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Interdisciplinary Collaboration in Sustainable Interior Architecture Education in the 4IR Era: A Grounded Theory Approach

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Abstract: The Fourth Industrial Revolution (4IR) has significantly transformed higher education by redefining pedagogical practices, technological integration, and skill requirements. In interior architecture education, the increasing emphasis on sustainability further necessitates interdisciplinary collaboration to address complex environmental and social challenges. This study develops a grounded theoretical framework to explain how interdisciplinary collaboration operates within sustainable interior architecture education in the 4IR era. Using a qualitative research design based on secondary data and a constructivist grounded theory approach, the study analyses existing literature on sustainability, interdisciplinary learning, and Education 4.0. The findings reveal that interdisciplinary collaboration is a dynamic and iterative process shaped by three core dimensions: pedagogical integration, technological mediation, and sustainability-oriented competencies. While digital technologies such as Building Information Modelling and virtual platforms enhance collaboration, institutional constraints, disciplinary silos, and uneven digital literacy remain significant barriers. The study proposes a conceptual model that integrates constructivist learning, systems thinking, and Education 4.0, offering insights for curriculum development and pedagogical innovation. The research contributes to advancing sustainable design education by providing a theoretically grounded understanding of interdisciplinary collaboration in the 4IR context.

Keywords: interdisciplinary collaboration; sustainable interior architecture; fourth industrial revolution (4ir); education 4.0; grounded theory; design education; sustainability competencies

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1. Introduction

The emergence of the Fourth Industrial Revolution (4IR) has fundamentally reshaped the structure and purpose of higher education across the globe. Characterised by the convergence of digital technologies, artificial intelligence (AI), the Internet of Things (IoT), and cyber-physical systems, the 4IR has accelerated the transformation of knowledge production, professional practices, and educational delivery systems (Schwab, 2017). In this rapidly evolving context, universities are increasingly expected to prepare graduates who can navigate complex, interdisciplinary challenges while integrating technological innovation with sustainable development goals.

Interior architecture education, as a hybrid discipline combining elements of architecture, design, environmental psychology, engineering, and material science, is particularly sensitive to these transformations. Traditionally grounded in studio-based pedagogy, interior architecture education has emphasised creativity, spatial thinking, and aesthetic expression. However, the growing urgency of environmental sustainability and the disruptive influence of 4IR technologies have expanded the scope of the discipline, requiring new competencies such as systems thinking, digital fluency, and interdisciplinary collaboration (Demirkan & Afacan, 2018).

Sustainability has emerged as a central paradigm within design education, driven by global concerns about climate change,

resource depletion, and environmental degradation. The built environment is responsible for a significant proportion of global energy consumption and carbon emissions, making sustainable design practices essential for mitigating environmental impact (United Nations Environment Programme [UNEP], 2020). In interior architecture, sustainability encompasses not only energy-efficient design but also the selection of eco-friendly materials, improvement of indoor environmental quality, and consideration of the lifecycle impacts of design interventions (Rashdan & Ashour, 2024).

Despite the increasing emphasis on sustainability, traditional educational models often struggle to address the complexity of sustainable design challenges. These challenges are inherently interdisciplinary, requiring the integration of knowledge from multiple domains, including environmental science, engineering, sociology, and digital technology. However, higher education institutions frequently operate within disciplinary silos, limiting opportunities for students to engage in meaningful interdisciplinary learning (Sørensen & Stenalt, 2025). This fragmentation hinders the development of holistic problem-solving skills necessary for addressing sustainability issues in the 4IR era.

Interdisciplinary collaboration has been widely recognised as a critical pedagogical approach for overcoming these limitations. It involves the integration of diverse disciplinary perspectives to generate innovative solutions to complex problems (Repko & Szostak, 2021). In the context of

interior architecture education, interdisciplinary collaboration enables students to engage with real-world design challenges, collaborate with professionals from different fields, and develop a comprehensive understanding of sustainability.

The integration of 4IR technologies further enhances the potential for interdisciplinary collaboration. Digital tools such as Building Information Modelling (BIM), virtual reality (VR), augmented reality (AR), and AI-driven design platforms facilitate collaborative design processes, enabling students to work across geographical and disciplinary boundaries (Miranda et al., 2021). These technologies not only support collaborative learning but also transform the way design knowledge is created, shared, and applied.

However, the adoption of interdisciplinary collaboration in sustainable interior architecture education is not without challenges. Institutional barriers, including rigid curricula, lack of coordination among departments, and limited resources, often impede the implementation of interdisciplinary approaches (Nasir & Kamal, 2024). Additionally, differences in disciplinary epistemologies and communication styles can create obstacles to effective collaboration.

Given these complexities, there is a need for a deeper understanding of how interdisciplinary collaboration operates within the context of sustainable interior architecture education in the 4IR era. While existing studies highlight the importance of interdisciplinary approaches and sustainability, there is a lack of grounded

theoretical frameworks that explain the processes, interactions, and outcomes of interdisciplinary collaboration in this field.

This study addresses this gap by employing a grounded theory approach based on qualitative secondary data. By analysing existing literature, the research aims to develop a conceptual framework that captures the dynamic interplay between pedagogy, technology, and sustainability in interdisciplinary collaboration. The study seeks to answer the following research questions:

- How is interdisciplinary collaboration conceptualised in sustainable interior architecture education?
- What role do 4IR technologies play in facilitating interdisciplinary learning?
- What are the key challenges and opportunities associated with interdisciplinary collaboration in this context?

By answering these questions, the study contributes to the advancement of design education by providing insights into how interdisciplinary collaboration can be effectively integrated into sustainable interior architecture curricula. Ultimately, the research aims to support the development of future-ready graduates who are equipped to address the complex challenges of the 21st century.

2. Literature Review

Sustainability has become a foundational principle in contemporary design education, reflecting the increasing urgency of

addressing global environmental challenges. In the context of interior architecture, sustainability extends beyond aesthetic considerations to encompass environmental performance, resource efficiency, and human well-being (Demirkan & Afacan, 2018). The integration of sustainability into interior design education is driven by the need to prepare students to create built environments that are both environmentally responsible and socially responsive.

Scholars have emphasised that sustainable interior architecture involves a holistic approach to design, incorporating factors such as energy efficiency, material selection, indoor environmental quality, and lifecycle assessment (Rashdan & Ashour, 2024). This approach requires students to develop a comprehensive understanding of the environmental impact of their design decisions, as well as the ability to balance competing priorities such as functionality, aesthetics, and sustainability.

Educational strategies for integrating sustainability into design curricula include project-based learning, experiential learning, and the use of real-world case studies. These approaches enable students to engage with complex sustainability challenges and develop practical skills for addressing them (Ibrahim & Nasreldin, 2025). For example, the incorporation of biomimicry and eco-materials into design projects has been shown to enhance students' creativity and promote sustainable thinking.

Despite these advancements, several challenges remain. One major issue is the lack of standardised frameworks for assessing sustainability in interior design

education. This makes it difficult to evaluate the effectiveness of sustainability initiatives and to ensure consistency across educational programs (Rashdan & Ashour, 2024). Additionally, there is often a gap between theoretical knowledge and practical application, with students struggling to translate sustainability concepts into design solutions.

2.1 Interdisciplinary Collaboration in Higher Education

Interdisciplinary collaboration is widely regarded as essential for addressing complex, real-world problems that cannot be solved within the boundaries of a single discipline. It involves the integration of knowledge, methods, and perspectives from multiple disciplines to generate new insights and solutions (Repko & Szostak, 2021).

In higher education, interdisciplinary collaboration is increasingly promoted as a means of enhancing student learning and fostering innovation. It encourages students to think critically, communicate effectively, and work collaboratively with individuals from diverse backgrounds. These skills are particularly important in the context of sustainability, where challenges are multifaceted and require holistic approaches (Sørensen & Stenalt, 2025).

In design education, interdisciplinary collaboration often takes the form of studio-based projects that involve students from different disciplines working together on shared design challenges. These projects provide opportunities for students to learn from each other, integrate diverse perspectives, and develop innovative

solutions. For example, collaborations between interior design students and engineering students can lead to more technically feasible and environmentally sustainable design outcomes.

However, implementing interdisciplinary collaboration in higher education is not without challenges. Institutional structures, such as departmental boundaries and rigid curricula, can hinder collaboration. Additionally, differences in disciplinary languages, methodologies, and epistemologies can create communication barriers and misunderstandings (Nasir & Kamal, 2024).

To overcome these challenges, scholars have proposed various strategies, including curriculum integration, faculty collaboration, and the use of digital technologies to facilitate communication and coordination. These strategies aim to create supportive environments for interdisciplinary learning and to enhance the effectiveness of collaborative projects.

2.2 The Role of 4IR in Educational Transformation

The Fourth Industrial Revolution has introduced new technologies and pedagogical approaches that are transforming higher education. Education 4.0, a concept associated with the 4IR, emphasises the integration of digital technologies, personalised learning, and interdisciplinary approaches (Miranda et al., 2021).

Technologies such as AI, VR, AR, and BIM are increasingly being used in design education to enhance learning experiences and support collaboration. These tools enable

students to visualise complex design concepts, simulate real-world scenarios, and collaborate with peers and professionals across different locations.

For example, VR and AR technologies allow students to experience and interact with virtual environments, providing immersive learning experiences that enhance spatial understanding. Similarly, BIM enables collaborative design processes by allowing multiple stakeholders to work on a shared digital model.

The 4IR also promotes the development of new competencies, including digital literacy, critical thinking, and adaptability. These competencies are essential for navigating the rapidly changing professional landscape and for addressing complex challenges such as sustainability (Schwab, 2017).

However, the integration of 4IR technologies into education also presents challenges. These include issues related to access, digital divide, and the need for faculty training. Additionally, there is a risk that technology may be used as a substitute for, rather than a complement to, effective pedagogy.

2.3 Integration of Sustainability, Interdisciplinarity, and 4IR

The intersection of sustainability, interdisciplinary collaboration, and 4IR technologies represents a critical area of development in interior architecture education. These three elements are interconnected and mutually reinforcing.

Sustainability challenges require interdisciplinary approaches, as they involve environmental, social, and economic

dimensions. Interdisciplinary collaboration, in turn, is facilitated by 4IR technologies, which enable communication, coordination, and knowledge sharing across disciplines.

Recent studies have highlighted the potential of integrating these elements to enhance design education. For example, the use of digital platforms for collaborative design projects can support interdisciplinary learning while addressing sustainability challenges. Similarly, the incorporation of systems thinking into design curricula can help students understand the complex interactions between different elements of the built environment.

Despite these opportunities, there is still a lack of comprehensive frameworks that integrate sustainability, interdisciplinarity, and 4IR coherently. Most studies focus on individual aspects rather than examining their interactions and combined impact.

2.4 Research Gap

The literature reveals several gaps that this study seeks to address:

- Lack of grounded theoretical models explaining interdisciplinary collaboration in interior architecture education.
- Limited integration of sustainability, interdisciplinarity, and 4IR in existing frameworks.
- Insufficient focus on qualitative insights derived from secondary data.

By addressing these gaps, this study contributes to the development of a comprehensive theoretical framework for

interdisciplinary collaboration in sustainable interior architecture education.

3. Theoretical Framework

This study is grounded in an integrative theoretical framework that combines constructivist learning theory, systems thinking, and the Education 4.0 paradigm. These theoretical perspectives collectively provide a foundation for understanding how interdisciplinary collaboration operates within sustainable interior architecture education in the context of the Fourth Industrial Revolution (4IR).

3.1 Constructivist Learning Theory

Constructivist learning theory posits that knowledge is actively constructed by learners through experience, interaction, and reflection rather than passively received from instructors (Piaget, 1972; Vygotsky, 1978). In design education, constructivism is particularly relevant because learning often occurs through studio-based practices, where students engage in problem-solving, experimentation, and iterative design processes (Schön, 1983).

Interdisciplinary collaboration aligns closely with constructivist principles, as it requires learners to integrate diverse perspectives and co-construct knowledge through dialogue and shared experiences. In sustainable interior architecture education, students must synthesise knowledge from multiple domains, such as environmental science, materials engineering, and social sciences, to develop holistic design solutions. This process fosters deeper learning by encouraging critical thinking, creativity, and

reflective practice (Demirkan & Afacan, 2018).

Moreover, constructivism emphasises the importance of social interaction in learning. Collaborative learning environments enable students to negotiate meaning, challenge assumptions, and develop shared understandings. This is particularly important in interdisciplinary contexts, where differences in disciplinary knowledge and perspectives can lead to richer learning outcomes (Repko & Szostak, 2021).

3.2 Systems Thinking

Systems thinking provides a critical lens for understanding the complexity of sustainability challenges in interior architecture. It emphasises the interconnectedness of components within a system and the need to consider relationships, feedback loops, and emergent properties (Meadows, 2008).

In the context of sustainable design, systems thinking enables students to analyse the environmental, social, and economic impacts of their design decisions. For example, the selection of materials not only affects the aesthetic quality of a space but also has implications for resource consumption, indoor air quality, and lifecycle sustainability. By adopting a systems perspective, students can better understand these interdependencies and develop more sustainable design solutions (Rashdan & Ashour, 2024).

Interdisciplinary collaboration is essential for implementing systems thinking in education. Since no single discipline can fully address the complexity of sustainability issues,

collaboration across disciplines allows for the integration of diverse knowledge systems. This integration supports a more comprehensive understanding of the built environment and enhances the capacity for innovative problem-solving (Sørensen & Stenalt, 2025).

Furthermore, systems thinking aligns with the goals of Education for Sustainable Development (ESD), which emphasises holistic and integrative approaches to learning. By incorporating systems thinking into interior architecture education, educators can foster sustainability competencies such as critical thinking, systems analysis, and ethical decision-making (UNESCO, 2024).

3.3 Education 4.0 Framework

The Education 4.0 framework emerges from the broader context of the 4IR and reflects the transformation of education in response to technological advancements. It emphasises the integration of digital technologies, personalised learning, and interdisciplinary approaches to education (Miranda et al., 2021).

In interior architecture education, 4IR technologies such as Building Information Modelling (BIM), virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) are increasingly being used to enhance learning and collaboration. These technologies enable students to visualise complex design concepts, simulate real-world scenarios, and collaborate across geographical and disciplinary boundaries (Schwab, 2017).

Education 4.0 also promotes the development of key competencies required in the 21st

century, including digital literacy, adaptability, innovation, and collaboration. These competencies are essential for addressing the complex challenges associated with sustainability and for navigating the rapidly changing professional landscape (Miranda et al., 2021).

Importantly, the Education 4.0 framework supports interdisciplinary collaboration by providing digital platforms and tools that facilitate communication and knowledge sharing. For example, collaborative design software allows students from different disciplines to work together on shared projects, enabling real-time interaction and feedback.

3.4 Integration of Theoretical Perspectives

The integration of constructivist learning theory, systems thinking, and Education 4.0 provides a comprehensive framework for understanding interdisciplinary collaboration in sustainable interior architecture education.

- **Constructivism** explains how students learn through interaction and collaboration.
- **Systems thinking** provides a lens for understanding the complexity of sustainability challenges.
- **Education 4.0** highlights the role of technology in facilitating collaboration and transforming learning environments.

Together, these perspectives suggest that interdisciplinary collaboration is a dynamic and iterative process shaped by pedagogical

practices, technological tools, and sustainability goals.

3.5 Conceptual Framework

Based on the integration of these theories, this study proposes a conceptual framework consisting of three interconnected components:

- **Pedagogical Integration** – Studio-based learning, project-based approaches, and collaborative teaching methods.
- **Technological Mediation** – Use of digital tools and platforms to support collaboration.
- **Sustainability Competencies** – Development of skills such as systems thinking, ethical decision-making, and environmental awareness.

These components interact to create a learning environment that supports interdisciplinary collaboration in sustainable interior architecture education.

4. Methodology

This study adopts a qualitative research design using a grounded theory approach to explore interdisciplinary collaboration in sustainable interior architecture education. Grounded theory is particularly suitable for this study because it allows for the development of a theoretical framework grounded in empirical data rather than relying solely on pre-existing theories (Glaser & Strauss, 1967; Charmaz, 2014).

The study employs a constructivist grounded theory approach, which recognises that

knowledge is co-constructed by researchers and participants (or data sources) and emphasises reflexivity and interpretation (Charmaz, 2014). This approach aligns with the study's focus on understanding complex social processes within educational contexts.

4.1 Data Source and Sampling

The research is based on qualitative secondary data, including:

- Peer-reviewed journal articles
- Systematic literature reviews
- Case studies
- Policy documents and educational frameworks

A **purposive sampling strategy** was used to select relevant literature. The inclusion criteria were:

- Studies related to interior architecture or design education
- Research focusing on sustainability or interdisciplinary collaboration
- Publications addressing 4IR or Education 4.0
- Articles published in reputable academic journals

This approach ensures that the data are rich, relevant, and aligned with the research objectives (Johnston, 2017).

4.2 Data Collection Procedure

Data were collected through a systematic review of academic databases such as Scopus, Web of Science, and Google Scholar. Keywords used in the search included:

- “sustainable interior architecture education”

- “interdisciplinary collaboration in design education”
- “Education 4.0 and architecture”
- “grounded theory in education research”

The selected articles were carefully reviewed and organised using thematic categorisation. Relevant sections of the texts were extracted for coding and analysis.

4.3 Data Analysis

The data analysis followed the three stages of grounded theory:

Open Coding: In the first stage, the data were broken down into discrete concepts and categories. Key themes such as “collaborative learning,” “digital tools,” and “sustainability competencies” were identified.

Axial Coding: In the second stage, relationships between categories were explored. For example, connections between technological tools and collaborative learning processes were identified.

Selective Coding: In the final stage, the core category, interdisciplinary collaboration, was identified and integrated with other categories to develop a coherent theoretical framework.

This iterative process allowed for the emergence of a grounded theory that explains the dynamics of interdisciplinary collaboration in the context of sustainable interior architecture education (Corbin & Strauss, 2015).

4.4 Trustworthiness and Rigour

To ensure the credibility and rigour of the study, several strategies were employed:

- **Triangulation:** Multiple data sources were used to validate findings.
- **Reflexivity:** The researcher maintained awareness of potential biases.
- **Audit trail:** Documentation of the research process was maintained.
- **Theoretical saturation:** Data collection continued until no new themes emerged (Charmaz, 2014).

These measures enhance the reliability and validity of the findings.

4.5 Ethical Considerations

Since the study relies on secondary data, no direct human participation was involved. However, ethical considerations were maintained by:

- Properly citing all sources
- Avoiding plagiarism
- Ensuring accurate representation of original findings (Mannan & Farhana, 2026)

4.6 Limitations

The study has several limitations:

- Reliance on secondary data may limit the depth of insights.
- The findings may not be generalizable to all educational contexts.
- Potential bias in the selection and interpretation of literature.

Despite these limitations, the study provides valuable theoretical insights into interdisciplinary collaboration.

5. Findings and Analysis

The grounded theory analysis of qualitative secondary data generated a comprehensive understanding of how interdisciplinary collaboration functions within sustainable interior architecture education in the context of the Fourth Industrial Revolution (4IR). Through systematic coding (open, axial, and selective), several key categories and subcategories emerged. These categories collectively form a dynamic framework explaining the processes, drivers, and constraints of interdisciplinary collaboration.

5.1 Core Category:

Interdisciplinary Collaboration as a Dynamic Process

The central phenomenon identified in this study is interdisciplinary collaboration as a dynamic, iterative, and context-dependent process. Rather than being a static pedagogical strategy, collaboration evolves through continuous interaction among students, educators, technologies, and institutional structures.

This finding aligns with constructivist perspectives, which emphasise learning as an active, socially mediated process (Vygotsky, 1978). In the context of interior architecture education, collaboration occurs primarily through studio-based environments, where students engage in iterative design processes, critique sessions, and group projects (Schön, 1983).

The analysis reveals that interdisciplinary collaboration is shaped by three interrelated dimensions:

- Pedagogical Integration
- Technological Mediation
- Sustainability-Oriented Competencies

These dimensions operate simultaneously and influence each other in complex ways.

5.2 Pedagogical Integration

5.2.1 Studio-Based Learning as a Collaborative Hub

Studio-based pedagogy emerged as a central mechanism for facilitating interdisciplinary collaboration. Design studios provide a flexible and interactive environment where students can experiment with ideas, engage in peer learning, and integrate knowledge from multiple disciplines.

The findings indicate that studio environments encourage:

- Collaborative problem-solving
- Iterative design thinking
- Reflective learning

These characteristics align with the concept of the “reflective practitioner” (Schön, 1983), where students learn through action and reflection. When interdisciplinary elements are incorporated into studio projects, such as collaboration with engineering or environmental science students, the learning experience becomes more holistic and contextually relevant.

5.2.2 Project-Based and Experiential Learning

Project-based learning (PBL) plays a crucial role in fostering interdisciplinary collaboration. The analysis shows that real-world design projects, particularly those focused on sustainability, require students to integrate diverse knowledge domains.

For example, a sustainable interior design project may involve:

- Material analysis (engineering perspective)
- Energy efficiency (environmental science perspective)
- User behaviour (social science perspective)

This integration enhances students’ ability to address complex challenges and develop innovative solutions. Experiential learning further reinforces this process by allowing students to engage directly with real-world contexts (Kolb, 1984).

5.2.3 Curriculum Design and Integration Challenges

Despite the benefits of interdisciplinary pedagogy, the findings highlight significant challenges in curriculum design. Many educational institutions maintain rigid disciplinary boundaries, limiting opportunities for cross-disciplinary collaboration (Nasir & Kamal, 2024).

Key issues include:

- Lack of coordination between departments
- Limited interdisciplinary course offerings

- Time constraints within academic programs

These barriers often result in fragmented learning experiences, where interdisciplinary collaboration is treated as an optional rather than an integral component of the curriculum.

5.3 Technological Mediation

5.3.1 Digital Tools as Enablers of Collaboration

The integration of 4IR technologies emerged as a critical factor in facilitating interdisciplinary collaboration. Tools such as Building Information Modelling (BIM), virtual reality (VR), and collaborative design platforms enable students to work together in real time, regardless of geographical location.

These technologies support:

- Visualisation of complex design concepts
- Real-time collaboration and feedback
- Integration of multidisciplinary data

For instance, BIM allows multiple stakeholders to contribute to a shared digital model, enhancing coordination and reducing design conflicts (Succar, 2009).

5.3.2 Virtual Learning Environments

The findings also highlight the growing importance of virtual learning environments in design education. Online platforms and digital tools enable asynchronous and synchronous collaboration, expanding opportunities for interdisciplinary engagement.

However, the effectiveness of these technologies depends on:

- Digital literacy of students and faculty
- Access to technological resources
- Institutional support

The digital divide remains a significant challenge, particularly in developing contexts, where access to advanced technologies may be limited (Miranda et al., 2021).

5.3.3 Technology as a Double-Edged Sword

While technology facilitates collaboration, it also introduces new challenges. The analysis reveals that over-reliance on digital tools can sometimes hinder deep learning if not integrated with effective pedagogical strategies.

For example:

- Students may focus more on technical aspects than conceptual understanding
- Communication may become fragmented in virtual environments
- Lack of face-to-face interaction may reduce collaborative depth

This finding underscores the importance of balancing technological innovation with pedagogical effectiveness.

5.4 Sustainability-Oriented Competencies

5.4.1 Systems Thinking and Holistic Understanding

Systems thinking emerged as a key competency developed through interdisciplinary collaboration. Students

learn to understand the interconnected nature of design elements and their environmental, social, and economic impacts (Meadows, 2008).

This competency enables students to:

- Analyse complex systems
- Identify interdependencies
- Develop integrated design solutions

5.4.2 Ethical and Environmental Awareness

The analysis indicates that interdisciplinary collaboration enhances students' awareness of ethical and environmental issues. By engaging with diverse perspectives, students develop a deeper understanding of the social implications of design. This aligns with the goals of Education for Sustainable Development, which emphasises the development of values and attitudes that support sustainable practices (UNESCO, 2024).

5.4.3 Innovation and Creativity

Interdisciplinary collaboration fosters innovation by encouraging students to combine ideas from different disciplines. This leads to more creative and effective design solutions.

The findings suggest that:

- Diverse perspectives stimulate creative thinking
- Collaboration enhances problem-solving abilities
- Exposure to different disciplines broadens design approaches

5.5 Barriers to Interdisciplinary Collaboration

Despite its benefits, several barriers were identified:

Institutional Constraints

- Rigid curricula
- Lack of interdisciplinary policies

Disciplinary Silos

- Limited interaction between departments
- Differences in terminology and methodologies

Resource Limitations

- Lack of funding
- Limited access to technology

Skills Gap

- Uneven digital literacy
- Lack of collaboration skills

These barriers highlight the need for systemic changes in educational institutions.

5.6 Grounded Theory Proposition

Based on the analysis, the study proposes:

Interdisciplinary collaboration in sustainable interior architecture education is a dynamic process shaped by the interaction of pedagogical integration, technological mediation, and sustainability competencies, within the socio-institutional context of the 4IR.

6. Discussion

The findings of this study provide important insights into the evolving nature of

interdisciplinary collaboration in sustainable interior architecture education. This section interprets the findings in relation to existing literature and theoretical frameworks.

6.1 Reframing Interdisciplinary Collaboration

The study reconceptualises interdisciplinary collaboration as a dynamic and systemic process, rather than a static instructional method. This perspective aligns with constructivist theory, which views learning as an active and socially constructed process (Vygotsky, 1978).

The findings suggest that collaboration is not merely about bringing together different disciplines but involves:

- Continuous interaction
- Negotiation of meaning
- Co-construction of knowledge

This challenges traditional educational models that treat disciplines as separate and highlights the need for integrated learning environments.

6.2 The Role of Systems Thinking in Sustainability Education

The prominence of systems thinking in the findings reinforces its importance in sustainability education. As Meadows (2008) argues, understanding complex systems is essential for addressing environmental challenges. In interior architecture education, systems thinking enables students to:

- Understand the lifecycle impacts of design
- Integrate environmental and social considerations

- Develop sustainable solutions

The study extends existing literature by demonstrating how interdisciplinary collaboration facilitates the development of systems thinking competencies.

6.3 Technology as a Transformative Force

The findings confirm that 4IR technologies play a transformative role in education. Consistent with the Education 4.0 framework, digital tools enhance collaboration, visualisation, and learning (Miranda et al., 2021).

However, the study also highlights the limitations of technology. While digital tools enable collaboration, they cannot replace effective pedagogy. This supports the argument that technology should be used as a complement to, rather than a substitute for, teaching (Schwab, 2017).

6.4 Pedagogical Implications

The study has significant implications for educational practice:

Curriculum Design

- Integration of interdisciplinary courses
- Emphasis on project-based learning

Teaching Strategies

- Collaborative studio environments
- Use of real-world projects

Assessment Methods

- Evaluation of collaborative skills
- Assessment of sustainability competencies

These changes are necessary to align education with the demands of the 4IR.

6.5 Addressing Barriers

The study highlights the need to address barriers to interdisciplinary collaboration. Institutional reforms are required to:

- Promote collaboration across departments
- Provide resources and support
- Enhance digital infrastructure

Additionally, training programs are needed to develop collaboration and digital skills among students and faculty.

6.6 Theoretical Contribution

This study contributes to theory by developing a grounded model that integrates:

- Constructivist learning
- Systems thinking
- Education 4.0

This integrated framework provides a comprehensive understanding of interdisciplinary collaboration in design education.

6.7 Implications for Future Research

Future research should:

- Conduct empirical studies with primary data
- Explore cross-cultural contexts
- Examine long-term impacts of interdisciplinary education

In conclusion, interdisciplinary collaboration is essential for advancing sustainable interior architecture education in the 4IR era. By

integrating pedagogy, technology, and sustainability, educational institutions can prepare students to address complex global challenges.

7. Conclusion

This study set out to explore and theorise the role of interdisciplinary collaboration in sustainable interior architecture education within the context of the Fourth Industrial Revolution (4IR). By employing a qualitative grounded theory approach based on secondary data, the research has developed a comprehensive conceptual framework that explains how pedagogical practices, technological advancements, and sustainability imperatives intersect to shape collaborative learning environments.

The findings demonstrate that interdisciplinary collaboration is not merely a supplementary pedagogical strategy but a fundamental process necessary for addressing the complexity of sustainability challenges in design education. The integration of diverse disciplinary perspectives enables students to develop holistic solutions that consider environmental, social, and technological dimensions. In particular, the study highlights the central role of studio-based and project-based learning environments in fostering collaboration, critical thinking, and creativity.

The influence of 4IR technologies emerges as a significant enabler of interdisciplinary collaboration. Tools such as digital modelling platforms, virtual environments, and collaborative software enhance

communication, visualisation, and knowledge sharing across disciplines. However, the study also underscores that technology alone is insufficient; its effectiveness depends on thoughtful pedagogical integration and institutional support. Without these, technological adoption may remain superficial or uneven.

At the same time, the research identifies several structural and institutional barriers, including rigid curricula, disciplinary silos, limited resources, and disparities in digital literacy. These challenges highlight the need for systemic transformation in higher education to support interdisciplinary and sustainability-focused learning.

Theoretically, this study contributes by integrating constructivist learning theory, systems thinking, and the Education 4.0 framework into a unified model. This model positions interdisciplinary collaboration as a dynamic and iterative process shaped by interactions between pedagogy, technology, and sustainability competencies.

In conclusion, advancing sustainable interior architecture education in the 4IR era requires a paradigm shift toward interdisciplinary, technology-enhanced, and sustainability-driven learning environments. Future research should build on this framework by incorporating empirical data and exploring its applicability across different cultural and institutional contexts.

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