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Research Paper

Green education's role in advancing sustainable architectural practices

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ABSTRACT

The world is facing significant climate challenges that demand immediate action. Sustainable practices in architecture are essential for addressing these challenges by enhancing energy efficiency, reducing carbon emissions, and promoting environmental resilience. Green education has gained considerable attention as a means of embedding sustainability principles into architectural practices. This research identifies a critical gap in existing literature regarding the clear definition of characteristics, principles, and frameworks for green education in architecture. Through the analysis of existing curricula and prior research, this study pinpoints key trends in green education that support sustainable architectural practices. The findings reveal a variety of green education approaches, incorporating diverse tools and practical strategies essential for preparing students to effectively adopt and implement sustainable practices across different levels of architectural development.

1. Introduction

The global community is currently facing unprecedented climate challenges that demand immediate and effective action. According to the Intergovernmental Panel on Climate Change (IPCC) report of 2023, global temperatures have already risen by approximately 1.2°C above pre-industrial levels, leading to severe environmental impacts such as rising sea levels, more frequent extreme weather events, and widespread biodiversity loss [1]. The World Meteorological Organization (WMO) also reported in 2023 that the past decade was the warmest on record, emphasizing the urgent need for sustainable solutions [2]. Modern sustainability concepts are rooted in the idea of meeting present needs without compromising the ability of future generations to meet their own. This involves a balanced approach that integrates environmental stewardship, social responsibility, and economic viability [3]. As defined by the United Nations' 2023 Sustainability Report, sustainability encompasses practices that promote energy efficiency, reduce carbon emissions, and enhance the resilience of communities and ecosystems [4]. In the field of architecture, sustainable practices have become crucial for addressing global challenges such as climate change and resource depletion. Sustainable architecture involves the use of renewable materials, energy-efficient building designs, and the integration of green technologies. These sustainable architectural practices not only reduce the environmental footprint but also enhance the well-being of communities and contribute to the economic stability of regions [5]. By promoting resource efficiency, reducing waste, and ensuring healthier living environments, sustainable architecture plays a vital role in creating a more resilient and sustainable future [6]. The environmental benefits of sustainable architecture include reduced greenhouse gas emissions, lower energy consumption, and conservation of natural resources. These practices improve indoor air quality, enhance occupant health and comfort by providing affordable and resilient housing. Economically, sustainable architecture can lead to significant cost savings in energy and maintenance, and can boost local economies through the use of locally sourced materials and labor [7]. Previous studies have explored various facets of green architecture, such as the use of renewable materials and the application of smart technologies [8, 9].

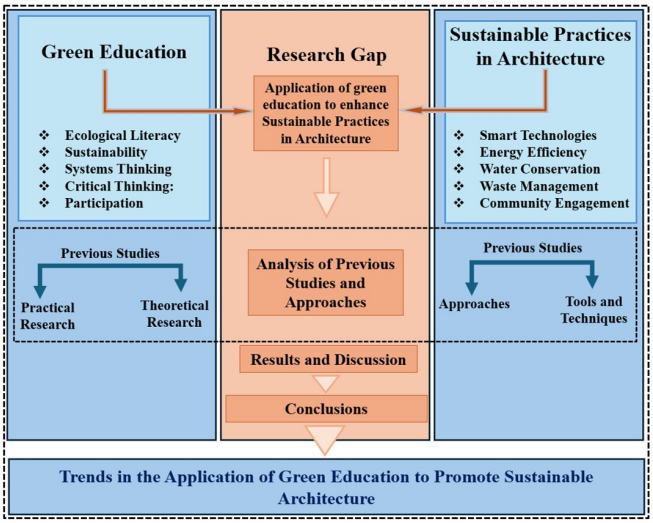

Figure 1. Schematic of the research methodology.

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Nomenclature

AR	Augmented Reality	PBL	Project-Based Learning
CEE	Centers for Environmental Education	UN	United Nations
IPCC	Intergovernmental Panel on Climate Change	VR	Virtual Reality
LEED	Leadership in Energy and Environmental	WMO	World Meteorological Organization

Research has also highlighted the benefits of integrating traditional and modern practices for holistic sustainability [10] and the importance of self-sustaining building designs [11]. Additionally, studies have examined the role of policy frameworks and community engagement in promoting sustainable practices [12]. However, there remains a gap in the literature regarding the systematic integration of green education principles into architectural curricula, which is crucial for equipping future architects with the skills to implement sustainable practices effectively.

Table 1. Strategies and key components for implementing green education in architecture.

Strategy	Key components	Description
Curriculum and content development	○Environmental knowledge kntegration.	→Include sustainability topics in core courses.
	○Case studies.	→Use real-world examples to teach sustainable design.
	○Curriculum Updates.	→Regularly update courses to reflect the latest in green architecture.
Project-based and practical learning	○Project-based learning (PBL).	→Focus on hands-on projects that emphasize green design.
	○Workshops and training.	→Provide practical experience through workshops.
	○Field trips.	→Organize visits to sustainable sites for real-world insights.
	○Community engagement.	→Involve students in local sustainability projects.
Technology and tools	○Specialized software.	→Teach the use of software tools for sustainable design.
	○Simulation and modelling.	→Use tools to predict the environmental impact of designs.
	○VR/AR.	→Use virtual/augmented reality for immersive design visualization.
Green certificates standards	○Green standards in projects.	→Encourage alignment with certifications like LEED.
	○Certification preparation.	→Prepare students for green building certifications.
Research and innovation	○Awareness workshops.	→Conduct workshops to raise environmental awareness.
	○Social responsibility.	→Encourage designs that benefit communities and reduce environmental impact.
Global enga. and open edu.	○Global networks.	→Engage in global sustainability and architecture networks.
	○Exchange programs.	→Facilitate international exchanges to learn diverse practices.
Sust. campus initiatives	○Green campus development.	→Implement sustainable practices on campus.
	○Student Sustainability projects.	→Encourage student-led projects that improve campus sustainability.
Ass. and continuous improv.	○Sustainability assessment.	→Include environmental impact as a criterion in project assessments.
	○Feedback and iteration.	→Continuously improve based on feedback from students and faculty.
Collab. with industry and gover.	○Industry partnerships.	→Partner with green industry leaders for real-world experience.
	○Policy engagement.	→Involve students in understanding and influencing sustainable building policies.

Through previous studies, it is clear that many studies have addressed the concept of green education only superficially, without delving into its details in terms of trends and methods. Therefore, this study aims to address the gap inthe literature concerning the specific characteristics, principles, and frameworks of green education in the context of architecture. Through a comprehensive analysis of existing curricula and previous studies, this study seeks to identify effective trends in green education that support sustainable architectural practices for preparing students to understand and apply sustainable practices in their future careers, ultimately contributing to a more sustainable built environment. Figur 1 illustrates the research framework adopted in this study, outlining the methodological steps taken to analyze green education concepts and their integration into sustainable architectural practices. Green education, also known as environmental education, promotes environmental consciousness, sustainability, and eco-friendly practices. This educational approach aims to equip individuals with the knowledge, skills, values, and attitudes necessary for contributing to a sustainable future. It emerged in response to growing awareness of environmental degradation and the need for sustainable development across various educational levels from primary to higher education [13]. The concept of green education gained prominence in the late 20th century, particularly after the 1972 United Nations Conference on the Human Environment in Stockholm, which emphasized the importance of environmental education. Over the years, international declarations like the Tbilisi Declaration (1977) and the Thessaloniki Declaration (1997) have underscored the critical role of education in achieving environmental sustainability [14]. Green education encompasses key principles, including the following:

- Ecological Literacy: Green education promotes ecological literacy, which helps individuals understand the natural systems and their interdependencies [15].
- Sustainability: The curriculum integrates sustainability principles to equip students with the knowledge and skills needed to address environmental challenges [16].
- Systems Thinking: Systems thinking is essential in understanding and solving complex environmental issues, making it a core component of green education [17].
- Critical Thinking: Critical thinking skills are fostered to enable students to analyze and evaluate environmental issues effectively [18].
- Participation and Empowerment: Green education encourages participation and empowerment, allowing students to actively engage in environmental conservation efforts [19].
- Sustainable Practices in architecture
- Sustainable practices in architecture refer to the design, construction, and operation of buildings and structures in a way that minimizes environmental impact, conserves natural resources, and enhances the quality of life for occupants.

These practices aim to create energy-efficient buildings, use resources wisely, and reduce waste and emissions. Key principles of sustainable architecture include:

- Integration of Green Building Practices: Using eco-friendly materials and energy-efficient systems to reduce environmental impact and operational costs [7].
- Use of Smart Technologies: Employing advanced sensors and automation to optimize energy consumption and enhance building performance [20].
- Energy Efficiency: Using design strategies and technologies like high-performance insulation and energy-efficient lighting to reduce energy consumption [9].
- Synergy of Traditional and Modern Practices: Combining traditional architectural wisdom with modern green technologies for a holistic sustainability approach [10].
- Self-Sustaining Building Design: Creating buildings that generate their own energy and manage water efficiently, reducing environmental impact [11].
- Water Conservation: Designing efficient water management systems and sustainable landscaping to minimize water usage [21].
- Waste Management: Implementing strategies to reduce waste during construction and operation, promoting recycling and sustainable materials [22].
- Use of Environmentally Friendly Materials: Utilizing renewable and non-toxic materials to reduce the environmental footprint [8].
- Policy Frameworks and Community Engagement: Creating regulations and involving stakeholders to support sustainable architectural practices [12].

Table 2. Analyze sustainable architecture research.

Ref.	Methods used	Limitations	Practical implications	Conclusions	Contributions
[23]	Examination of two modules: post-occupancy evaluations and computational simulation tools.	Potential challenges in the practical implementation of suggested methodologies in diverse educational.	Equips students with critical and analytical skills necessary to integrate sustainability in their designs.	Highlights the importance of experiential and interdisciplinary learning in fostering sustainable design skills.	Provides a framework for enhancing Architectural education by incorporating sustainability-focused modules.
[24]	Literature review, site investigations, and qualitative assessments.	Limited to specific case studies, which may not represent broader applicability.	Offers a comprehensive framework for evaluating the ecological quality of CEEs, aiding architects and policymakers.	Identifies key parameters for assessing CEEs, promoting ecological education through sustainable practices.	Develops an evaluation framework for CEEs, enhancing the integration of ecological principles in educational architecture.
[25]	Presentation of techniques used in the Architectural Ecology course, including green roofs and living walls.	Focused on specific architectural techniques which may need adaptation for broader educational contexts.	Enhances the aesthetic, psychological, and energy-efficient qualities of buildings, promoting green technologies and sustainable practices in urban environments.	Green architecture is emphasized as a key element for modern urban development, improving environmental and human well-being.	Provides practical techniques for integrating green architecture into education, contributing to more sustainable urban development.
[26]	Review of existing curricula and proposals for integrating green education components.	Limited by the scope of curricula examined and the variability in educational institutions.	Promotes the incorporation of green education in Architectural programs to enhance sustainability awareness.	Highlights the necessity of green education for addressing environmental challenges within architectural.	Proposes actionable steps for embedding green education into architectural curricula, contributing to sustainable development.
[27]	Prospective analysis based on the Sustainable Development Goals and Paris Agreement.	Proposal is forward-looking and speculative, relying on long-term projections.	Emphasizes the need for training architects to adopt sustainable lifestyles and practices, aiming for net-zero emission buildings.	Suggests an action plan to align architectural education with global sustainability goals.	Provides a visionary framework for future architectural education that align with international agreements.
[28]	Data collection via questionnaires, interviews, and analysis of learning activities and teaching methods.	Study limited to the context of a specific university program, which may not be generalizable.	Demonstrates the effectiveness of interdisciplinary contributions and practical applications in teaching sustainability.	Highlights the role of integrated design studios in developing holistic sustainable design thinking.	Provides evidence for the benefits of interdisciplinary, practical approaches in enhancing sustainability education.
[29]	Analytical survey of three Egyptian architectural programs and comparison with three international programs.	Focused on specific programs, which may limit generalizability to all educational institutions.	Highlights the need for enhancements in curricula, especially in design and planning courses, to better incorporate sustainability principles.	Although recent programs emphasize sustainability, there is a need for more practical application in the professional field.	Provides a comparative analysis highlighting the current and expected inclusion of sustainability concepts in architectural education.
[30]	Comprehensive literature review and analysis of different pedagogical approaches and case studies.	Limited by the variability in implementation across different educational institutions and regions.	Offers insights into effective teaching strategies and practical implementation methods for integrating sustainability in architectural education.	Emphasizes the importance of a coordinated interdisciplinary approach to teaching environmental sustainability in architecture programs.	Provides a detailed review of emerging trends and best practices in integrating environmental sustainability within architectural education.
[31]	Examination of environmental education theories and their application in architectural design.	Focused on a single institution, which may not represent broader applicability.	Highlights the need for activating advanced environmental design theories, such as biomimicry, to improve the environmental efficiency of buildings.	Identifies weaknesses in the current curriculum and recommends enhancements to incorporate advanced environmental education stages.	Provides a case study on the integration of environmental education in architectural departments, emphasizing the need for curriculum improvement.
[32]	Case study of the design course Ënvironmentally Friendly Housing architecture,ïncluding statistical summaries.	Focused on a specific course, which may limit generalizability to other educational contexts.	Introduces new design indicators related to sustainability, energy efficiency, and environmental impact in architectural education.	Highlights the effectiveness of incorporating the New European Bauhaus principles to achieve sustainability goals in architecture education.	Provides practical insights and methodologies for integrating the New European Bauhaus principles in architectural education, emphasizing sustainability.

2. Research concepts

The research is based on the following two points, which are the research gap and research methodology.

2.1 Research gap

The research gap lies in the need to bridge the disconnect between existing theoretical and practical studies on green education and their application in architectural practices. While there is a wealth of information on green education concepts, there is limited research focusing on how these concepts are specifically integrated into sustainable architectural practices and the trends influencing their application. Addressing this gap involves identifying how green education can be more effectively applied in architecture to enhance sustainability practices.

2.2 Research methodology

The methodology relies on analyzing the latest theoretical and practical studies that address the concept of green education to identify sustainable practices in architecture and discern trends in the application of these concepts of green education within the field Fig. 1.

i) Collect and analyse green education researches: Gather studies; identify strategies and methodologies.

ii) Collect and analyse sustainable architecture researches: Gather studies; identify tools and methods.

iii) Define key variables: Identify variables for integrating green education into architecture.

iv) Conduct comparative analysis: Compare studies to find gaps and trends.

v) Identify trends: Analyse trends in green education and relate to strategies.

Table 3. Overview of approaches and methodologies in sustainable.

Focus trend	Ref.	Methods used	Practical implications	Conclusions	Approaches
Energy efficiency	[33]	Life cycle assessment, energy modeling	Enhances urban housing with energy-efficient designs	Significant reduction in carbon emissions and energy use	Integrating Environmental Knowledge, Using Specialized Software, Simulation and Modeling
	[34]	Comparative analysis of passive and active technologies	Encourages the use of both passive and active energy-saving technologies in building designs	Effective combination of technologies can achieve substantial energy savings	Integrating Environmental Knowledge, Supporting Interdisciplinary Research, Case Studies
Use of smart technologies	[9]	AI-driven energy modeling, case studies	Optimizes building performance through AI and smart technologies	AI integration significantly enhances energy efficiency and operational sustainability	Using Specialized Software, Simulation and Modeling, Leveraging Technology-Based Education
	[7]	Review of green technologies, case studies	Adoption of advanced technologies in construction enhances sustainability	Green technologies are crucial for achieving low energy consumption and reducing environmental impacts	Case Studies, Supporting Interdisciplinary Research, Implementing Green Standards
Integration of green building	[35]	Field experiments, environmental impact assessments	Vertical greenery systems are effective in reducing urban heat island effects and enhancing biodiversity	Integration of greenery in urban areas contributes significantly to urban sustainability and livability	Environmental Project Assessment, Simulation and Modeling, Implementing Green Standards
	[36]	Lifecycle analysis, case studies	Focuses on sustainability across the entire building lifecycle from construction to maintenance	Sustainable practices at all stages of the building lifecycle significantly reduce environmental impacts	Case Studies, Integrating Environmental Knowledge, Supporting Interdisciplinary Research.
Self-Sustaining building design	[11]	Case studies, design modeling	Promotes the design of self-sustaining buildings that operate independently of external resources	Self-sustaining buildings are feasible and offer long-term sustainability solutions	Case Studies, Simulation and Modeling, Implementing Green Standards
	[37]	Analytical Hierarchy Process, multi-criteria decision analysis	Assists architects in evaluating and optimizing the performance of self-sustained houses	Analytical Hierarchy Process is an effective tool for decision-making in sustainable house design	Supporting Interdisciplinary Research, Case Studies, Simulation and Modeling
Water conservation techniques	[38]	Case studies, water management modeling	Integrates water conservation techniques in urban architectural design	Water management is crucial for sustainable urban development and disaster resilience	Environmental Project Assessment, Case Studies, Simulation and Modeling
	[39]	Survey analysis, statistical modeling	Provides insights into farmers' perceptions of water conservation practices	Socio-demographic factors and cost-benefit perceptions significantly influence water conservation practices	Educational Content, Environmental Awareness Workshops, Survey Analysis.
Waste management in construction	[40]	Policy analysis, case studies	Encourages the adoption of policies that optimize waste management in construction	Effective policy frameworks are essential for reducing construction waste and enhancing sustainability	Case Studies, Implementing Green Standards, Policy Development
	[41]	Literature review, case studies	Focuses on the importance of managing end-of-life waste in construction	Effective end-of-life waste management is critical for the sustainability of construction	Case Studies, Policy Analysis, Circular Economy Principles
Green building materials	[8]	Material analysis, environmental impact assessment	Promotes the use of renewable building materials to reduce environmental impact and enhance sustainability	Green building materials significantly contribute to reducing the environmental footprint of construction practices	Environmental Project Assessment, Integrating Environmental Knowledge, Implementing Green Standards
	[42]	Case studies, material analysis	Highlights the potential of using transparent sustainable materials in smart architecture	Transparent sustainable materials offer new possibilities for energy efficiency and aesthetic design in architecture	Case Studies, Supporting Interdisciplinary Research, Implementing Green Standards
Community engaged education	[12]	Educational case studies, community engagement strategies	Integrates community health and sustainability in architectural education	Community-engaged architectural education can lead to healthier and more sustainable living environments	Project-Based Learning, Community Engagement, Educational Content
	[43]	Community engagement analysis	Enhances community participation in blue-green infrastructure projects	Community engagement is critical for the successful implementation of sustainable urban infrastructure	Community Engagement, Implementing Green Standards, Policy Development
Synergy of traditional and modern practices	[10]	Case studies, comparative analysis	Combines traditional and modern practices to achieve holistic sustainability in architecture	The integration of traditional and modern practices enhances sustainability and preserves cultural heritage	Case Studies, Integrating Environmental Knowledge, Supporting Interdisciplinary Research
	[44]	Field surveys, historical analysis	Shows the potential of traditional Igala architecture to inform contemporary sustainable practices	Traditional building practices offer valuable insights for sustainable architecture in modern contexts	Community Engagement, Environmental Project Assessment, Case Studies

3. Practical section

This section consists of these three stages: i) Green education research; ii) Framework for green education in architecture; iii) Framework for green education in architecture.

3.1 Green education researches

Ten studies were selected based on their focus on applying green education concepts to sustainable architecture. The criteria for selection were that the studies had to include defined methodologies and approaches, cover both theoretical

and practical aspects, and be published in recent years Table 1.

3.2 Framework for green education in architecture

The framework for Green Education in architecture embodies a systematic approach to incorporating sustainability principles into architectural education. These strategies are grounded in insights from prior research on the application of green education within the field of architecture. They function as strategic, methodological tools and frameworks through which the principles of green education are effectively integrated into the architectural curriculum as listed in Table 2.

3.3 Framework for green education in architecture

Several studies focused on sustainable practices in architecture within contemporary trends were identified and analyzed to determine the methodologies, strategies, and approaches used to implement sustainable architecture in these practices. The Table 3 provides a summarized overview of various research efforts, highlighting key approaches.

4. Results and discussions

The findings of this study provide significant insights into the alignment between educational strategies and sustainability trends within architectural education. In addition, Fig. 11 illustrates the overall correlation between these strategies and their practical methods of application within green architectural education. Each sustainability trend is supported by specific strategies, indicating a targeted approach in fostering sustainable practices in the next generation. Figure 2 up to Fig. 10 provide the overview of how key educational strategies are distributed across the nine main trends in green architectural education.

4.1 Key green education trends

4.1.1 Green building

As illustrated in Fig. 2, the integration of green building practices is supported by curriculum and content development and project-based learning strategies. The integration of green building practices is supported by curriculum and content development and project-based learning strategies. The use of environmental knowledge integration and case studies ensures that students gain both theoretical and practical understanding, while project-based learning and community engagement offer hands-on experience as illustrated in Fig. 3, smart technologies are emphasized through the Technology and Tools strategy in real-world projects.

4.1.2 Energy efficiency

As shown in Fig. 4, the energy efficiency is supported by curriculum and content development, technology, and tools strategies. Simulation and modelling tools are vital for optimizing energy performance, and Interdisciplinary Research further enhances students' ability to implement energy-efficient designs.

4.1.3 Curriculum

According to Fig. 5, the synergy of traditional and modern practices is reinforced by curriculum and content development, research, and innovation strategies. The use of Case Studies demonstrates successful integrations of traditional and modern practices, while Interdisciplinary Research explores the potential of these synergies in contemporary design.

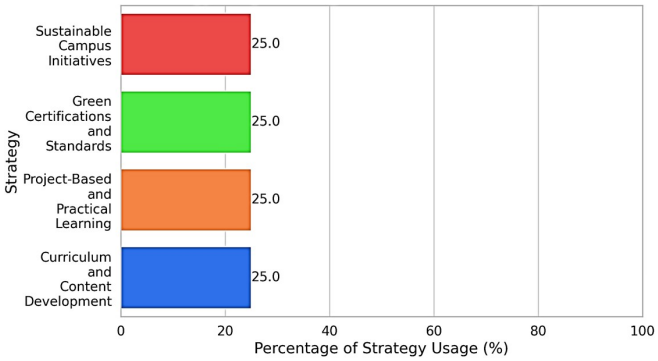

Figure 2. Strategy usage in integration of green building practices.

4.1.4 Smart technologies

Smart technologies are emphasized through the technology and tools strategy, particularly the use of Specialized Software and Simulation and modelling tools. Research and innovation also plays a key role, encouraging students to explore new applications of smart technologies in sustainable design.

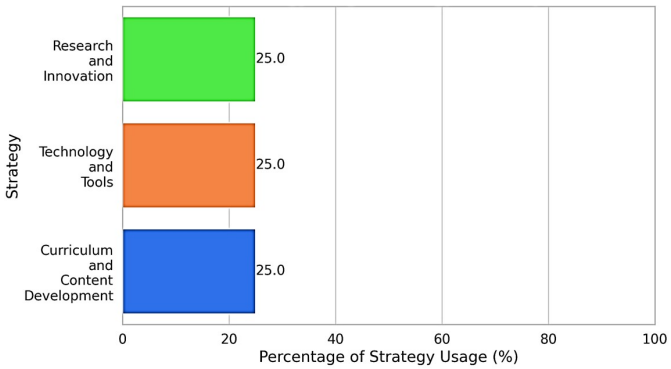

Figure 3. Strategy usage in energy efficiency.

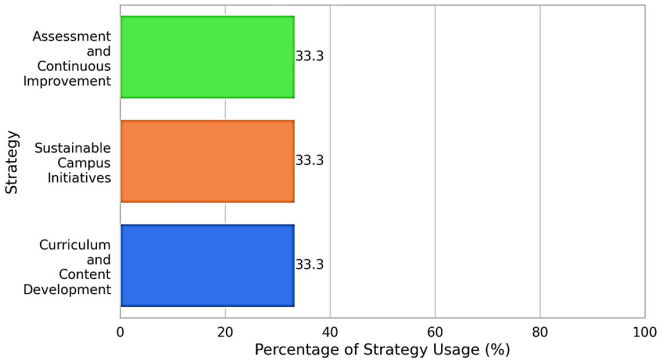

Figure 4. Strategy usage in water conservation.

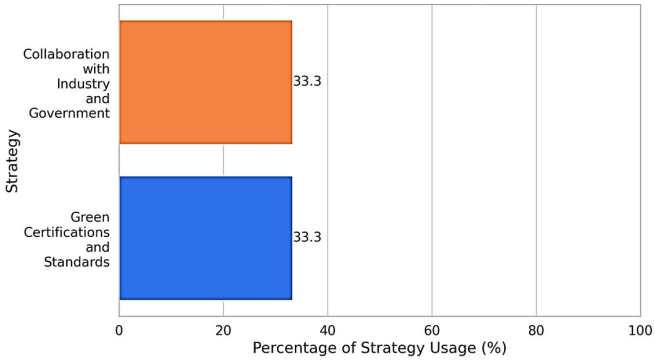

Figure 5. Strategy usage in waste management.

4.1.5 Sustaining building

As shown in Fig. 6, self-sustaining building design is emphasized through project-based learning and technology and tools strategies. Simulation and modelling and design modeling tools are essential for evaluating the viability of self-sustaining systems, preparing students to contribute to long-term sustainability goals.

4.1.6 Water conservation

As depicted in Fig. 7, water Conservation is supported by Curriculum and Content Development and Sustainable Campus Initiatives. Case Studies and Student Sustainability Projects provide students with both theoretical knowledge and practical experience, while Sustainability Assessment ensures continuous improvement.

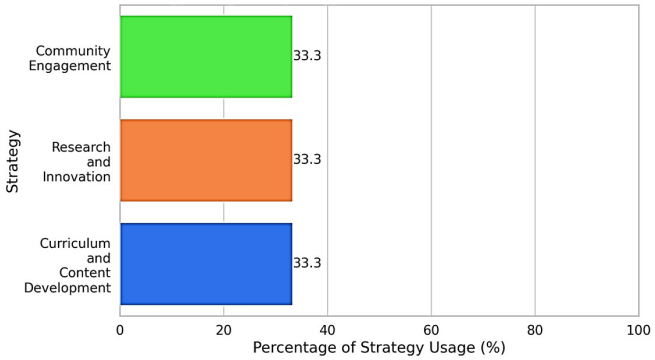

Figure 6. Strategy usage in synergy of traditional and modern practices.

4.1.7 Waste Management

In Fig. 8, waste Management is addressed through Green Certifications and Standards and Collaboration with Industry and Government strategies. The focus on Implementing Green Standards and Policy Engagement equips students with the skills needed to design buildings that minimize waste.

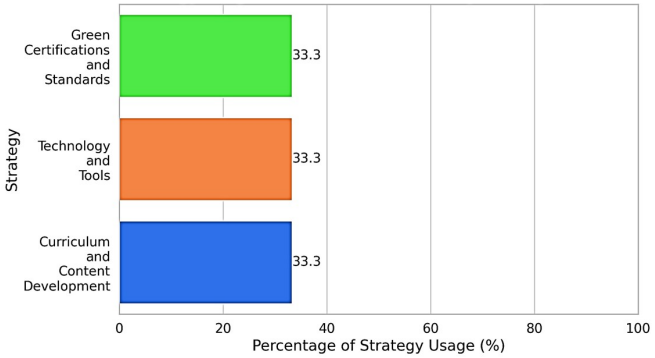

Figure 7. Strategy usage in the use of environmentally friendly materials.

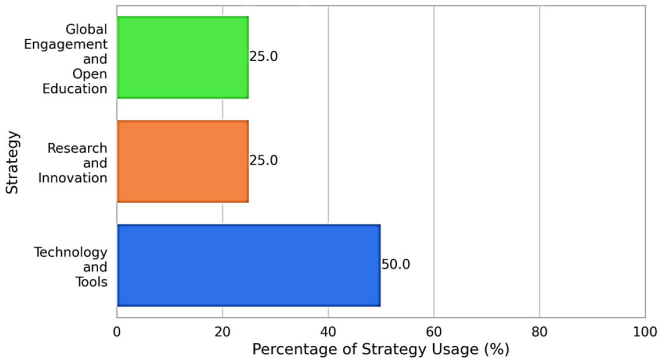

Figure 8. Strategy usage in the use of smart technologies.

4.1.8 Friendly materials

Figure 9 use of environmentally friendly materials is supported by curriculum and content development, and technology and tools strategies, particularly through Material analysis and environmental impact assessment. These approaches ensure that students are well-versed in selecting sustainable materials.

4.1.9 Policy frameworks

Figure 10 presents the policy frameworks and community engagement are crucial for the adoption of sustainable practices, supported by global engagement and open education and collaboration with industry and government strategies. Community engagement and policy development equip students to navigate and influence sustainability policies effectively.

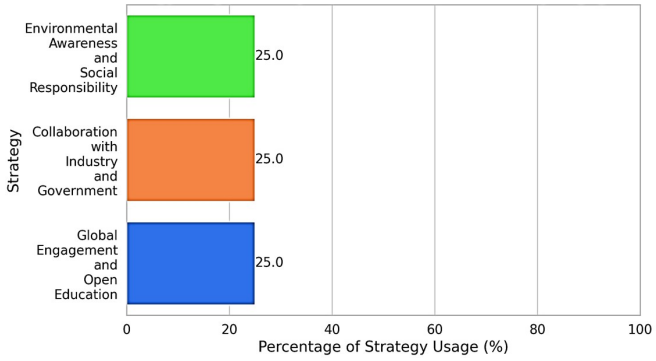

Figure 9. Strategy usage in policy frameworks and community engagement.

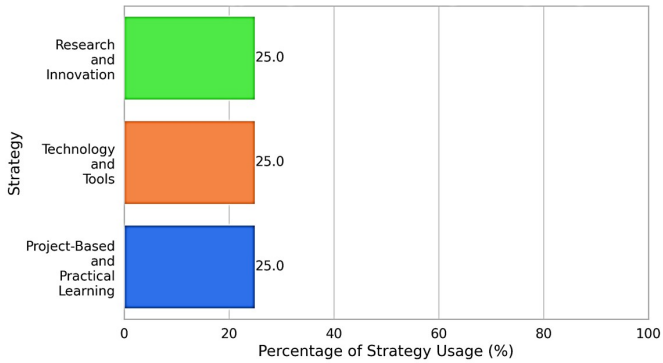

Figure 10. Strategy usage in self-sustaining building design.

4.2 The findings

The findings of this study underscore the importance of a multifaceted approach to architectural education in fostering long-term sustainability. As the built environment continues to evolve in response to growing environmental challenges, the role of education in shaping the architects of tomorrow becomes increasingly critical.

4.3 Strategies

One of the key strengths of the strategies identified in this study is their holistic integration of sustainability across multiple dimensions of architectural education. By incorporating sustainability into the curriculum, practical learning experiences, and research initiatives, educators are ensuring that students not only understand the importance of sustainability but also develop the skills needed to apply these principles in practice. This approach moves beyond the traditional siloed teaching of environmental issues, fostering a more interconnected understanding of how sustainability interacts with various aspects of architectural design, technology, and policy.

4.4 Innovation

The emphasis on technology and innovation within the identified strategies reflects the growing importance of these elements in driving sustainable architectural practices. Advanced tools such as simulation software, VR/AR technologies, and data-driven modeling are not only enhancing the precision and efficiency of sustainable design but also enabling architects to explore new possibilities in terms of materials, energy systems, and building performance.

4.5 Collaboration

Another significant finding is the emphasis on collaboration and interdisciplinary approaches. Sustainability is a complex, multifaceted issue that requires input from a range of disciplines, including engineering, environmental science, social sciences, and policy studies. The strategies highlighted in this study, particularly those focused on research and innovation, emphasize the importance of interdisciplinary collaboration in developing effective sustainable solutions.

4.6 Sustainability

Sustainability is a dynamic field, with new challenges and solutions emerging constantly. The emphasis on continuous improvement and adaptation within the educational strategies identified in this study is crucial for ensuring that architectural practices remain relevant and effective in the face of

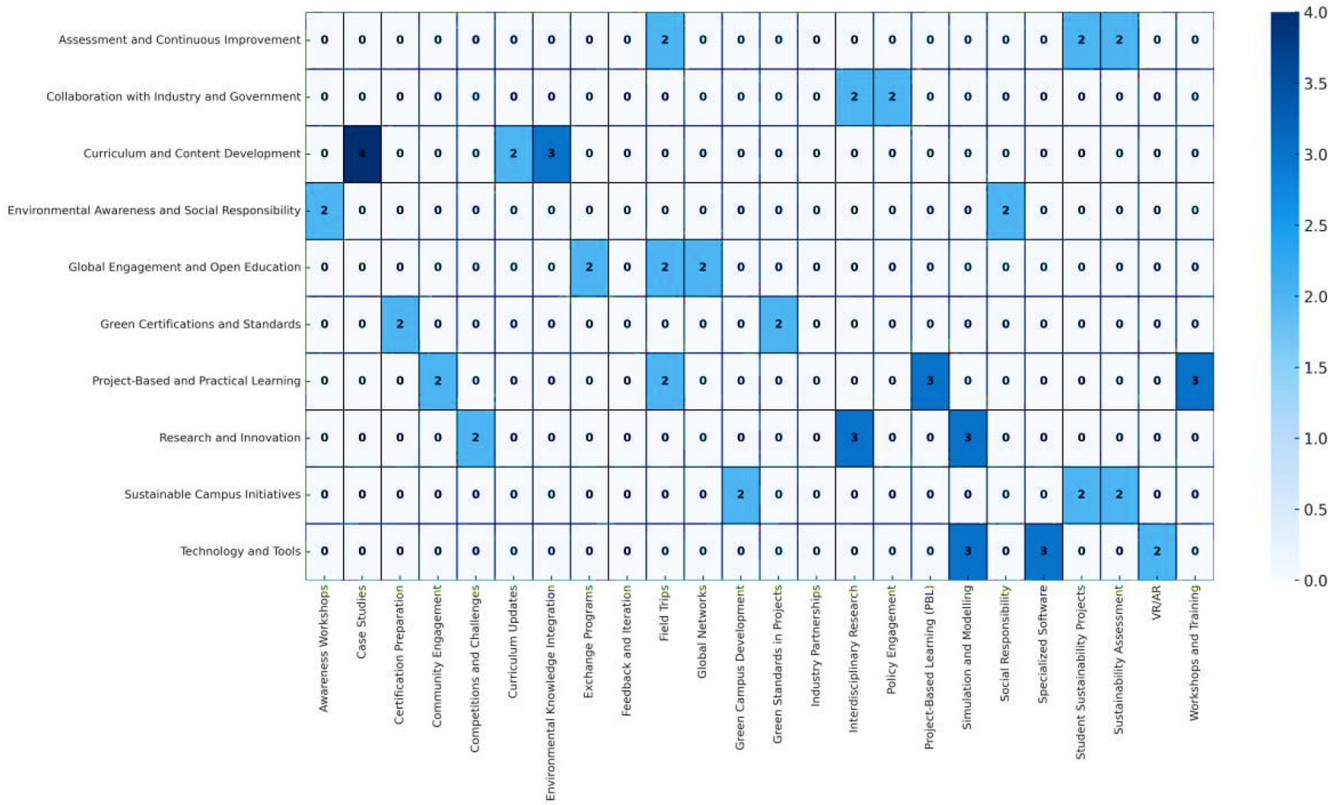

Figure 11**.** Correlation between strategies and methods of applying green education in architecture .

changing environmental conditions. The use of assessment tools and feedback mechanisms helps to create a culture of continuous learning and refinement, enabling students to adapt their designs and approaches as new information and technologies become available.

5. Conclusion

This study underscores the critical role of green education in advancing sustainable architectural practices, highlighting the strategic integration of sustainability principles into architectural education. Through a comprehensive analysis of existing curricula and research, the study identifies key strategies that effectively prepare future architects to address environmental challenges and contribute to a more sustainable built environment. The research identifies nine main sustainability trends in architectural education: Integration of Green Building Practices, Use of Smart Technologies, Energy Efficiency, Synergy of Traditional and Modern Practices, Self-Sustaining Building Design, Water Conservation, Waste Management, Use of Environmentally Friendly Materials, and Policy Frameworks and Community Engagement. Each of these trends is supported by specific tools, methods, and strategies that are crucial for their application in green architecture. The use of specialized software, simulation and modeling tools, project-based learning, and interdisciplinary research are among the key methods identified as essential for embedding these sustainability trends into architectural education. The findings reveal that a multifaceted approach, which includes curriculum development, project-based learning, the use of advanced technologies, and interdisciplinary research, is essential for embedding sustainability into architectural education. These strategies not only equip students with the theoretical knowledge needed to understand sustainability but also provide them with practical skills and experiences to apply these principles in real-world scenarios. The primary contribution of this study lies in its comprehensive identification and analysis of the key trends and strategies necessary for integrating green education into architectural curricula. By defining specific tools, methods, and approaches that support the application of sustainability principles in architecture, this research provides a clear framework for educators and policymakers to follow. Furthermore, the study contributes to the existing literature by bridging the gap between theoretical concepts of green education and their practical implementation in architectural practices. This work lays the groundwork for future research and educational development, ensuring that the next generation of architects is well-equipped to address the pressing environmental challenges of our time. The integration of green education into architectural curricula is crucial for fostering a sustainable future. By equipping students with the tools, knowledge, and values needed to address complex environmental issues, architectural education can play a pivotal role in shaping a resilient, energy-efficient, and environmentally responsible built environment. Future research should continue to explore and refine these educational strategies, ensuring that they evolve in tandem with the changing demands of sustainability in architecture.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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