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Environmental education using SARITHA-Apps to enhance environmentally friendly supply chain efficiency and foster environmental knowledge towards sustainability

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A B S T R A C T

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This study aimed to investigate the impact of Environmental Education on sustainability and the mediating role of Environmentally Friendly Supply Chain Efficiency (EFSC) and Fostered Environmental Knowledge (FENK). Employing a quantitative approach, data were collected from supply chain professionals who participated in Environmental Education programs. The research findings indicate a positive relationship between Environmental Education and supply chain sustainability. The study revealed that Environmental Education significantly enhances EFSC and FENK and positively influences sustainability practices within supply chains. The implications of this research are twofold. Firstly, it underscores the importance of incorporating Environmental Education as a fundamental component of supply chain management, contributing to more environmentally responsible practices. Secondly, the study highlights the mediating role of EFSC and FENK, indicating that not only does Environmental Education directly impact sustainability but also through the enhancement of these mediating factors. This research offers a novel perspective by establishing the link between Environmental Education, EFSC, FENK, and supply chain sustainability. However, certain limitations should be acknowledged, such as the potential for response bias and the need for further research to explore other potential mediators. Nevertheless, this study provides valuable insights for practitioners and policymakers seeking to promote sustainability in supply chains by emphasizing the role of Environmental Education and its interconnectedness with EFSC and FENK.

1. Introduction

Environmental conservation is of paramount importance in both human life and our planet's well-being (Jax et al., 2018; Wallach et al., 2018). Global challenges such as climate change, deteriorating air and water quality, soil degradation, and biodiversity loss necessitate immediate attention and action (Roy et al., 2023; Seddon et al., 2021; Wassie, 2020). One critical avenue for addressing these issues is the development of sustainable and environmentally friendly practices, particularly within the context of supply chains (Dharmayanti et al., 2023; Saberi et al., 2019). The supply chain encompasses a series of processes, including planning, procurement, production, distribution, and product or service management, from producers to end consumers (Wang et al., 2016). An efficient and sustainable supply chain significantly impacts the environment due to its involvement in transportation, resource utilization, and waste management (Das, 2018; Kalyar et al., 2020; Li et al., 2020). Hence, it is crucial for companies and organizations to comprehend environmental concepts and integrate them into their supply chain operations (Awan et al., 2021; Panigrahi et al., 2019; Xu et al., 2023). Simultaneously, environmental knowledge is vital for individuals, including business leaders and consumers, enabling them to make informed decisions regarding consumption, investment, and support for eco-friendly business practices (Park & Kang, 2022; Raza & Khan, 2022; Rusyani

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et al., 2021). One effective method of raising environmental awareness and knowledge is through education (Shelest et al., 2017; Türkoğlu, 2019; Yeşilyurt et al., 2020). In the digital era, technology plays a pivotal role in disseminating information and supporting environmental learning (Madani et al., 2017; Mollah et al., 2023). One such tool is the SARITHA-Apps, a specialized application designed for environmental education. However, despite its significant potential, there is limited research specifically focusing on the use of educational applications like SARITHA-Apps to enhance both environmentally friendly supply chain management and environmental knowledge. While extensive research exists on environmental education and sustainable business practices, the integration of these aspects within a single research framework through the utilization of educational applications remains unexplored. Therefore, this research aims to bridge this knowledge gap by comprehensively examining these elements within one cohesive research framework.

Currently, there are numerous studies that have explored environmental education and sustainable business practices, few have amalgamated these aspects holistically using educational technology (Glackin & King, 2020; O'Malley & Pierce, 2023; Sáez de Cámara et al., 2021). Consequently, this research endeavors to address this knowledge gap by integrating these elements into a unified research framework. The novelty of this research lies in its holistic approach to consider the use of SARITHA-Apps in integrating sustainable supply chain management and environmental knowledge. This study will investigate how educational applications can effectively modify corporate and individual behaviors, with a focus on more responsible environmental business practices. Furthermore, it will examine the impact of such interventions on sustainable supply chain management, an area that remains underexplored in the context of educational applications.

The primary motivation behind this research is to enhance our understanding of how educational technology, such as SARITHA-Apps, can contribute to environmental sustainability efforts. With an increasing global concern for environmental issues, this study will provide valuable insights into how environmental education can be more effectively integrated into business practices and supply chains. This research holds significant implications on several fronts. Firstly, it will provide practical guidance for companies and organizations looking to adopt educational applications to enhance sustainability within their supply chains. Secondly, it will contribute to a better understanding of how environmental education can influence individual environmental knowledge, subsequently shaping more responsible consumer behavior. Lastly, it will stimulate further research into the use of educational technology within the context of environmental sustainability. The main objectives of this research are as follows:

1. To evaluate the effectiveness of SARITHA-Apps in enhancing sustainable business practices within the supply chains of companies.
2. To measure the impact of SARITHA-Apps usage on the improvement of individual environmental knowledge.
3. To identify factors influencing the adoption and acceptance of SARITHA-Apps within business environments.
4. To provide recommendations for companies and developers of similar applications to enhance the implementation of environmental education using educational technology.

2. Literature Review and Hypothesis Development

2.1 Environmental Education and Environmentally Friendly Supply Chain Efficiency

Bhat et al. (2017) assess that Environmental Education refers to the process of educating individuals, communities, and organizations about environmental issues, conservation, and sustainability. It aims to enhance knowledge, awareness, attitudes, and skills related to the environment. Environmental education can cover a wide range of topics, including climate change, ecosystem conservation, pollution prevention, and sustainable resource management (Ardoin et al., 2020). According to Khan & Qianli (2017), Environmentally Friendly Supply Chain Efficiency involves optimizing the processes and practices within a supply chain to minimize negative environmental impacts while maintaining or improving overall supply chain performance. This includes reducing greenhouse gas emissions, conserving natural resources, minimizing waste, and adopting sustainable business practices across the supply chain(Amankwah-Amoah, 2020).

Environmental Education plays a pivotal role in raising awareness and disseminating knowledge about environmental issues (Saleh et al., 2018). When individuals within an organization, including supply chain professionals, are educated about environmental concerns, they become better equipped to identify areas within the supply chain where improvements can be made to reduce its environmental footprint (Saberi et al., 2019). Environmental education aims to change attitudes and behaviors towards the environment (Gules Bal & Karakas, 2018). Employees and stakeholders who have undergone environmental education are more likely to adopt environmentally friendly practices within the supply chain (Alraja et al., 2022). This includes making sustainable choices in sourcing, production, transportation, and waste management (Al-Aomar & Alshraideh, 2019). Through environmental education, organizations gain insights into sustainable business practices that can be integrated into their supply chains (Fontoura & Coelho, 2022). These practices may involve selecting eco-friendly suppliers, optimizing transportation routes to reduce emissions, and implementing efficient resource management strategies (Govindan et al., 2020). Environmental education can facilitate collaboration between companies and their suppliers (Yu et al., 2019). When suppliers are educated about environmental concerns and sustainable practices, they are more likely to align their operations with the sustainability goals of their clients, contributing to a more environmentally friendly supply chain

(Kurita et al., 2023). In summary, Environmental Education serves as a foundational element in promoting environmentally friendly supply chain efficiency. It enhances knowledge, fosters behavioral change, and encourages the implementation of sustainable practices throughout the supply chain, ultimately leading to more sustainable and environmentally friendly supply chain operations. Therefore, the hypothesis we propose is as follows:

H_1: *Environmental education using SARHITA-Apps influences environmentally friendly supply chain efficiency.*

Environmental Education and Foster Environmental Knowledge

West et al. (2020) argue that foster environmental knowledge means to nurture and cultivate a deeper understanding and awareness of environmental issues, concepts, and phenomena. This process involves providing individuals with information, experiences, and opportunities that contribute to their growth in environmental knowledge and expertise. Monroe et al. (2019) explain that Environmental Education is the deliberate process of imparting knowledge and fostering environmental awareness. It serves as a structured framework through which individuals, whether students, community members, or professionals, can gain a comprehensive understanding of environmental issues. Based on the notion of Liefländer et al. (2015) is that the primary goal of Environmental Education is to increase environmental knowledge. This involves educating individuals about topics such as ecology, conservation, pollution, climate change, and sustainability. Talebpour et al. (2020) assert that fostering environmental knowledge is a key component of environmental education. Environmental Education not only imparts knowledge but also encourages individuals to take action and make informed decisions regarding environmental issues. When people are well-informed about the environment, they are more likely to engage in environmentally responsible behaviors and advocate for positive change. Hanemann (2019) assesses that fostering environmental knowledge is not limited to formal education but extends to lifelong learning. Environmental education continues beyond the classroom, fostering an ongoing quest for knowledge and understanding of environmental matters throughout one's life. Furthermore, Schild (2016) assumes that environmental education and fostering environmental knowledge contribute to the broader goals of sustainability. By educating individuals about the environment and nurturing their environmental knowledge, we empower them to contribute to sustainable practices, conservation efforts, and the protection of ecosystems. In essence, Environmental Education is the intentional and structured process through which we foster environmental knowledge. This knowledge, in turn, equips individuals and communities with the awareness and capacity to address environmental challenges and work towards a more sustainable and ecologically responsible future.

H_2: *Environmental education using SARHITA-Apps influences foster environmental knowledge.*

Environmental Education and Sustainability

According to Duran et al. (2015), sustainability refers to the capacity to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. It involves a balanced and responsible approach to economic, social, and environmental aspects, seeking to minimize negative impacts on the planet's ecosystems and resources. Klein et al. (2021) explain that Environmental Education serves as a vital tool for raising awareness and enhancing understanding about the principles of sustainability. It educates individuals about the ecological, social, and economic dimensions of sustainability and fosters a sense of responsibility toward environmental stewardship. Environmental Education is instrumental in driving behavioral change toward more sustainable practices. It empowers individuals with the knowledge and skills necessary to make environmentally conscious choices in their daily lives, influencing consumption patterns, resource use, and waste reduction (Begum et al., 2022). Environmental Education encourages active engagement in sustainability initiatives. Informed individuals are more likely to advocate for sustainable policies, practices, and technologies at personal, community, and societal levels, contributing to the broader sustainability agenda (Law et al., 2017). Both Environmental Education and Sustainability emphasize the interconnectedness of human activities with the natural world (Kosta et al., 2022). Environmental Education teaches individuals about the intricate relationships between ecosystems, human society, and the economy, reinforcing the importance of considering these connections in sustainability efforts (Jordan & Kristjánsson, 2017). Sustainability is inherently future-oriented, focusing on the well-being of future generations (Pacis & VanWynsberghe, 2020). Environmental Education instills a long-term perspective by teaching individuals to consider the consequences of their actions on the environment and society over time, aligning with the principles of sustainability (Begum et al., 2021). Environmental Education empowers individuals to become agents of change. By equipping them with knowledge, critical thinking skills, and a sense of responsibility, it enables people to actively contribute to sustainable solutions and environmentally friendly practices (Walshe & Tait, 2019). Therefore, Environmental Education is a foundational component of sustainability. It equips individuals with the awareness, knowledge, and motivation to embrace sustainable behaviors and actively participate in efforts to create a more sustainable world. Both concepts are essential in addressing environmental challenges and working towards a harmonious coexistence between human society and the natural environment.

H_3: Environmental education using SARHITA-Apps influences sustainability.

Environmentally Friendly Supply Chain Efficiency and sustainability

Khan et al. (2023) argue that Environmentally Friendly Supply Chain Efficiency focuses on minimizing negative environmental impacts throughout the supply chain processes. It includes reducing greenhouse gas emissions, improving energy efficiency, optimizing waste management, and selecting more sustainable raw materials. These actions align with sustainability goals by minimizing the ecological footprint. Schmidt et al. (2017) explain that efficient and environmentally friendly supply chains often result in more efficient use of natural resources. By reducing waste and overuse of raw materials and energy, it supports the conservation of natural resources, which is crucial for long-term sustainability. More consumers are concerned about environmental issues and seek environmentally friendly products and services. By running an environmentally friendly supply chain, companies can meet these demands, enhance customer satisfaction, and support sustainable business growth (Wei et al., 2018). Higher supply chain efficiency often translates into improved economic efficiency. Less waste and lower energy costs can enhance a company's profitability, which is a vital component of maintaining business sustainability (Rehman Khan & Yu, 2021). Building an environmentally friendly supply chain also involves closer collaboration with business partners, including suppliers. These partnerships can create mutually beneficial agreements for sustainable practices and overall sustainability (Mishra et al., 2022). Many countries and regions have regulations that require companies to reduce their environmental impact. By operating an environmentally friendly supply chain, companies can comply with these regulations and avoid potential legal sanctions (Litvinenko et al., 2022). In conclusion, Environmentally Friendly Supply Chain Efficiency plays a critical role in achieving sustainability goals by reducing environmental impact, optimizing resource use, supporting economic growth, and responding to consumer demands. It is a key element in sustainable business strategies that aim to balance economic, social, and environmental interests.

H_4: *Environmentally friendly supply chain efficiency influences on sustainability.*

Foster Environmental Knowledge and sustainability

Fostering environmental knowledge involves increasing awareness and understanding of environmental issues, ecological processes, and the interconnectedness of human activities with the natural world. This awareness is foundational to promoting sustainability, as informed individuals are more likely to appreciate the importance of protecting the environment for current and future generations (Shutaleva, 2023). People with strong environmental knowledge are better equipped to make informed decisions that support sustainability. It includes choices related to consumption, resource use, waste reduction, and support for sustainable practices and policies (Congretel & Pinton, 2020). Environmental knowledge can drive behavioral change. When individuals understand the environmental consequences of their actions, they are more likely to adopt sustainable behaviors and lifestyles. It might involve reducing energy consumption, conserving water, recycling, and supporting environmentally responsible products and services (Amoah & Addoah, 2021). Based on the notion of Richard and David (2018) is that knowledgeable individuals are often more engaged in sustainability initiatives. They may become advocates for environmental protection, climate action, and sustainable practices, both at the individual and community levels. Advocacy and engagement are essential for driving broader sustainability efforts. Fostering environmental knowledge often involves educational programs and effective communication strategies. These initiatives raise awareness, disseminate information, and engage people in sustainability-related topics and initiatives (Burger, 2015). Education is a powerful tool for empowering individuals and communities to take action for a more sustainable future (Agbedahin, 2019). Sustainability is inherently future-oriented, emphasizing the responsible use of resources and the well-being of future generations (Kinski & Whiteside, 2023). Fiel'ardh et al. (2023) thought that fostering environmental knowledge instills a long-term perspective by teaching individuals to consider the consequences of their actions on the environment and society over time. A well-informed population can support scientific research and evidence-based policymaking. This can lead to the development and implementation of policies and practices that promote sustainability, address environmental challenges, and mitigate climate change. Fostering environmental knowledge is integral to sustainability. It empowers individuals and communities to understand, appreciate, and act in ways that protect the environment and support long-term ecological, social, and economic well-being. Environmental knowledge is an essential component of building a sustainable and resilient society.

H_5: *Fostering environmental knowledge influences sustainability.*

Environmentally Friendly Supply Chain Efficiency and Foster Environmental Knowledge as mediator

In the context of the relationship between "Environmentally Friendly Supply Chain Efficiency" and "Fostering Environmental Knowledge" with "Building Environmental Awareness" as a mediator, one can envision a scenario where the development of environmental knowledge acts as an intermediary variable influencing the connection between environmentally friendly supply chain efficiency and the overall endeavor to foster environmental awareness and responsible behaviors. In this scenario, environmentally friendly supply chain efficiency, through its practices aimed at reducing environmental impacts and optimizing resource use, may lead to increased awareness of sustainability and environmentally friendly practices among supply chain professionals and stakeholders. This heightened environmental knowledge, in turn, is expected to influence and mediate the adoption of environmentally friendly behaviors and attitudes within the supply chain, ultimately contributing to a more sustainable and environmentally conscious approach to supply chain management.

H_6: *Environmentally friendly supply chain efficiency mediates the relationship between environmental education using SARHITA-Apps and sustainability.*
H_7: *Foster environmental knowledge mediates the relationship between fostering environmental knowledge and Sustainability.*

3. Methods

The methodology employed in this study utilizes a quantitative research design to explore the hypothesized relationships among environmentally friendly supply chain efficiency, environmental knowledge, and the fostering of environmental awareness and behaviors (Suseno & Basrowi, 2023). A random sample of 132 supply chain professionals will be selected, and data will be collected through survey questionnaires and standardized environmental knowledge assessments (Mustofa et al., 2023; Purwaningsih et al., 2022). The primary variables under investigation include environmentally friendly supply chain efficiency, serving as the independent variable, (Suseno et al., 2018) ecological knowledge, acting as the mediating variable, and fostering environmental awareness and behaviors, which will be examined as the dependent variable (Basrowi & Utami, 2020). Data will be subjected to rigorous statistical analyses to scrutinize the mediation effect of environmental knowledge (Basrowi & Maunnah, 2019; Purwaningsih et al., 2019), potentially utilizing structural equation modeling (SEM) or regression analysis techniques (Suwarno et al., 2020; Purwaningsih & Suhaeri, 2019). Throughout the research process, strict adherence to ethical considerations will be upheld. It includes obtaining informed consent from all participating individuals and ensuring the utmost protection of data privacy (Soenyono & Basrowi, 2020; Purwaningsih et al., 2018). This study aims to contribute valuable insights into the intricate relationships between supply chain practices and the development of environmental awareness and behaviors (Marwanto et al., 2020; Purwaningsih, 2019). The findings are expected to have significant implications for promoting sustainability within supply chain management, thereby advancing environmentally responsible practices in this critical domain (Purwaningsih, 2020).

Table 1
Measurement instrument

Variable	Indicators		Source
Environmental education	1.	Knowledge Enhancement: Assessing participants' increased environmental knowledge through pre- and post-tests or surveys.	(Ardoin et al., 2020; Saberi et al., 2019; Saleh et al., 2018)
	2.	Behavioral Shift: Measuring changes in participants' actions, such as reduced energy use, increased recycling, or adopting eco-friendly habits.	
	3.	Attitude Change: Evaluating shifts in participants' attitudes toward environmental issues, often via surveys or interviews.	
	4.	Environmental Awareness: Measuring participants' awareness of environmental challenges, including local and global issues.	
	5.	Practical Skills: Assessing participants' acquisition of practical environmental skills, such as gardening or waste reduction techniques.	
	6.	Engagement in Environmental Activities: Monitoring participants' involvement in environmental initiatives like volunteering or community sustainability projects.	
	7.	Feedback Collection: Gathering participant input through surveys, questionnaires, or focus groups to understand their perspectives and suggestions.	
	8.	Long-Term Impact: Evaluating the program's enduring influence by tracking participants' environmental behaviors and attitudes over time.	
	9.	Success of Environmental Projects: Measuring the achievements of projects initiated by participants, such as community gardens or pollution reduction efforts.	
	10.	Resource Efficiency: Assessing participants' ability to use environmental resources efficiently, including water and energy conservation and waste reduction.	
Environmentally Friendly Supply Chain Efficiency	1.	Reducing Emissions: Environmental Education imparts knowledge about emissions reduction strategies and their importance in sustainable supply chains. It educates on efficient practices in transportation, energy use, and waste reduction to achieve emission reductions.	(Khan et al., 2023; Rehman Khan & Yu, 2021; Schmidt et al., 2017)
	2.	Efficient Energy Use: Environmental Education teaches individuals and organizations about energy efficiency and the significance of lowering energy consumption per production or transportation unit in supply chains.	
	3.	Waste Reduction: Environmental Education emphasizes waste reduction and recycling as key components of sustainable supply chains, guiding professionals on evaluating and improving waste management practices.	
	4.	Water Efficiency: Environmental Education raises awareness about responsible water usage in supply chain activities, promoting efficient water management and pollution prevention.	
	5.	Sustainable Sourcing: Environmental Education advocates for responsible sourcing practices, teaching the importance of obtaining materials from eco-friendly suppliers in line with sustainability criteria.	
	6.	Optimized Transportation: Environmental Education encourages the adoption of transportation efficiency measures, such as reducing miles traveled, optimizing routes, and using fuel-efficient vehicles within supply chains.	
	7.	Inventory Management: Environmental Education underscores the importance of inventory management in reducing excess inventory and minimizing waste, contributing to supply chain sustainability.	
	8.	Supplier Collaboration: Environmental Education promotes collaboration with suppliers for sustainable practices, emphasizing the role of partnerships and stakeholder engagement in supply chain sustainability.	
	9.	Regulatory Compliance: Environmental Education ensures that individuals and organizations are aware of and adhere to environmental regulations, including emissions standards and waste management requirements, within the supply chain.	
	10.	Life Cycle Assessment (LCA): Environmental Education educates on the concept of Life Cycle Assessment (LCA) to assess a product's environmental impact comprehensively, from raw materials to disposal, aiding in supply chain decision-making.	
	11.	Certifications: Environmental Education teaches the importance of obtaining and maintaining environmental certifications as a means to demonstrate commitment to green supply chain practices.	
	12.	Cost Savings: Environmental Education highlights the financial benefits of eco-friendly practices, including reduced energy and transportation costs, promoting the adoption of cost-effective sustainability measures.	
	13.	Customer Feedback: Environmental Education encourages organizations to gather customer feedback on eco-friendly practices, recognizing the role of customers' opinions in shaping sustainable supply chains.	
	14.	Environmental Reporting: Environmental Education emphasizes the importance of clear reporting on sustainability efforts to stakeholders, educating on transparent communication practices within supply chains.	

Table 1
Measurement instrument

Variable	Indicators		Source
Fostering Environmental Knowledge	1.	Knowledge Assessment: Measure participants' knowledge before and after the program to gauge improvement.	(Hanemann, 2019; Talebpour et al., 2020; West et al., 2020)
	2.	Environmental Literacy: Evaluate participants' ability to understand and communicate environmental information.	
	3.	Curriculum Alignment: Assess how well the curriculum aligns with environmental education standards.	
	4.	Curriculum Depth: Measure the program's depth in covering local and global environmental issues.	
	5.	Critical Thinking: Evaluate participants' ability to analyze and solve environmental problems.	
	6.	Behavioral Intentions: Determine if participants plan to engage in eco-friendly behaviors.	
	7.	Application of Knowledge: Assess how well participants apply environmental knowledge.	
	8.	Environmental Engagement: Monitor participants' involvement in environmental activities.	
	9.	Environmental Projects: Evaluate the success of projects initiated by participants.	
	10.	Long-Term Retention: Measure knowledge retention over time.	
	11.	Feedback and Evaluation: Collect feedback on program quality and effectiveness.	
	12.	Environmental Literacy Assessments: Use standardized tools to assess overall environmental knowledge.	
Sustainability	1.	Social Responsibility: Environmental Education teaches the ethical and social responsibilities individuals and organizations have towards the environment, emphasizing fair labor practices and responsible sourcing as part of supply chain education.	(Klein et al., 2021; Liefländer et al., 2015; Schild, 2016)
	2.	Eco-Friendly Packaging: Environmental Education raises awareness about the environmental impact of packaging materials and educates on the adoption of eco-friendly packaging practices as a key aspect of sustainable supply chains.	
	3.	Sustainability Audits: Environmental Education includes training on sustainability assessments and audits, equipping professionals with the knowledge and skills to evaluate and improve supply chain sustainability.	
	4.	Renewable Resources: Environmental Education highlights the importance of using renewable energy sources, such as solar and wind power, within the supply chain, emphasizing their environmental benefits.	
	5.	Eco-Efficient Facilities: Environmental Education emphasizes the significance of energy efficiency, waste reduction, and resource conservation, which can be applied to the design and management of eco-efficient supply chain facilities.	
	6.	Stakeholder Engagement: Environmental Education promotes stakeholder involvement and collaboration in sustainability efforts, teaching individuals and organizations to engage with employees, suppliers, and the community in sustainable supply chain decision-making.	
	7.	Emission Reduction Targets: Environmental Education informs individuals and businesses about the importance of setting emission reduction goals within supply chains, linking sustainability goals with supply chain management.	
	8.	Green Procurement: Environmental Education teaches the principles of green procurement, guiding organizations in making environmentally responsible purchasing decisions and sourcing practices.	
	9.	Environmental Compliance: Environmental Education ensures that individuals and organizations are aware of and adhere to environmental regulations and standards, fostering compliance within supply chain operations.	
	10.	Circular Economy: Environmental Education promotes the concept of a circular economy, teaching waste reduction and resource conservation principles that can be integrated into supply chain practices.	
	11.	Sustainable Transportation: Environmental Education advocates for sustainable transportation options within supply chains, educating professionals on the use of eco-friendly vehicles and logistics methods.	
	12.	Sustainable Packaging Design: Environmental Education emphasizes sustainable packaging design, educating professionals about efficient design and material choices that reduce environmental impact.	
	13.	Sustainability Metrics: Environmental Education provides knowledge about measuring and tracking sustainability progress using specific metrics and KPIs, enabling informed decision-making within supply chains.	
	14.	Supply Chain Transparency: Environmental Education highlights the importance of transparent reporting and communication about environmental aspects within supply chains, fostering openness and accountability.	
	15.	Sustainable Agriculture: Environmental Education promotes sustainable agricultural practices that can be integrated into supply chain sourcing and procurement strategies.	
	16.	Green Building Standards: Environmental Education includes an understanding of green building codes and certifications, encouraging the construction of eco-friendly supply chain facilities.	

4. Results

4.1 Validity and reliability

The provided data consists of four constructs: “Environmental Education”, “Environmentally Friendly Supply Chain Efficiency”, “Fostering Environmental Knowledge”, and “Sustainability”. Each construct is associated with multiple items, and the data includes various statistical measures such as Outer Loading, Cronbach's Alpha, rho_A, CR (Composite Reliability), and AVE (Average Variance Extracted). For the "Environmental Education" construct, all ten items (ENDU1 to ENDU10) exhibit strong outer loadings, ranging from 0.895 to 0.946. The Cronbach's Alpha, rho_A, and CR values for this construct are high, exceeding 0.98, indicating excellent internal consistency. The AVE value is 0.861, suggesting that the construct captures substantial variance. Similarly, the "Environmentally Friendly Supply Chain Efficiency" construct comprises fourteen items (EFSC1 to EFSC14), all exhibiting substantial outer loadings, ranging from 0.807 to 0.962. The Cronbach's Alpha, rho_A, and CR values for this construct are also exceptionally high (above 0.98), and the AVE value is 0.823, indicating strong construct validity. The "Fostering Environmental Knowledge" construct consists of twelve items (FENK1 to FENK12) with outer loadings ranging from 0.877 to 0.969. Like the previous constructs, this one also demonstrates excellent internal consistency with Cronbach's Alpha, rho_A, and CR values above 0.98. The AVE value is 0.843, signifying high construct validity. Lastly, the "Sustainability" construct includes sixteen items (SUST1 to SUST16) with outer loadings varying from 0.740 to 0.901. While the outer loadings are slightly lower than in the previous constructs, the Cronbach's Alpha, rho_A, and CR values remain above 0.97, indicating good internal consistency. The AVE value for this construct is 0.710, suggesting a reasonably high level of construct validity.

The data analysis demonstrates that all constructs have strong internal consistency and construct validity. These findings provide confidence in the reliability and validity of the measurement model for each construct in the study (see Table 2).

Table 2
Confirmatory factor analysis

Construct	Items	Outer	Cronbach's	rho_A	CR	AVE
Environmental Education	ENDU1	0.914	0.982	0.983	0.984	0.861
	ENDU2	0.946				
	ENDU3	0.936				
	ENDU4	0.945				
	ENDU5	0.932				
	ENDU6	0.922				
	ENDU7	0.936				
	ENDU8	0.934				
	ENDU9	0.919				
	ENDU10	0.895				
Environmentally Friendly Supply Chain Efficiency	EFSC1	0.843	0.983	0.985	0.985	0.823
	EFSC2	0.946				
	EFSC3	0.950				
	EFSC4	0.920				
	EFSC5	0.962				
	EFSC6	0.807				
	EFSC7	0.896				
	EFSC8	0.916				
	EFSC9	0.909				
	EFSC10	0.928				
	EFSC11	0.899				
	EFSC12	0.909				
	EFSC13	0.876				
	EFSC14	0.930				
Fostering Environmental Knowledge	FENK1	0.877	0.983	0.985	0.985	0.843
	FENK2	0.926				
	FENK3	0.969				
	FENK4	0.964				
	FENK5	0.957				
	FENK6	0.879				
	FENK7	0.922				
	FENK8	0.921				
	FENK9	0.930				
	FENK10	0.881				
	FENK11	0.885				
	FENK12	0.901				
Sustainability	SUST1	0.866	0.972	0.974	0.975	0.710
	SUST2	0.880				
	SUST3	0.901				
	SUST4	0.887				
	SUST5	0.783				
	SUST6	0.836				
	SUST7	0.844				
	SUST8	0.888				
	SUST9	0.864				
	SUST10	0.740				
	SUST11	0.745				
	SUST12	0.844				
	SUST13	0.849				
	SUST14	0.877				
	SUST15	0.866				
	SUST16	0.786				

4.2 Hypothesis testing

The presented Table 3 outlines the results of a hypothesis testing analysis involving several constructs, specifically Environmental Education (ENDU), Environmentally Friendly Supply Chain Efficiency (EFSC), Fostering Environmental Knowledge (FENK), and Sustainability (SUST). Each hypothesis (H1 to H7) investigates the relationships between these constructs with associated statistics and results. Below is a summary of the findings:

The first hypothesis: The hypothesis suggesting a relationship between Environmental Education (ENDU) and Environmentally Friendly Supply Chain Efficiency (EFSC) is supported. The original sample data indicates a positive relationship with a statistically significant T statistic of 3.541 ($p < 0.001$). Thus, this hypothesis is accepted.

The second hypothesis: The hypothesis suggesting a relationship between Environmental Education (ENDU) and Fostering Environmental Knowledge (FENK) is also supported. The original sample data shows a positive relationship with a statistically significant T statistic of 4.111 ($p < 0.001$), leading to the acceptance of this hypothesis.

The third hypothesis: The hypothesis connecting Environmental Education (ENDU) and Sustainability (SUST) is supported. The original sample data reveals a positive relationship with a statistically significant T statistic of 3.913 ($p < 0.001$), resulting in the acceptance of this hypothesis.

The fourth hypothesis: The hypothesis relating Environmentally Friendly Supply Chain Efficiency (EFSC) and Sustainability (SUST) is supported. The original sample data displays a positive relationship with a statistically significant T statistic of 4.028 ($p < 0.001$), leading to the acceptance of this hypothesis.

The fifth hypothesis: The hypothesis connecting Fostering Environmental Knowledge (FENK) and Sustainability (SUST) is also supported. The original sample data indicates a positive relationship with a statistically significant T statistic of 2.718 ($p = 0.007$), resulting in the acceptance of this hypothesis.

The sixth and seventh hypotheses are examples of mediation hypotheses in statistical analysis. In this context, they indicate that there is a mediator variable that influences the relationship between two independent variables (ENDU and FENK) and a dependent variable (SUST).

The sixth hypothesis: Hypothesis H6 states that Environmentally Friendly Supply Chain Efficiency (EFSC) acts as a mediator between Environmental Education (ENDU) and Sustainability (SUST). It means that EFSC is considered a mediator explaining how the relationship between ENDU and SUST occurs. Supporting H6 suggests that the effect of ENDU on SUST predominantly occurs through the mediation of EFSC.

The seventh hypothesis: Hypothesis H7 states that Fostering Environmental Knowledge (FENK) acts as a mediator between Environmental Education (ENDU) and Sustainability (SUST). It indicates that FENK is considered a mediator that explains how the relationship between ENDU and SUST occurs. Supporting H7 suggests that the effect of ENDU on SUST primarily occurs through the mediation of FENK. In other words, H6 and H7 test whether the mediation of EFSC and FENK explains how the variable ENDU influences the variable SUST. Positive results prove that this mediation plays a significant role in the relationship between these variables.

In summary, all seven hypotheses are supported by the original sample data, indicating significant and positive relationships between the specified constructs in the study. These findings contribute to a better understanding of the interconnections among Environmental Education, Environmentally Friendly Supply Chain Efficiency, Fostering Environmental Knowledge, and Sustainability.

Table 3
Hypothesis result

Hypothesis	Construct*)	Original Sample	STDEV	T Statistics	P Values	Result
H1	ENDU → EFSC	0.374	0.106	3.541	0.000	Accepted
H2	ENDU → FENK	0.430	0.104	4.111	0.000	Accepted
H3	ENDU → SUST	0.342	0.087	3.913	0.000	Accepted
H4	EFSC → SUST	0.319	0.079	4.028	0.000	Accepted
H5	FENK → SUST	0.199	0.073	2.718	0.007	Accepted
H6	ENDU → EFSC→ SUST	0.119	0.043	2.782	0.006	Accepted
H7	ENDU → FENK→ SUST	0.085	0.038	2.236	0.026	Accepted

*) ENDU=Environmental Education; EFSC=Environmentally Friendly Supply Chain Efficiency; FENK=Fostering Environmental Knowledge; SUST=Sustainability

5. Discussion

The results of the study provide strong support for Hypothesis 1 (H1), which posited that "Environmental Education using SARHITA-Apps influences Environmentally Friendly Supply Chain Efficiency". The data analysis revealed a significant positive relationship between the implementation of SARHITA-Apps for environmental education and the improvement of environmentally friendly supply chain efficiency among the participants. This finding suggests that utilizing SARHITA-Apps as an educational tool effectively enhances the awareness and knowledge of environmental issues within the supply chain context, subsequently leading to the adoption of more sustainable practices and the optimization of resource utilization. The acceptance of H1 underscores the potential of SARHITA-Apps in driving positive changes within supply chains by promoting environmental education and aligning with sustainability goals. This outcome holds practical implications for organizations seeking to enhance their supply chain sustainability efforts through educational technology. The acceptance of Hypothesis 1 (H1), indicating that "Environmental Education using SARHITA-Apps influences Environmentally Friendly Supply Chain

Efficiency," carries significant theoretical and practical implications. From a theoretical standpoint, this finding underscores the pivotal role of educational technology, such as SARHITA-Apps, in fostering environmental knowledge and awareness within the supply chain context. It aligns with the broader body of research that emphasizes the importance of environmental education as a catalyst for sustainable practices and underscores the relevance of technology-driven learning tools in achieving these objectives. On a practical level, the results have practical implications for businesses and organizations aiming to enhance their supply chain sustainability efforts. By incorporating SARHITA-Apps or similar educational platforms into their training and development programs, companies can empower their supply chain professionals with the knowledge and awareness needed to make environmentally responsible decisions. This, in turn, can lead to the adoption of sustainable practices, resource optimization, reduced environmental impact, and improved supply chain efficiency. Ultimately, it contributes to the organization's broader sustainability goals, enhances its reputation as a socially responsible entity, and aligns with the increasing consumer demand for environmentally conscious products and services. Thus, the practical implications emphasize the strategic importance of investing in environmental education tools like SARHITA-Apps as a means to achieve both supply chain efficiency and sustainability objectives.

The study's findings provide compelling support for Hypothesis 2 (H2), which posited that “Environmental Education using SARHITA-Apps influences Foster Environmental Knowledge”. The data analysis revealed a significant positive relationship between the utilization of SARHITA-Apps for environmental education and the development of environmental knowledge among the participants. This result underscores the effectiveness of SARHITA-Apps as an educational tool in enhancing participants' understanding of environmental issues, conservation, and sustainability concepts. It highlights the role of technology-driven environmental education in promoting informed and environmentally aware individuals. The acceptance of H2 carries theoretical significance by adding to the body of research emphasizing the importance of technology-based environmental education in fostering environmental knowledge. Moreover, it has practical implications for organizations and educational institutions seeking to enhance environmental literacy and awareness, which are fundamental aspects of addressing pressing environmental challenges and promoting sustainable practices at both individual and organizational levels. Thus, the acceptance of H2 underscores the potential of SARHITA-Apps in advancing environmental education and knowledge, contributing to more environmentally conscious and responsible behaviors, and ultimately supporting broader sustainability objectives.

Hypothesis 3 (H3), which postulates that “Environmental Education using SARHITA-Apps influences Sustainability”, stands as a pivotal component in the study's findings. The data analysis reveals a substantial and positive association between the utilization of SARHITA-Apps for environmental education and the promotion of sustainability. This outcome underscores the profound impact of incorporating SARHITA-Apps as an educational tool in instilling a sense of environmental responsibility and knowledge, which subsequently contributes to broader sustainability objectives. The acceptance of H3 holds significant theoretical implications by emphasizing the role of technology-driven environmental education as a catalyst for achieving sustainability. In practical terms, it carries considerable weight for organizations, institutions, and policymakers striving to promote sustainable practices and values. By integrating SARHITA-Apps or similar educational platforms into their initiatives, they can harness the potential to foster a more sustainable and ecologically conscious society, address environmental challenges, and work towards a harmonious coexistence between human society and the natural environment. Thus, the acceptance of H3 underscores the transformative potential of SARHITA-Apps in advancing environmental education and ultimately contributing to the overarching goal of sustainability.

Hypothesis 4 (H4), which suggests that “Environmentally Friendly Supply Chain Efficiency influences Sustainability”, is a critical focal point in the study's findings. The data analysis reveals a substantial and positive correlation between environmentally friendly supply chain efficiency and sustainability. This outcome highlights the significance of adopting environmentally responsible practices within the supply chain to advance sustainability goals. The acceptance of H4 holds significant theoretical implications by reinforcing the essential role of supply chain efficiency in promoting sustainability. Moreover, it carries substantial practical implications for businesses, organizations, and policymakers. It underscores that optimizing supply chain operations to minimize environmental impacts, reduce waste, and conserve resources is not only ecologically beneficial but also contributes to long-term economic and social sustainability. By embracing environmentally friendly supply chain practices, entities can simultaneously enhance their environmental stewardship, economic viability, and social responsibility. In summary, the acceptance of H4 emphasizes the instrumental role of supply chain efficiency in advancing sustainability and underlines the importance of sustainable supply chain management in contemporary business and environmental strategies.

Hypothesis 5 (H5), which posits that “Foster Environmental Knowledge influences Sustainability”, emerges as a pivotal component of the study's findings. The data analysis demonstrates a strong and positive connection between the promotion of environmental knowledge and sustainability. This outcome underscores the critical role of fostering environmental knowledge in driving sustainability initiatives. The acceptance of H5 carries profound theoretical implications by emphasizing that informed individuals, equipped with environmental knowledge, are more likely to engage in sustainable practices and advocate for environmentally responsible behaviors. On a practical level, this finding has substantial implications for educational institutions, organizations, and policymakers. It underscores the importance of educational programs and initiatives aimed at enhancing environmental literacy, as these programs contribute significantly to promoting sustainable

behaviors, resource conservation, and the mitigation of environmental challenges. By fostering environmental knowledge, entities can empower individuals and communities to actively participate in creating a more sustainable and ecologically responsible future. In summary, the acceptance of H5 underscores the transformative potential of environmental education in advancing sustainability and highlights the central role of informed individuals in driving sustainable practices and positive environmental change.

The study's results provide insightful interpretations regarding Hypotheses 6 (H6) and 7 (H7). Hypothesis 6, which proposed that "Environmentally Friendly Supply Chain Efficiency mediates the relationship between Environmental Education using SARHITA-Apps and Sustainability", was supported by the data analysis. This suggests that, in the context of this study, environmentally friendly supply chain efficiency act as a significant mediator between environmental education using SARHITA-Apps and sustainability outcomes. However, Hypothesis 7, which posited that "Environmentally Friendly Supply Chain Efficiency mediates the relationship between Fostering Environmental Knowledge and Sustainability", was supported. The data analysis revealed that environmentally friendly supply chain efficiency played a mediating role in the relationship between fostering environmental knowledge and sustainability. This indicates that the promotion of environmental knowledge, when coupled with efforts to optimize supply chain practices for environmental sustainability, leads to enhanced sustainability outcomes. The acceptance of H7 underscores the practical importance of fostering environmental knowledge within organizations and supply chains and aligning it with sustainable supply chain practices to achieve broader sustainability objectives. In similarity, the accepting of H6 suggests that, environmental education using SARHITA-Apps contributes to knowledge and awareness, and directly influence sustainability outcomes through supply chain efficiency in the context examined by this study. These findings provide valuable insights for organizations and policymakers aiming to design effective sustainability strategies by emphasizing the combined significance of knowledge dissemination and supply chain efficiency improvements.

6. Conclusion

This comprehensive study has examined the interplay of environmental education, environmental knowledge, environmentally friendly supply chain efficiency, and sustainability. The findings provide valuable insights into these relationships. First, it was established that environmental education using SARHITA-Apps has a positive influence on both environmentally friendly supply chain efficiency (H1) and the development of environmental knowledge (H2). Additionally, fostering environmental knowledge significantly influences sustainability (H5). The study also confirmed the positive impact of environmentally friendly supply chain efficiency on sustainability (H4). However, hypotheses related to mediation yielded mixed results. While environmentally friendly supply chain efficiency mediate the relationship between environmental education using SARHITA-Apps and sustainability (H6), it effectively mediated the relationship between fostering environmental knowledge and sustainability (H7). These findings underscore the multifaceted dynamics at play in the pursuit of sustainability, where knowledge, education, and supply chain efficiency intertwine to influence outcomes.

Implications

The implications of this study are substantial. Firstly, organizations and educational institutions should recognize the importance of leveraging technology-driven environmental education tools like SARHITA-Apps to enhance both supply chain efficiency and environmental knowledge. This approach can lead to more sustainable supply chain practices and a workforce that is better equipped to contribute to sustainability goals. Secondly, fostering environmental knowledge should be a central component of sustainability initiatives. Promoting awareness and understanding of environmental issues can empower individuals and supply chain professionals to make informed decisions, thereby facilitating sustainable practices and behaviors. Finally, businesses and policymakers should prioritize environmentally friendly supply chain practices, as these are instrumental in advancing sustainability objectives. Efficient supply chain management, aligned with sustainability principles, can drive economic, environmental, and social benefits.

Limitations

Despite its contributions, this study has certain limitations. Firstly, the data collected relied on self-report measures, which could introduce response bias. Secondly, the research focused on a specific context and sample, potentially limiting the generalizability of the findings to broader settings. Future research should aim for more diverse and representative samples. Additionally, the study primarily examined the mediation role of environmentally friendly supply chain efficiency, leaving room for further exploration of alternative mediators. Furthermore, the study did not encompass all potential variables that could influence sustainability outcomes, emphasizing the need for comprehensive analyses in future research. Lastly, the temporal aspect of the relationships studied was not addressed, and future research could benefit from longitudinal designs to explore how these relationships evolve over time.

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