internal consistency (Cronbach alpha and composite reliability), convergent validity average variance extracted (AVE), and discriminant (or divergent) validity (heterotrait–monotrait ratio). The reflective measurement model assessment is detailed in Table 4.

Table 4: Evaluation of the measurement model

Construct/ indicators	Outer loadings	Weights	Alpha	CR	AVE
SC1	0.811	0.117	0.833	0.911	0.602
SC2	0.829	0.121			
SC3	0.796	0.11			
AW1	0.836	0.17	0.924	0.916	0.684
AW2	0.857	0.171			
AW3	0.826	0.169			
AW4	0.799	0.166			
AW5	0.853	0.181			
AW6	0.852	0.178			
AW7	0.813	0.165			
AW8	0.866	0.176			
PB1	0.771	0.127	0.902	0.939	0.822
PB2	0.766	0.114			
PB3	0.731	0.106			
PB4	0.914	0.366			
PB5	0.924	0.382			
PB6	0.907	0.345			

AVE: Average variance extracted

Indicator Reliability

With regard to indicator reliability, the outer loadings are >0.731, as seen in Table 4. As the threshold is higher than 0.70, it is considered appropriate (Hair et al., 2022). In the model, all items have loads varying from 0.731 (PB3) to 0.924 (PB5). This indicates that the items used in the model reliably represent the underlying constructs. This suggests that the items in the survey are appropriate and consistent measures of the constructs they are intended to assess.

Internal Consistency

The overall composite reliability or internal consistency is >0.911. The Cronbach alpha value was also over 0.833 for all constructs (Table 4). This supports the claims of Hair et al. (2022) that irrespective of the techniques used an internal consistency reliability >0.70 is considered acceptable. This indicates that the internal consistency of the constructs is strong, indicating that the measurement model is reliable and the constructs measured are internally consistent.

Convergent Validity

As regards convergent validity, the AVE was used and the value must be larger than 0.50 (Hair et al., 2022). AVE values were substantially higher than the suggested 0.5 thresholds (Hair et al., 2022; 2019) and so all indicators were retained (Table 4). This confirms that the constructs have sufficient convergent validity and suggests that the indicators are adequately measuring the underlying construct, supporting the model's validity.

Discriminant Validity

Discriminant validity was assessed to ensure that the reflective constructs have robust relationships with their own indicators in the path model (Hair et al., 2022). Although Fornell-Larcker is widely used to evaluate discriminant validity in SEM, academics claim that it is not consistent and does not detect most indicators or items with poor discriminant validity (Voorhees et al., 2016). Therefore, the HTMT or heterotrait–monotrait ratio criterion for discriminant validity assessment was used as it useful in reflective measurement models (Henseler et al., 2015). According to Henseler et al. (2015), the HTMT value should be lower than 0.90 in order to establish discriminant validity. As illustrated in Table 5, the highest HTMT value is 0.890 which is below the recommended threshold of 0.90. Thus, the discriminant validity of reflective constructs was confirmed. In SEM-PLS, bootstrapping and confidence intervals were used to calculate HTMT. The HTMT values indicate no discriminant validity issues for the endogenous and exogenous constructs, meaning the constructs are distinct and the model does not suffer from excessive similarity between them.

The assessment of the measurement model, including indicator and composite reliability, along with convergent and discriminant validity, indicates that the reflective constructs in this research successfully meet the established criteria for reliability and validity.

Assessment of Inner or Structural Model

The structural model was evaluated by evaluating collinearity, explained variance (R^2), effect size (f^2), predictive relevance (Q^2), and path coefficients (size and statistical significance).

Assessment of collinearity

Collinearity occurs when two variables are highly correlated and so the variance inflation factor (VIF) is used to detect multicollinearity (Hair et al., 2022). The rule of thumb is that VIF values of each indicator should be lower than 5.0. The VIF values for all constructs are below 5.0 (Table 6), suggesting that multicollinearity is not an issue in the model. This means that the constructs are not highly correlated with one another, ensuring the stability of the model's estimates.

Coefficient of Determination (R^2)

In gauging the Coefficient of Determination or the predictive power of the model, the calculation of the degree of variance explained (R^2) for the endogenous construct was conducted. The R^2 value spans from 0 to 1, where higher values signify greater levels of predictive accuracy (Hair et al., 2022). The R^2 is >0.700 (Table 7 and Figure 2), indicating that 72% of the variance in pro-environmental behavior is explained by the independent variables (Awareness of Pollution and SC). This shows that the model has a high level of predictive accuracy.

Assessment of Predictive Relevance (Q^2)

In addition to evaluating the R^2 values, blindfolding procedure was used to assess the Q^2 value or predictive relevance. The Q^2 values of 0.02, 0.15, and 0.35, correspondingly suggest that an exogenous construct has a small, medium, or large predictive relevance for a particular endogenous construct (Hair et al., 2022). All the constructs had Q^2 values greater than zero in this study (Table 7), indicating that the model has predictive relevance. This suggests that the exogenous constructs (SC and Awareness) provide meaningful predictions for the endogenous construct (Pro-environmental Behavior).

Assessment of Path Coefficients

The PLS-SEM algorithm was employed to derive values for the relationships within the structural model, specifically the path coefficients, representing the hypothesized relationships among the constructs (Table 7 and Figure 2). In terms of significance, the values of the path coefficients (ranging from +1 to −1) were used to evaluate the strength of the hypothesized associations. Estimated path coefficients which are close to +1 represent strong positive relationships and those closer to 0 signify weak relationships (Hair et al., 2022). Significance tests (t and p values) were also used to report the significance of path coefficient values. The hypothesized relationships vary from 0.586 to 0.876 and all estimated path coefficients are significant at a 5% significance level except H_{03} and H_{04} (Table 7 and Figure 2). Therefore, the path coefficient estimates for H_{01} and H_{02} are considered statistically significant while for H_{03} and H_{04} it was moderately significant.

Effect Size (f^2)

The thumb rule for assessing effect sizes (f^2) are the values of 0.02, 0.15, and 0.35, respectively, which represent small, medium, and large effects (Hair et al., 2022) of the exogenous latent variables. Respectively, the results for this research study show H_{01} has a medium effect ($f^2 = 0.304$), H_{02} has a large effect ($f^2 = 3.043$) while H_{03} also has a medium effect ($f^2 = 0.076$).

Hypothesis Testing

Hypothesis 1 (H_{01}): This study hypothesized (H_{01}) that there is a significant relationship between students' awareness of the effects of pollution (AW) and students' pro-environmental behaviors for reducing pollution (PB). The results show (Table 7) that students' AW has a positive and significant effect on students' PB for reducing pollution at the 0.05 level of significance ($\beta = 0.586$, $t = 9.451$, $p < 0.005$). This strong positive relationship indicates that students' awareness of pollution has a moderate but significant impact on their pro-environmental behaviors. In simpler terms, as students become more aware of pollution, they are more likely to engage in behaviors aimed at reducing pollution.

Hypothesis 2 (H_{02}): This study hypothesized (H_{02}) that there is a significant relationship between SC and AW. The results show (Table 7) that there is a positive relationship between SC and students' AW ($\beta = 0.876$, $t = 16.123$, $p < 0.005$). The strong positive path coefficient suggests that the SC plays a major role in increasing AW. This supports the idea that a well-designed SC can significantly enhance students' understanding of environmental issues.

Hypothesis 3 (H_{03}): This study hypothesized (H_{03}) that there is a significant relationship between SC and students' PB for reducing pollution. While the relationship between the SC

Table 5: Discriminant validity assessment using HTMT

Construct	Awareness (AW)	Science curriculum (SC)	Pro-environmental behaviors (PB)
Awareness		**0.890** [0.848; 0.935]	0.898 [0.881; 0.916]
Science curriculum			**0.824** [0.810; 0.839]
Pro-environmental behaviors			

The bold elements are the square root of average variance extracted

Table 6: Assessment of collinearity (VIF values)

Exogenous constructs	Pro-environmental behaviors (PB)
Science curriculum	1.916
Student awareness of effects of pollution (AW)	2.244

VIF: Variance inflation factor

Table 7: Structural model results

Hypothesis	Path coefficient	t-test	p-value	Effect size (f^2)	Explained variance (R^2)	predictive relevance (Q^2)
H_{01} (AW→PB)	0.586	9.451	0.000	0.304	0.720	0.678
H_{02} (SC→AW)	0.876	16.123	0.000	3.043	0.753	0.753
H_{03} (SC→PB)	0.290	4.433	0.000	0.076		
H_{04} (AW→SC→PB)	0.251	4.239	0.000			

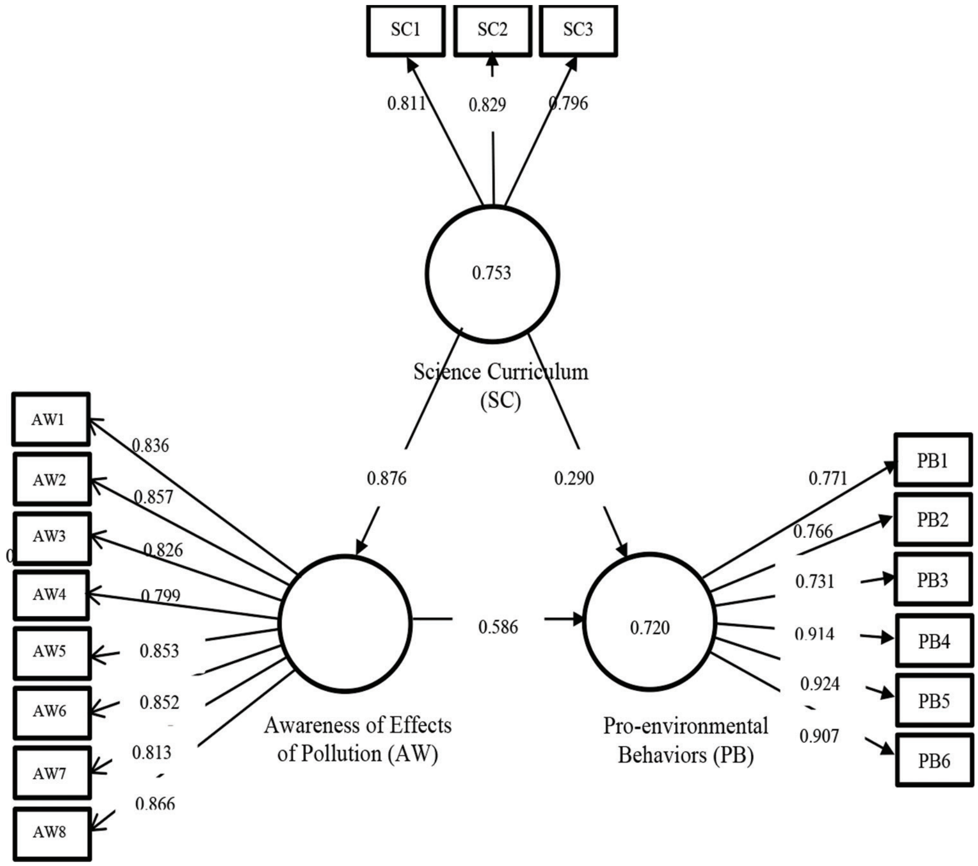

Figure 2: Path coefficients and coefficient of determination (R^2)

and pro-environmental behavior is positive and significant ($\beta = 0.290$, $p < 0.005$), the effect is relatively small compared to other relationships in the model. This suggests that while the SC does influence students' behavior, it may not be the sole or most powerful factor driving pro-environmental actions.

Hypothesis 4 (H_{04}): This study hypothesized (H_{04}) that SC mediates the relationship between students' AW and students' PB for reducing pollution (indirect effect). The results indicate that there was partial mediation ($\beta = 0.251$, $p < 0.005$). It indicates that SC plays a key role in translating students' AW into PB. This suggests that while awareness alone may influence behavior, the SC enhances this effect by providing the knowledge and context necessary for students to act.

DISCUSSION

The results indicate that the structural model is complementary, suggesting partial mediation. Complementary mediation is observed when both the indirect and direct effects are significant and aligned in the same direction (Zepeda et al., 2017; Hair et al., 2022). In this study, the SC plays a mediating role between students' awareness of pollution and their pro-environmental behaviors, reinforcing its relevance as a channel for influencing sustainable behaviors. However, while the curriculum supports this pathway, its direct effect on pro-environmental behavior was weaker than that of awareness alone (H_{03} vs. H_{01}). This implies that awareness of pollution had a stronger impact on students' pro-environmental behaviors than the curriculum did directly.

This finding has important implications for science educators and curriculum designers. It suggests that simply including sustainability content in the curriculum may not be sufficient to influence behavioral outcomes unless that content meaningfully enhances students' awareness, understanding, and personal connection to environmental issues. Awareness appears to act as a more immediate driver of behavioral intention and action. For science educators, this means shifting instructional focus toward student-centered, inquiry-based approaches that prioritize experiential learning and real-world applications of environmental science. Classroom experiences that link scientific knowledge to students' lived experiences and community challenges may increase emotional engagement and the perceived relevance of environmental action.

For curriculum designers and policymakers aiming to promote sustainability education, the findings suggest a need to design curricula that do more than deliver information. Curricula should integrate critical thinking, systems thinking, values education, and community engagement components that explicitly foster environmental awareness and empower students to act. Embedding pollution awareness and sustainability principles across disciplines – not just within science – can ensure broader and deeper engagement with pro-environmental behaviors. In addition, environmental awareness campaigns or interdisciplinary projects supported through policy initiatives could amplify the impact of science education and translate awareness into sustainable action more effectively.

This study also supports the theoretical position that awareness significantly influences behavioral outcomes (Cordero et al., 2020). Students who demonstrated a stronger awareness of the effects of pollution were more likely to report intentions to engage in pro-environmental behaviors (H_{01}). Moreover, the SC had a positive and significant relationship with students' pollution awareness (H_{02}), which aligns with earlier research showing that science education can increase environmental consciousness (Hogan and O'Flaherty, 2021; Geiger et al., 2019; Goldman et al., 2014).

While previous studies have predominantly focused on contexts in advanced economies, this research contributes new insights from the Middle East. The conceptual framework developed in this study provides a clearer understanding of how science curricula in higher education can facilitate pollution reduction by enhancing environmental awareness, which in turn stimulates behavioral change. These findings underscore the role of the SC not just as a conveyor of scientific facts but also as a transformative platform for fostering sustainability values and behaviors.

Limitations

One of the limitations of the study is that it is causal, and the findings were mainly based on questionnaire data which are generally susceptible to measurement errors and to unreliable reporting. The focus was on self-reported data on awareness and environmental behavior, which is subject to bias as respondents may respond in a manner that might be viewed favorably by others. Future research could focus on a mixed methods research design which would produce more robust results.

ETHICS STATEMENTS

In writing this research paper, ethical considerations were paramount. A delicate balance between scientific inquiry and the well-being of participants was maintained, ensuring the dignity, privacy, and rights of individuals involved. Transparent disclosure of potential conflicts of interest and adherence to established ethical guidelines safeguarded the integrity of the research process. Responsible handling of data, respect for cultural sensitivities, and obtaining informed consent were critical ethical considerations.

REFERENCES

Ardoin, N.M., Bowers, A.W., Roth, N.W., & Holthuis, N. (2018). Environmental education and K-12 student outcomes: A review and analysis of research. *Journal of Environmental Education,* 49, 1-17.

Braun, T., Cottrell, R., & Diekers, P. (2018). Fostering changes in attitude, knowledge and behaviour: Demographic variation in environmental education effects. *Environmental Education Research*, 24, 899-920.

Bray, B.J., & Cridge, A.G. (2013). Can education programmes effect long-term behavioural change? *International Journal of Innovative Interdisciplinary Research*, 2, 27-33.

Cepeda, G., Nitzl, C., & Roldán, J.L. (2017). Mediation analyses in partial least squares structural equation modeling: Guidelines and empirical examples. In: Latan, H., & Noonan, R. (Eds.), *Partial Least Squares Path Modeling: Basic Concepts, Methodological Issues and Applications*. Cham, Switzerland: Springer, pp. 173-195.

Chankrajang, T., & Muttarak, R. (2017). Green returns to education: Does schooling contribute to pro-environmental behaviours? Evidence from Thailand. *Ecological Economics,* 131, 434-448.

Cordero, E.C., Centeno, D., & Todd, A.M. (2020). The role of climate change education on individual lifetime carbon emissions. *PLOS ONE,* 15(2), e0206266.

Craig, C.A., & Allen, M.W. (2015). The impact of curriculum-based learning on environmental literacy and energy consumption with implications for policy. *Utilities Policy*, 35, 41-49.

D'Amato, G., Pawankar, R., Vitale, C., Lanza, M., Molino, A., Stanziola, A., Sanduzzi, A., Vatrella, A., & D'Amato M. (2016). Climate change and air pollution: Effects on respiratory allergy. *Allergy, Asthma and Immunology Research*, 8, 391-395.

De Leeuw, A., Valois, P., Ajzen, I., & Schmidt, P. (2015). Using the theory of planned behaviour to identify key beliefs underlying pro-environmental behaviour in high-school students: Implications for educational interventions. *Journal of Environmental Psychology*, 42, 128-138.

Geiger, S.M., Dombois, C., & Funke, J. (2018). The role of environmental knowledge and attitude: Predictors for ecological behaviour across cultures. *Environmental Psychology*, 22, 69-87.

Geiger, S.M., Geiger, M., & Wilhelm, O. (2019). Environment-specific vs. General knowledge and their role in pro-environmental behaviour. *Frontiers in Psychology,* 10, 718.

Goldman, D., Yavetz, B., & Peer, S. (2014). Student teachers' attainment of environmental literacy in relation to their disciplinary major during undergraduate studies. *International Journal of Environmental and Science Education*, 9(4), 369-383.

Gould, R.K., Ardoin, N.M., Thomsen, J.M., & Wyman Roth, N. (2018). Exploring connections between environmental learning and behaviour through four everyday-life case studies. *Environmental Education Research,* 24(7), 965-991.

Goulgouti, A., Plakitsi, K., & Stylos, G. (2019). Environmental literacy: Evaluating knowledge, affect, and behaviour of pre-service teachers in Greece. *Interdisciplinary Journal of Environmental and Science Education*, 15(1), e02202.

Hair, J.F., Hult, G.T.M., Ringle, C.M., & Sarstedt, M. (2022). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. 3rd ed. Thousand Oaks, CA, USA: Sage.

Hair, J.F., Risher, J.J., Sarstedt, M., & Ringle, C.M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*. 31(1), 2-24.

Heath, A.G. (2018). *Water Pollution and Fish Physiology*. Florida: CRC Press.

Henseler, J., Ringle, C.M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115-135.

Hoffmann, R., & Muttarak, R. (2020). Greening through schooling: understanding the link between education and pro-environmental behaviour in the Philippines. *Environmental Research Letters*, 15(1), 014009.

Höfner, S., & Schütze, A. (2021). Air quality measurements and education: Improving environmental awareness of high school students. *Frontiers in Sensors,* 2, 657920.

Hogan, D., & O'Flaherty, J. (2021). Addressing education for sustainable development in the teaching of science: The case of a biological sciences teacher education program. *Sustainability*, 13, 12028.

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, 29, 1347-1362.

Johnson, B., Duffin, M., & Murphy, M. (2012). Quantifying a relationship between place-based learning and environmental quality. *Environmental Education Research*, 18, 609-624.

Kabir, M.I., Rahman, M.B., Smith, W., Lusha, M.A.F., Azim, S., &

Milton, A.H. (2016). Knowledge and perception about climate change and human health: Findings from a baseline survey among vulnerable communities in Bangladesh. *BMC Public Health,* 16, 266.

Kaya, V.H., & Elster, D. (2019). A critical consideration of environmental literacy: Concepts, contexts, and competencies. *Sustainability*, 11, 1581.

Kim, S.Y., & Hamdan Alghamdi, A.K. (2019). Female secondary students' and their teachers' perceptions of science learning environments within the context of science education reform in Saudi Arabia. *International Journal of Science and Mathematics Education*. 17, 1475-1496.

Kiraz, A., Antip, T.M., & Gunduz, S. (2020). Contributing water pollution control through the use of selected instructional strategies amongst secondary school students. *Desalination and Water Treatment*, 177, 257-263.

Kubsch, M., Opitz, S., Nordine, J., Neumann, K., Fortus, D., & Krajcik, J. (2021). Exploring a pathway towards energy conservation through emphasizing the connections between energy, systems, and fields. *Disciplinary and Interdisciplinary Science Education Research,* 3(2), 2.

LaVeaux, D., Simonds, V.W., Picket, V., Cummins, J., & Calkins, E. (2018). Developing a curriculum for change: Water and environmental health literacy in a native American community. *Progress in Community Health Partnerships*, 12(4), 441-449.

Lelieveld, J., Klingmüller, K., Pozzer, A., Burnett, R.T., Haines, A., & Ramanathan, V. (2019). Effects of fossil fuel and total anthropogenic emission removal on public health and climate. *Proceedings of the National Academy of Sciences*, 116(15), 7192-7197.

Lutz, W., Muttarak, R., & Striessnig, E. (2014). Universal education is key to enhance climate adaption. *Science,* 346, 1061-1063.

Malhotra, N.K. (2012). *Basic Marketing Research: Integration of Social Media*. 4th ed. New Jersey: Prentice Hall.

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: A review. *Frontiers in Public Health*, 8, 14.

Muttarak, R., & Chankrajang, T. (2016). Who is concerned about and takes action on climate change? Gender and education divides among Thais. *The Vienna Yearbook of Population Research,* 13, 193-220.

Nakajima, T., Ohara, T., Masui, T., & Kusaka, H. (2020). A development of reduction scenarios of the short-lived climate pollutants (SLCPs) for mitigating global warming and environmental problems. *Progress in Earth and Planetary Science,* 7, 33.

Okumah, M., & Ankomah-Hackman, P. (2020). Applying conditional process modelling to investigate factors influencing the adoption of water pollution mitigation behaviours. *Sustainable Water Resource Management*, 6, 17.

Okumah, M., Chapman, P.J., Martin-Ortega, J., & Novo, P. (2019). Mitigating agricultural diffuse pollution: Uncovering the evidence base of the awareness-behaviour-water quality pathway. *Water*, 11, 29.

Olstrup, H., Forsberg, B., Orru, H., Spanne, M., Nguyen, H., Molnár, P., & Johansson, C. (2018). Trends in air pollutants and health impacts in three Swedish cities over the past three decades. *Atmospheric Chemistry and Physics*, 18, 15705-15723.

Ortega-Egea, J.M., García-de-Frutos, N., & Antolín-López, R. (2014). Why do some people do "more" to mitigate climate change than others? Exploring heterogeneity in psycho-social associations. *PLoS One,* 9, e106645.

Poortinga, W., Whitmarsh, L., Steg, L., Böhm, G., & Fisher, S. (2019). Climate change perceptions and their individual-level determinants: A cross-European analysis. *Global Environmental Change,* 55, 25-35.

Ringle, C.M., Wende, S., & Becker, J.M. (2015). *SmartPLS 3 [Computer Software]*. Available from: https://www.smartpls.com [Last accessed on 2023 Oct 11].

Ritchie, H., & Roser, M. (2021). *Clean Water and Sanitation*. [Online] Available from: https://ourworldindata.org/clean-water-sanitation [Last accessed on 2023 May 23].

Robson, C., & McCartan, K. (2016). *Real World Research*. Hoboken, NJ: John Wiley and Sons.

Salvador, S.L., Prietoa, J.M.M., & Pastrana, M.R. (2017). Environmental awareness as a mediator variable on conceptions of science teaching and learning. *International Journal of Environmental and Science Education*, 12(5), 1401-1426.

Sharpe, E.J., Perlaviciute, G., & Steg, L. (2021). Pro-environmental behaviour and support for environmental policy as expressions of pro-environmental motivation. *Journal of Environmental Psychology*, 76, 101650.

Voorhees, C.M., Brady, M.K., Calantone, R., & Ramirez, E. (2016). Discriminant validity testing in marketing: An analysis, causes for concern, and proposed remedies. *Journal of the Academy of Marketing Science*, 44, 119-134.

Voulvoulis, N., & Burgman, M.A. (2019). The contrasting roles of science and technology in environmental challenges. *Critical Reviews in Environmental Science and Technology*, 49(12), 1079-1106.

Walls, A.E.J., Brody, M., Dillon, J., & Stevenson, R.B. (2014). Convergence between science and environmental education, *Science*, 344, 583-584.

Wan, Y., & Bi, H. (2019). What major "socio-scientific topics" should the science curriculum focused on? A Delphi study of the expert community in China. *International Journal of Science and Mathematics Education*. 18, 61-77.

West, J.J., Cohen, A., Dentener, F., Brunekreef, B., Zhu, T., Armstrong, B., Bell, M.L., Brauer, M., Carmichael, G., Costa, D.L., Dockery, D.W., Kleeman, M., Krzyzanowski, M., Künzli, N., & Wiedinmyer, C. (2016). What we breathe impacts our health: Improving understanding of the link between air pollution and health. *Environmental Science & Technology,* 50(9), 4895-4904.