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Pushing the Boundaries of Architectural and Engineering Education: A Case Study Analysis of the Experience, Outcomes, and Challenges of an Interdisciplinary and Collaborative Design Studio

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A B S T R A C T

This study investigates the impact of an interdisciplinary and collaborative approach to architecture and engineering education through a case study analysis based on a Solar Decathlon studio conducted in Turkey. The studio, which competed in the Solar Decathlon Design Challenge 2024, engaged architecture and engineering students, academics, and professionals in collaboration with design and industry partners to repurpose an abandoned school site. The study uses a hermeneutic methodology to explore the lived experiences of team participants and assess the outcomes, benefits, and challenges of the interdisciplinary and collaborative studio experience in developing a professional horizon and design knowledge and skills to address contemporary issues. Through semi-structured interviews, surveys, and thematic analysis, the study sheds light on the symbiotic relationship between academia, industry, civil society, and state departments in architectural and engineering education. This research contributes to understanding the potential of interdisciplinary design education in addressing the 21st-century problems in the built environment.

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1. Introduction

Architectural and engineering education stands at a critical moment, struggling to evolve in response to a rapidly changing world. Traditionally rooted in the study of compositional theory and formal design principles, architectural education is embedded in a convention that highlights aesthetic outcomes. However, in the 21st century, architects face a shifting landscape characterized by increased complexity, digital advancements, climate crises, and changing societal needs. While responding to the contemporary issues, architecture must also transition from traditional leading roles to facilitating roles within multidisciplinary teams and collaborate across various fields to shape the built environment

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(Stone & Sanderson, 2022). Architectural education must evolve accordingly to prepare students for this dynamic future, emphasizing the acquisition of knowledge and its contextualization within contemporary challenges and opportunities.

Meanwhile, engineering education is focused on safety and serviceability in response to loading conditions, with limited project management integration for economically viable designs. However, as environmental and societal concerns escalate, there is a consensus that collaboration between architects and engineers is vital to address 21st-century problems, such as the housing crisis, climate change, environmental pollution, resource depletion, spatial injustice, poverty, and public health. Education must evolve to meet these demands by providing students with multifaceted knowledge, design skills, and critical perspectives. Consequently, engaging in real-world problems, scenarios, and dynamics is vital in practicing becoming an architect and engineer, starting from formal education.

By drawing from the literature that assesses the education of architects and engineers and employing real-world experiences, this paper untangles the dynamics of a studio model grounded in a real-world problem, interdisciplinarity, and collaboration, which aims at tackling the complex "wicked problems" of the built environment in the 21st century, containing environmental, economic, and socio-cultural issues. While the seminal works of architectural education indicate the need for counteracting fragmentation and distance within the built environment practice, the case study presented in this paper allows us to identify the potency and challenges in facilitating real-world design problems in an interdisciplinary and collaborative model in architecture and engineering education. The case study is based on a design studio conducted in 2023-2024 academic year by the authors, along with other advisors and partners, toward participating in a Solar Decathlon Design Challenge—a competition that aims to address the most pressing issues of the 21st century, through interdisciplinary teams and academia-industry partnerships.

Our research employs a hermeneutic methodology to explore the experiences of team participants and to assess the outcomes, benefits, and challenges of the interdisciplinary and collaborative studio model in developing a professional horizon, design knowledge and skills to address contemporary issues. This paper aims to address the following research objectives through semi-structured interviews, surveys, and thematic analysis:

a) To assess the development of complex thinking and design skills and awareness of contemporary issues of the built environment through a realistic, interdisciplinary, and collaborative studio model by tracking the indicators of complex design understanding;
b) To identify and describe the learning outcomes based on this model; and
c) To identify and describe the challenges and limitations based on implementing this model.

Through this study, the authors seek to contribute to the ongoing debates on integrating knowledge and bridging education and practice in architecture and engineering.

2. Contemporary issues in architectural education and civil engineering education

2.1. Splits and ruptures in architectural education

The education of architects and engineers is critical in addressing the crisis within the built environment, requiring critical self-reflection for its progress after a history of splits, fragmentation, and distancing.

Bernard Tschumi's review on architectural education illuminates the changing dynamics of the architectural profession and their reflection on education. Following the deep interconnection between the history of architecture and its educational methods, Tschumi (1995, p. 24) delineates significant shifts in architectural education throughout history, marked by distinct thresholds or dissociations. These dissociations represent critical moments in the evolution of architectural education.

The first dissociation has roots in Leon Battista Alberti's separation of the intellectual task of architecture from the craftsmanship of construction (Moravánszky, 2017, pp. 41-42), which marks an essential pivotal point in the history of architecture. Alberti's redefinition of the architect as a thinker rather than a maker also established "a crucial reciprocity … between theory and practice" (Leach, 1995, p. 26) since the Renaissance, but the establishment of the School of Architecture in the late 17th century facilitated the separation of theory and practice within architecture to assert academic authority over practical skills (Tschumi, 1995, p. 24). The second dissociation in the late 19th century is the replacement of the logic of materials with the logic of paper rendering (Tschumi, 1995, p. 24). Peggy Deamer's (2020) critique of the traditional Beaux-Arts design, which offers valuable insights into the shortcomings of current pedagogical practices, also highlights this turn to paper renderings as a pivotal moment in the history of architectural education, which continues to influence the current practices. The last dissociation took place in the 20th century, with the further split between 'design' and 'job' architects (Tschumi, 1995, p. 25) and the development of a "theoretical practice" (Tschumi, 1995, pp. 24-25).

The extreme fragmentation within the profession is also reflected in education. At the same time, the current pedagogical practices heavily derive from the academic stance, they heavily focus on "the study of compositional theory and the traditional principles of formal design" (Salama, 2016, p. 60). Deamer's (2020) critique of traditional Beaux-Arts design education highlights the shortcomings of current pedagogical practices, particularly the overemphasis on formal education at the expense of engaging with contemporary challenges. Deamer (2020) advocates for a new pedagogy integrating theory, technology, and the environment and proposes reforms in architectural academia toward a more flexible and relevant curriculum, collaborative research, and re-evaluating professional practice courses.

Deamer (2020) also emphasizes the importance of architecture schools as think tanks to address contemporary issues and prepare students to confront them effectively. This stance resonates with Tschumi's (1995, p. 25) proposal to redefine the role of architects in the construction of technology rather than the technology of construction. It also resonates with Neil Leach's proposal for widening the horizon of architectural education beyond its traditional limits and engaging new theoretical tools by fostering cross-disciplinary engagement as "a way of addressing the problems of contemporary architecture" (1995, pp. 27-28). Thus, architectural education must integrate theory, technology, society, and environmental considerations with realistic design problems while fostering collaborations among and beyond disciplines.

Based on the discussion above, there is a need to redefine the role of architects in the construction of technology and equip future professionals with a horizon to confront the complex challenges of the built environment in the 21st century. In essence, the education of architects must evolve to reflect the complex dynamics of the contemporary world.

2.2. New horizons in engineering education

The engineering profession's creative, hence dynamic nature requires that education should continually evolve and incorporate new technologies and practices (Hall, 2021; ASEE, 1955), and it must engage with environmental stewardship, innovation and integration capacity, risk and uncertainty management, and public stewardship (Hall, 2021). Bae et al. (2022) further emphasize the need for knowledge and skills development for employability to meet industry expectations. The development of competencies on emerging technologies, integration of systems thinking into education, incorporation of real-world problem-solving, project-based education, and experiential learning are seen essential while the development of personal skills, teamwork, responsibility, lifelong learning skills incorporating humanistic and social sciences, and communication skills were emphasized by practicing engineers (Hall, 2021).

Engineering discipline aims to design and guide production through a creative application of scientific principles rather than developing knowledge based on observed facts and tested truths, and thus, bringing different personality traits together in a teamwork setting will facilitate both in-depth learning and lateral broadening of the knowledge base in a collective setting (Liang & Yeh, 2014). According to Liang and Yeh (2014), teamwork and agreeableness positively affect “transforming imagination,” while an introverted personality is good for “conceiving imagination.” Thus, both aspects are necessary for engineering practice. Liggett and Etterna (2001) further propose that technology offers an opportunity to replace the time occupied in the past for hand calculations with a depth of knowledge, along with a broader spectrum of knowledge on several other disciplines, to aid the development of the students as professional engineers to guide the society towards a sustainable economy, without the expense of depth of knowledge.

Based on the discussion above, an integrated educational curriculum that takes advantage of technological tools for the guidance of students for in-depth learning within the discipline and provides awareness and understanding of a broader range of knowledge of other disciplines must be facilitated by using different teaching methods to develop a different range of personality traits in each course. In synthesizing these insights, this study aims to revisit engineering education with a model that integrates diverse skills, scenario-based thinking, and interdisciplinary collaboration toward addressing the 21st-century built environment.

2.3. Crossing disciplinary boundaries in architectural and civil engineering education

In response to the challenges posed by contemporary social and environmental problems, there is a surge of interest in integrating knowledge across disciplinary boundaries. There are various integration approaches with different levels of integration, including multidisciplinarity, interdisciplinarity, and transdisciplinarity: multidisciplinarity indicates several scientific disciplines working on a common problem, each discipline contributing its perspective without crossing boundaries; interdisciplinarity requires scientists from various disciplines to cross boundaries and create new knowledge collaboratively to address real-world problems; and transdisciplinarity involves integrating non-scientists in addressing real-world problems (Stock & Burton, 2011). Along these lines, Borucka and Macikowski (2017) discuss the challenges and complexities inherent in contemporary architectural practice and education and emphasize the need for specialization alongside interdisciplinary education to prepare students for the multifaceted challenges of the built environment. Rifaat (2019) proposes actions to improve architectural education, including forming multidisciplinary teams, introducing real-world projects, and engaging industry stakeholders. Andrews et al. (2020) advocate for a transdisciplinary approach to address climate change impacts, bringing together students and faculty from multiple disciplines.

Navarro et al. (2014) and Oliveira et al. (2022) present methodologies and findings regarding multidisciplinary educational initiatives and indicate the benefits of multidisciplinary teamwork and skill development. The findings by Navarro et al. (2014) suggest an increased understanding of the construction process, sustainable built environment, and solar energy systems with improved communication skills and abilities to work in multidisciplinary teams under realistic conditions and a better understanding of professional and ethical responsibility. Chang et al. (2022) and Heinendirk and Cadez (2013) investigate the impact of interdisciplinary pedagogical approaches on students’ creativity, teamwork, and self-development, further suggesting the importance of crossing disciplinary boundaries in the education of civil engineering and architecture students. A study by Jin et al. (2018) also highlights the positive outcomes of interdisciplinary coursework, including improved collaboration and design quality, in addition to shortcomings, including deficiencies in the software skills of some students and drawbacks in linking BIM to building energy simulation software. Ali (2019) explores the benefits and challenges of interdisciplinary collaboration in the Architecture, Engineering, and Construction disciplines, similarly highlighting the importance of collaboration skills and software tools. Badawi and Abdullah (2021) evaluate interdisciplinary design courses and suggest improvements to enhance collaboration among architecture and engineering students after their study observed the unwillingness of architectural student groups to collaborate with the other disciplines, while some teams recognized the benefit of cross-disciplinary collaboration. Their findings suggest the need to increase the physical time spent working together to overcome introversion. Thus, strategies to improve collaboration skills and use collaborative tools are essential for fostering successful interdisciplinary design courses.

Overall, the literature highlights the significance of beyond disciplinary collaboration in architectural and engineering education to address real-world challenges effectively (Figure 1).

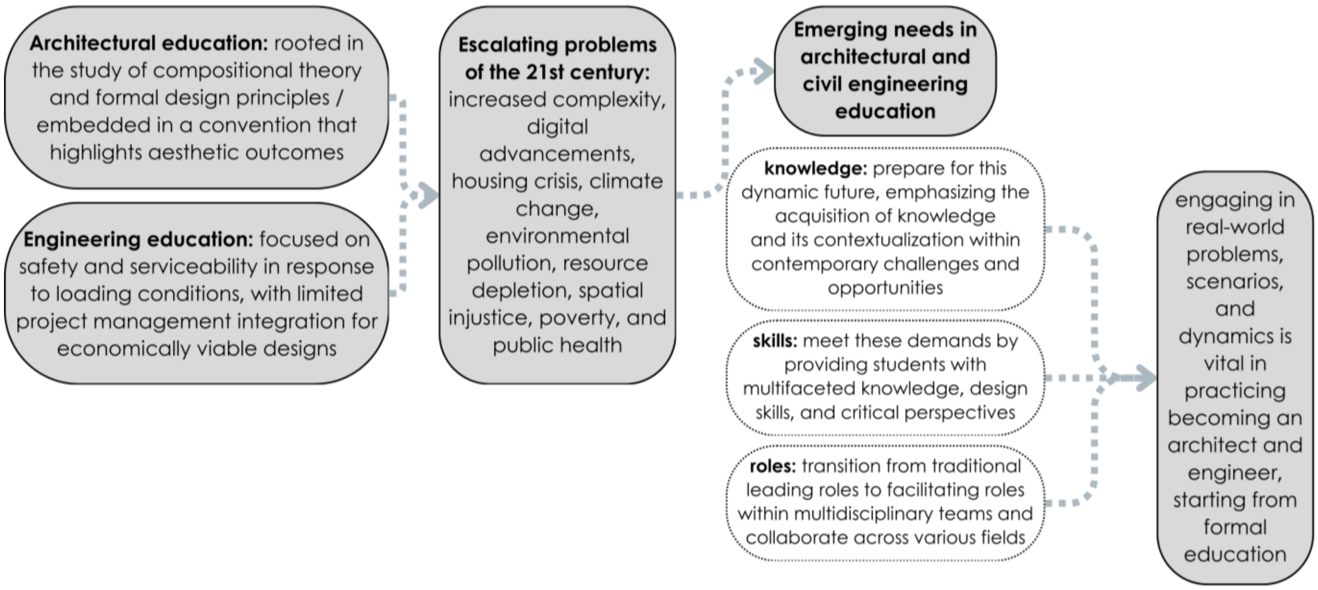

Figure 1. Theoretical background (Source: Developed by Authors, 2024).

3. The case of solar decathlon studio

In 2023 Fall, an experimental design studio was facilitated at the Architecture Department of Yeditepe University to undertake the Solar Decathlon Design Challenge 2024 as an interdisciplinary team with a collaborative studio model and realistic project. The Solar Decathlon is a collegiate competition organized by the U.S. Department of Energy to prepare "the next generation of building professionals to design and build high-performance, low-carbon buildings powered by renewables" (U.S. Department of Energy). While the competition aims to equip students for "the clean energy workforce" and "educate students and the public about the latest technologies and materials in zero energy design and technologies, smart home solutions, and high-performance buildings" (U.S. Department of Energy), it fosters collaboration and cooperation among academia, disciplines, design partners, and industry.

3.1. Team structure

Facilitated by two instructors and a teaching assistant from the Architecture Department, the studio officially included twenty second-year architecture students. The team further consisted of a civil engineering student, advisors from engineering and architecture, design partners (clients) who assigned the studio a real-life design problem, industry partners, and a specialist mentor assigned by the competition organizers (Table 1).

Table 1. Team structure (Source: Developed by Authors, 2024).

Student Lead	1	Architecture Department / Graduate Student / Teaching Assistant
Students	20	Architecture Department / Sophomores (two double-majoring in C.E.)
	1	Civil Engineering Department / Senior
Faculty Advisors	3	Architecture Department
	1	Civil Engineering Department / Cost and LCA Specialist
	1	Civil Engineering Department / Structural Design Specialist
	1	Civil Engineering Department / Water Systems Design Specialist
	1	Industrial Engineering Department / Solar Energy Supply Specialist
Acting Advisors	1	Civil Engineer / Sustainability Specialist
	1	Electrical Engineer
	1	Mechanical Engineer
	1	Architect / Visualization Expert
Mentor	1	Sustainability Specialist
Design Partners	1	State Department
	1	NGO
	1	University
Industry Partners	1	Lightweight Steel Construction Firm
	1	Opening Systems and Mechanisms Firm
	1	Glass and Glazing Firm

3.2. Course aims, content, and process

This experimental studio was conducted in the first architectural design studio. In the first architectural design studio at Yeditepe University, students conventionally design a house or housing by considering natural, spatial, social, and cultural contexts and the relationships between interior and exterior spaces, circulation systems, structural systems, and materials. They investigate the brief and site and prepare an architectural scenario and program for the intended users. They develop design through scaled site plan, silhouettes, floor plans, sections, elevations, system details, point details, 3D drawings, and physical models. Within the scope of the Solar Decathlon Design Challenge, students worked on a net-zero house design. In contrast to the regular competitive studio model, the studio aimed for one final project by integrating building systems beyond its conventional scope. The studio met once a week for a full day with the participation of the studio instructors and the students officially enrolled in the studio while the rest of the team mainly contributed through seminars and had input during the reviews. The syllabus remained flexible except for the set milestones, such as review days and competition submissions. The team worked beyond the academic calendar until its participation in the semi-final competition event (Table 2).

Table 2. Solar Decathlon studio course flow, achieved milestones, engagement with complex design thinking, and crossing boundaries of the disciplines with a collaborative model (Source: Developed by Authors, 2024).

Week #	Course Flow	Topics
1	Introduction	Introduction to the Solar Decathlon Design Challenge; Team building activities
2	Discussion Day and Workshop	Theoretical readings on house, dwelling, and housing informed by the fields of architectural theory, philosophy, and culture
3	Case studies	Introduction of the design problem (real-world complex problem) by the design partners or clients; Presentations on house design from the past solar decathlon winners are conducted by pairs of students
4	Theoretical lectures	Lectures on sustainable building, carbon emissions, earthquake ordinances, water sources, solar energy, quantity survey, zoning ordinances, contextual and environmental analysis, and site documentation by all team advisors; Visit to Bodrum (site visit) on the weekend

5	Site analysis, scenario and program	Analysis studies assigned to pairs of students
6	Conceptual design *First review with stakeholders*	Design proposals by four groups of students and evaluation of the proposals; Feedback by advisors and partners and consideration of how various systems inform the proposals
7	Conceptual design	Design proposals by two groups of students and evaluation of the proposals; Visit to the industry partner (lightweight steel construction) in that week and integration of structural system
8	Conceptual design	Convergence to one design proposal on the site plan after the evaluation of the progress
9	Design development, estimations, and simulations *Submission of the project summary to the Solar Decathlon Competition*	Students are assigned different tasks in pairs to develop spatial systems, water systems, energy systems, cost estimation, simulations, etc. after the evaluation of the progress - integration of systems; Visit to the industry partners (opening and glazing systems) in that week
10	*Second review with stakeholders*	Integration of systems
11	Design development, estimations, and simulations	Student pairs and tasks were reshuffled after the evaluation of the progress
12	Design development, estimations, and simulations	A structural model is built with the guidance of civil engineering student and topic understood well by architecture students
13	Presentation studies	Exchange of works for the completion of the presentation as a precise and inter-referential output after the evaluation of the progress
14	*Final review with stakeholders*	Integration of systems
15	Design revision and visualization workshops	Integration of the project systems, including resolved gutter system and shading devices after daylight simulation
16	*Submission and participation in the semi-final competition event*	Integration of systems

3.3. Realistic design challenge and brief

The design partners assigned the design problem to the team: designing affordable, movable, and deconstructible teacher homes on the derelict school sites in Bodrum. The region has witnessed a significant increase in property values and rental prices, impacting the economic feasibility of accommodations for middle-income individuals. Public school teachers assigned to the Bodrum region struggle with finding affordable rental homes, often resulting in transfer requests. This further impacts the viability of primary education. Furthermore, the decline in the permanent population in some villages in Bodrum and the consolidation of schools have left some village schools inactive, with their buildings in ruins. Responding to these challenges, the Bodrum District National Education Directorate collaborated with the Architecture for All Association and İstinye University to develop projects for the abandoned school sites. The studio received the brief and, after visiting the site and talking with local authorities, developed it further to consider the culture and history of the place, passive design strategies, generation of clean energy and reduction of energy demand, water cycle and conservation, material and site circularity, disaster resilience, health, local and renewable materials, logistics, and carbon emissions.

3.4. Complex design problem and integration of systems

The team responded to the competition requirements for net zero building, the client brief and site conditions. Initially, students conducted various historical and site analyses and collected climate data to evaluate opportunities and risks. Considering the site's life cycle, material circularity, and other factors, such as earthquake and fire resistance, the team opted for a steel structural system placed on stone plinths, a reminder of the site's historical past.[1] An industry partner specializing in lightweight steel buildings joined the team and provided initial lectures and ongoing consultancy, assisting in resolving material connections and building physics requirements.

The students undertook tasks within and beyond architectural design, including the study of the connection between form, climate, envelope, energy, mechanical systems and materials' insulation values and carbon footprints. Energy modelling software was utilized with guidance from advisors and mentors, facilitating iterative investigations into shell and flooring systems and material alternatives. The civil engineering student assessed structural system options, and several students conducted calculations and analyses to determine material requirements, embodied carbon, cost, and the integration of water systems. Demand calculations, rainwater harvesting, and plumbing system designs were developed to mitigate water scarcity and achieve water circularity, with considerations for structural loads. Furthermore, several students learned to utilize local unit price books and software for cost calculations, providing feedback on material selection to optimize cost-effectiveness. Through collaborative efforts and guidance from mentors, the team navigated various challenges, informing the design process and improving the project's overall sustainability, integration, and feasibility.

3.5. Integration of Architectural and Engineering Perspectives and Collaboration with Stakeholders

The lack of engineering students from various fields pushed architecture students to explore various systems of building with guidance from advisors and gain literacy on systems integration. Starting with the site visit, architecture students investigated the environmental and experiential conditions of the place, and they conducted research and communicated with locals to understand the constraints of the site, its history, local culture, and economy, as well as the connections between the site and neighboring settlements. After collecting data, liaising with the relevant advisors, and dwelling on more resources, architecture students converted the data into usable information, crossing the boundary of their own discipline. Reflection of this information on the design has proven satisfactory for the preliminary design stage.

At the design development stage, different groups of architecture students working on solar energy, water systems, plumbing, energy analysis, envelope insulation, and cost estimates carried out more detailed analyses with guidance from advisors and partners. The implications of acquired knowledge were shared with the team during weekly studio hours to integrate the necessary principles of the systems into the project. On the other hand, the civil engineering student worked only on the structural system to suit the architectural forms that architecture students predominantly defined. Therefore, the civil engineering student remained like a service provider to respond with solutions to the demands of the architects.

The group's collaboration was facilitated during studio hours and through the online classroom and a shared online folder, where the team archived the work weekly. Hence, the whole team facilitated a timely understanding of the components. Reviews were the driving force in integrating and aligning different project components with the team and investigating the areas that needed revision or further development. Design partners, as the clients, provided feedback on all studio reviews. While most advisors were physically present at these reviews and some regular course days, online meetings made participation and feedback from most stakeholders possible.

[1] The stone plinth was envisioned to be built from local stone and left as a permanent part of the site after the potential removal of the houses.

4. Methodology

Hermeneutic methodology guides this research, which seeks to describe and interpret the experience, outcomes, and challenges of interdisciplinary collaborative models based on realistic projects. Hermeneutics is the theory and methodology of interpretation (Gadamer, 2006). Hermeneutics' interpretative framework is a dynamic engagement rather than a search for a singular meaning, and the interpretation originates within a researcher's horizon—a temporal and cultural context that defines understanding (Gadamer, 1988). In hermeneutic research, the horizon has a dual role: a limitation defined by our existing perspectives and an opening to transcend those limits through engagement with new interpretations. The researcher continually expands this horizon by studying fragments to derive meaning for the whole and studying the whole to derive meaning for the fragments (Gadamer, 1988), which unfolds in a dialogue with the text. Another implication of the hermeneutic approach, as also employed in this research, is the continual expansion of knowledge based on a dialogue between people.

4.1. Research design

This research entails a process of collection and reflection on experiential data to gain insight into the outcomes and challenges of an interdisciplinary and collaborative studio model (Figure 2).

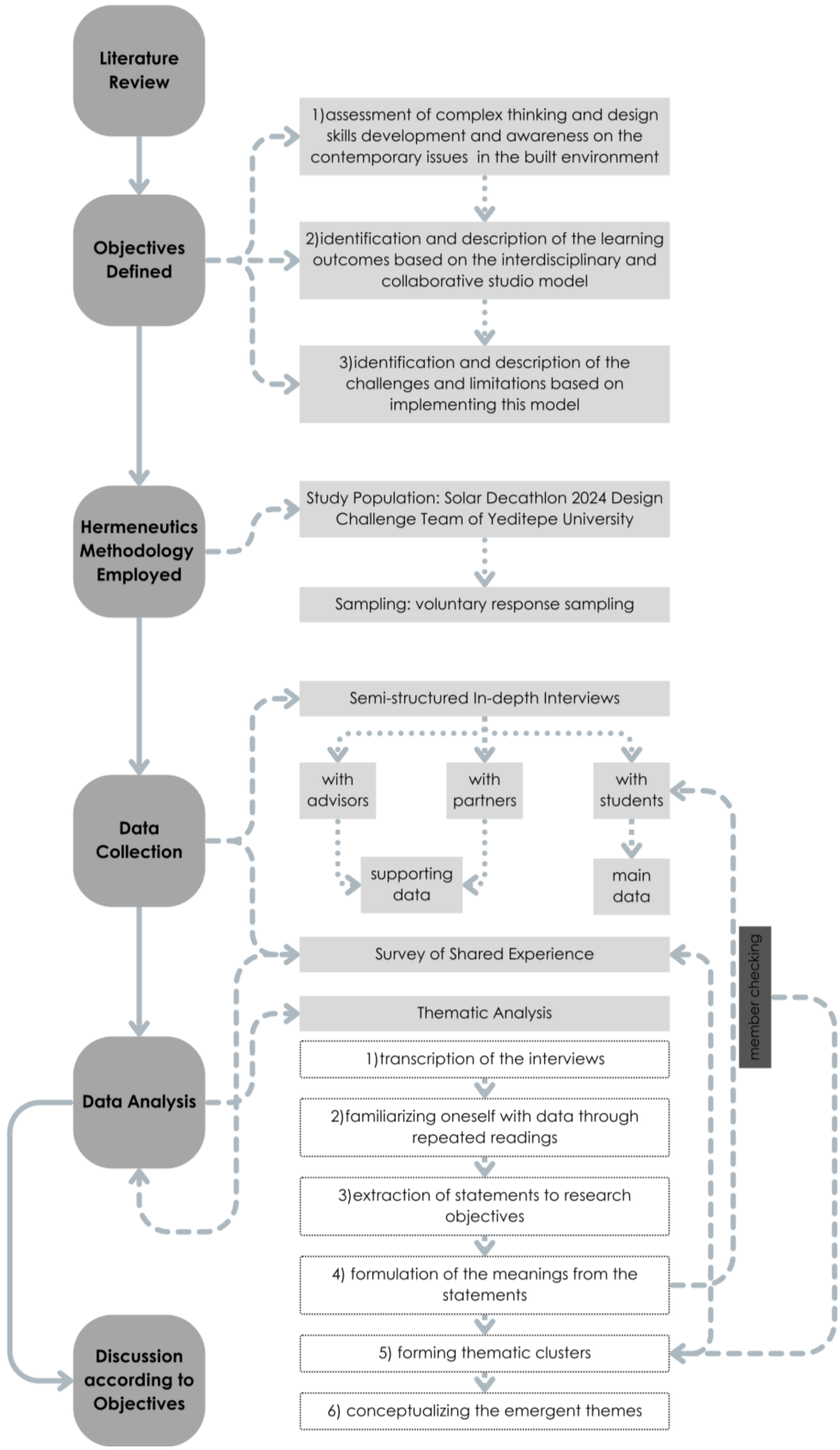

Figure 2. Research design (Source: Developed by Authors, 2024)

4.2. Data collection

The data was collected through semi-structured interviews with team members using a voice recorder and a follow-up survey based on the formulated meanings that emerged from the interviews. The interview questions were shared with the respondents in advance to allow them to reflect on their experiences adequately.

4.3. Sampling

The population of this research consists of the Solar Decathlon studio team members. The sample size is adaptive or emergent, and it uses the principle of saturation, in which the sample size is decided a posteriori since “determining qualitative sample size a priori is an inherently problematic approach” (Sim et al., 2018, p. 619). This research uses voluntary response sampling (Stratton, 2023, p.148).

4.4. Data analysis

The authors interpret the data in dialogue until they establish a shared and commonly agreed meaning. The data interpretation follows the steps of thematic analysis outlined by Braun and Clarke (2006):

1) The authors transcribe the interviews.
2) The authors familiarize themselves with data through repeated readings.
3) The authors extract statements from the transcripts and list them under the relevant research objectives.
4) The authors formulate meanings from the statements.
5) Thematic clusters are formed based on the formulated meanings.
6) The authors conceptualize emergent themes.

Once the themes emerge, the authors revisit the relationship between the themes and whole transcripts to record any new insights. The authors conduct the process together to converge the findings. The findings are presented in tables and narrative format. The follow-up survey sheds light on the percentage of respondents sharing the experience presented in the formulated meanings.

4.5. Reliability and validity

In qualitative research, reliability and validity are defined as “trustworthiness, rigor and quality” (Golafshani, 2003, p. 604). In hermeneutic research, validity is not a linear and predetermined condition. However, it is rather established within the process of research as an “audit trail” (Freeman, 2011, p. 544), which Freeman describes as “a view of research representation as a form of correspondence to reality” (2011, p. 544). The researcher thus focuses on “the public disclosure of processes” (Anfara Jr et al., 2002, p. 29). Trustworthiness in this research was ensured through the thick description (Geertz, 1973), transparency, and member-checking techniques. Member-checking involves respondents acting as co-analysts and co-interpreters, helping in understanding both the realities and the researchers’ interpretations of those realities (Livari, 2018, p. 111).

5. Findings

The authors interviewed 16 respondents: eight students, five advisors, and three partners. After transcribing the interviews, two authors concurrently conducted thematic analysis in dialogue. They created formulated meanings by going through each team membership role in three consecutive phases, creating thematic clusters, and finally reflecting on all clusters to list the emergent themes. The emerging formulated meanings were shared with the respondents to verify the authors’ interpretations.

The findings are presented in tables 3 through 11, focusing on one team membership role and a particular research objective.

Table 3. Formulated meanings, thematic clusters, and emergent themes from student experiences within the scope of the first research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Thematic Clusters	Formulated Meanings
environmental frameworks	1a	design with climate data	understanding that decisions on building orientation relative to the sun and wind, window openings, and system placements have influenced the design
	1b	design with environmental impact	understanding the environmental impact of building siting
			awareness on the carbon footprint of selected materials and systems
	1c	design with the consideration of life cycle analysis of resources	awareness on materials selection based on recycling potential, environmental impacts, and construction advantages
	1d	design with energy systems and performance	understanding the relationship between envelope design, passive ventilation, and building's energy consumption
socio-cultural frameworks	2a	design with the consideration of historical and cultural heritage	awareness on historical context and its effect on design decisions
socio-economic frameworks	3a	design with affordability	understanding affordability principles and incorporation of cost calculations to inform design decisions
	3b	design with life cycle use	awareness on incorporation of flexible and adaptable design approaches considering user profile change
economic performance frameworks	4a	design with the cost of engineering systems	understanding the role of architectural layout decisions in cost reduction of mechanical, electrical, and plumbing systems
constraints of demands	5a	design with local regulations	awareness on project development in accordance with regulations, specifications, and zoning plans
			awareness on the impact of building ordinances and regulations on building design
	5b	design with client demands	awareness of carefully and thoroughly evaluating client needs to develop the design
	5c	design with user demands	awareness on spatial organization for user needs
	5d	design with energy criteria	awareness of design criteria related to net-zero buildings
constraints of supply	6a	design with logistics	awareness on design options evaluation for logistics
	6b	design with local and renewable resources	understanding limits of local conditions for circularity
	6c	design with the spatial requirements of engineering systems	awareness on distribution systems' effect on building design and its spatial layout
			understanding the impact of structural system on spatial and facade design
	6d	design with limited resources	definition of success in design as a design developed under constraints and restrictions
	6e	design with variability of resources	[extracted from other roles]

Table 4. Formulated meanings and emergent themes from advisor experiences within the scope of the first research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Advisors)
environmental frameworks	1a	understanding the value of ecological and climatic data and their impact on design / designing sustainably considering climate data
	1b	awareness on importance of integrating climate, ecological data and passive strategies for a sustainable project
	1c	awareness on the design for water circularity and distributions of blue-gray-black water
	1d	Understanding the demands for net-zero and its interaction of passive systems, facade design, and generation of solar energy / awareness of the design for water circularity and distributions of blue-gray-black water / awareness of the design of water circularity and distributions of blue-gray-black water
socio-economic frameworks	3b	negotiation between client demands and varying user profiles
constraints of demands	5b	negotiation between client demands and varying user profiles
	5c	
constraints of supply	6b	beginning and developing design by utilizing local resources
	6c	awareness of the importance of connection details on building performance / reflecting electrical systems requirements by consulting with professionals / incorporating implications and constraints of structural system selection with openings, systems, and connection details / ability to reflect supplier information for requirements of the treatment systems
	6d	ability to reflect rainfall data to calculate the roof catchment area for rainwater harvesting
	6e	indication of a detailed perspective about the realistic constraints of the seasonal and temperature-related variability of data

Table 5. Formulated meanings and emergent themes from partner experiences pertaining to the first research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Partners)
environmental frameworks	1b	understanding how system choices affect each other and the environment in a real project
	1c	understanding the benefits and disadvantages of the lightweight steel system in terms of sustainability
	1d	design detailing for energy conservation
socio-cultural frameworks	2a	understanding the impact of settlement, environment and history data on design/building
constraints of supply	6a	awareness on modularity parameter and off-site building selection, which must be reflected in the design, transportation of building elements, and structural calculations

Table 6. Formulated meanings, thematic clusters, and emergent themes from student experiences within the scope of the second research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Thematic Clusters	Formulated Meanings
content of knowledge acquisition	1a	knowledge on building detailing and systems integration	gained building assembly and envelope knowledge and developed technical drawing skills based on a project with a specific structural system
			learned to design by reflecting systems' details
	1b	knowledge on cumulative design phases	learned all project development phases from the pre-design phase to the construction drawings
	1c	knowledge on the preparation and methodology of design process	experienced the shift from individual theoretical readings toward smaller and then larger groups to be immersed in the process
	1d	understanding space requirements of systems	ability to translate technical constraints into spatial design
method of knowledge acquisition	2a	learning through models and/or mock-ups	understanding systems function and integration via mock-ups/details of industry
			understanding building's structural system with a physical model produced by peers

	2b	interdisciplinary peer learning	understanding building's structural system facilitated by a student from another discipline
	2c	awareness on the value of critique, panel discussion and multiple perspectives	gaining new perspectives through a wider range of jury critiques
	2d	data collection methods	[extracted from other roles]
integration of knowledge	3a	developing a holistic and integrated design perspective	ability to design with a holistic and integrated approach, as opposed to discipline-bound design studios with individually-led projects
	3b		learned about holistic thinking and system integration in design at an earlier stage in their education
	3c	learning to reformulate the design brief	learned to extract and respond to user needs in an architectural project
expansion of knowledge	4a	beyond curriculum learning	acquired knowledge on a structural system that is not typically included in the curriculum
	4b		acquired higher-level knowledge through research and articles
	4c	beyond curriculum learning on environmental sustainability	developed a capacity to learn and understand building physics and environmental design subjects and tools
	4d		learned the concept of energy performance through interdisciplinary seminars and analysis tools
ability to design with limits and constraints	5a	awareness on the constraints imposed by systems	understood how engineering systems affected the architectural design decisions through consulting with engineers
	5b	understanding on the impact of contextual, physical and local constraints on design decisions	understood decision-making in accordance with contextual conditions, logistical considerations, and performance requirements
	5c	ability to work within the limits and constraints of systems	learned to work within the limits of engineering, contextual and environmental systems
technical skills	6a	development of presentation skills	learned the importance and method of conveying their project idea and developed expression skills
	6b	learning new software and tools for analysis	developed a capacity to learn and understand building physics and environmental design subjects and tools
	6c	gaining technical drawing skills	gained assembly and envelope knowledge and detailing skills with a specific structural system
personal and organizational skills	7a	development of coordination and communication skills	acted as a bridge between different stakeholders and developed coordination and communication skills
	7b	development of conflict management and consensus-building skills	learned to facilitate diverse project solutions through compromise and consensus-building in teamwork
	7c	gaining communication skills with different stakeholders	learned to communicate project-based needs to supplier companies and communicate with team members
	7d	gaining outreach skills	sought additional consultancy beyond advisors and disciplines offered by the studio
	7e	gaining change management or iterative design skills	learned change management as the design changed with the feedback from all systems and stakeholders
	7f	gaining self-motivation skills	learned to stay motivated within the chaos of a large team
	7g	gaining resilience	learned to stay patient with team members
professional equippedness	8a	preparing for professional practice in advance	gaining unique experience toward professional career

Table 7. Formulated meanings and emergent themes from advisor experiences within the scope of the second research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Advisors)
content of knowledge acquisition	1a	consideration of all details, not common to a typical architecture studio / learning to incorporate advice from other disciplines into design
method of knowledge acquisition	2a	designing with advice from other disciplines
	2b	fostering a professional project approach in an interdisciplinary environment rather than treating it solely as a course / improved project expression technique owing to learning from others, recognizing and addressing own shortcomings
	2c	learning to design with advice from other disciplines / acquisition of interdisciplinary vision and development of different perspectives through seminars and non-architecture advisors
	2d	learning data sources, open sources, and collection methods, such as solar radiation, rainfall data, and regional data
integration of knowledge	3a	developing a more holistic approach / bringing holistic presentations including sketches, examples, and analysis to the lessons / materialization of technical dimensions and calculations of the project in students' eyes, owing to the study's project-based nature since it serves a particular purpose
expansion of knowledge	4a	familiarization with systems other than reinforced concrete and discovering their potential in design
	4b	acquisition of values and experience in real-world problems, including sustainability, as future professionals
designing with limits and constraints	5b	understanding the influence of interdisciplinary collaboration on project concept
technical skills	6b	learning to perform sunlight and solar path analysis and use digital tools accordingly / experimenting with different software tools for building energy analysis by learning relevant parameters
personal and organizational skills	7a	gaining skills in creating mutual work time, managing the design process despite enforcements to aim for a specific target, being mutually dependent, and accepting differences of opinion
	7b	developing the experience of designing with consensus-building rather than majority decision or individual decision-making
	7c	ability to communicate well with the parties they contacted for decisions regarding system layouts
	7d	realization of insufficiency of knowledge from one's field for a successful project and seeking support from other disciplines
	7e	recognition of the collaborative nature of decision-making in architecture, understanding the influence of engineering data, embracing interdisciplinary learning and project's continuous evolution based on shared knowledge, effective self-assessment of findings, identifying areas for improvement, and gaining insights into own capabilities
professional equippedness	8a	importance of experiencing and learning the information that will be beneficial to their profession at as early as second-grade level

Table 8. Formulated meanings and emergent themes from partner experiences within the scope of the second research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Partners)
content of knowledge acquisition	1c	an enriching experience, encouraging the students to engage in multifaceted research and requiring both collaborative and individual work
method of knowledge acquisition	2c	emergence of a collective project produced with students and experienced academics and professionals
integration of knowledge	3b	learning not to settle for the client's brief only but also to collect and analyzing own data, developing and detailing the brief based on field observation
expansion of knowledge	4a	developing a vision for new systems like modular building systems, gaining awareness of off-site building production techniques, cultivating insights into new approaches for construction methodologies
personal and organizational skills	7a	experiencing working together, dividing work, and taking responsibility for 3rd-semester students / developing individual knowledge and skills within a collaborative and collective setting persistently during the semester
	7g	long-term intensive work conducted in this studio with great benefit to the students
professional equippedness	8a	gaining insight into the architecture profession after graduation / remembering and benefitting from this process while practicing the profession of architecture / gaining a complex design awareness in the design process for future application

Table 9. Formulated meanings, thematic clusters, and emergent themes from student experiences within the scope of the third research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Thematic Clusters	Formulated Meanings
complexity	1a	burden of handling a realistic project as a student	limiting nature of design, contextual and other constraints making the studio too serious
project coordination	2a	difficulty of coordinating a large team	lack of work coordination due to the involvement of a large number of people
	2b	coordination related delays in collaborative design	large team resulting in delays in subsequent phases
	2c	partial presence of some stakeholders negatively impacted the process	lack of all advisors' and partners' full presence during all course hours resulting in integrating other-field-specific issues
schedule management	3a	progressive delays impacting peers	cumulative work resulting in delays in receiving tasks from peers to continue with one's tasks
	3b	time and scope conflict with the project's collaborative and realistic nature	conflict between formal semester duration and time required for a realistic project with a collaborative model
	3c	need for a detailed advance-planning	lack of planning in the sharing of tasks
	3d	lack of advance definition of deliverables	lack of clarity of tasks to be completed
	3e	coping with stress because of delays in predecessor work	becoming interdependent resulting in stress as the tasks were received from the teammates shortly before their deadlines
	3f	idle time impacting productivity of team members	unproductive stand-by times while waiting to receive work from peers
conflict management	4a	intragroup conflicts	social conflicts and controversies among student team members
	4b	intra-group adaptation requirements	time required to get adjusted to team members and resolve conflicts
			time required to resolve communication problems
interdisciplinary representation	5a	lack of student representation from all relevant disciplines	lack of students from other disciplines resulting in struggle to understand the subjects of other disciplines
	5b	limited engineering impact on the project outcome due to unbalanced student representation	limited number of engineering students resulting in deficiency in innovation despite the development of a functioning project

foundational knowledge	6a	lack of area-specific background	lack of subject-specific knowledge required in design process
	6b	lack of design knowledge	lack of general knowledge required in design process
	6c	lack of individual design experience	lack of foundational and individual design experience
	6d	lack of foundational knowledge and skills due to engaging lower division students	necessity of placing a studio informed by sustainability in upper division after taking a conventional design studio, building physics, BIM, etc.
	6f	task-specific knowledge	lack of developing detailed knowledge possessed by classmates due to the fragmentation of tasks
tool experience	7a	prior acquaintance with analysis tools is needed	lack of prior knowledge of tools for energy analysis
	7b	prior acquaintance with coordination tools is needed	lack of knowledge of useful tools for collaborative design
fragmentation	8a	losing holistic view of the project	lack of understanding on the whole and all aspects of the project due to the fragmentation of knowledge
diffusion	9a	feeling less accountable for the outcomes	lack of addressing individual responsibility
	9b	collective product is affected by each individual's performance and cannot be guaranteed	interdependence for speed and quality of work
individual skill development	10a	hindrance of individual creativity and accountability	limitation of self-creativity and self-responsibility due to the collective nature of decisions
	10b	the collaborative studio model led to shortcomings in self-organizational skills	lack of advantages in problem-solving and managing uncertainties due to individual work
			struggle with scope management of an individually-driven design project in the following semester
	10c	weight on analytical process hindered visual communication skill development	shortcomings in visual communication due to data-driven design

Table 10. Formulated meanings and emergent themes from advisor experiences within the scope of the third research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Advisors)
project coordination	2c	suggested benefit of full-time contributions from various disciplines in the studio process / proposed increased instructional value with continuous involvement of all advisors / deficiencies in integrating studies conducted with the industry partner into the project
schedule management	3b	challenges on collaboration due to varying course schedules and personal life demands / difficulty of aligning specific client needs with competition requirements, potentially leading to unmet expectations / rushed calculations resulting from students' workload in other courses
	3c	delaying calculations of the water systems that should start from the beginning of the work to the end of the project
conflict management	4a	difficulty of managing differences of opinions and not being offensive on students' side
	4b	managing to adapt in the end, despite the difficulty of managing differences of opinions and not being offensive on students' side
interdisciplinary representation	5a	possible achievement of a more functional project if an engineering student team was constantly involved in the production process in the design team / lack of mechanical and electrical engineering students resulting in deficiencies in a clear expression of the solutions produced for passive strategies
foundational knowledge	6a	challenges for the students due to a lack of theoretical background in energy and building physics
	6d	hampered project efficiency due to limited program/tool knowledge and planning foundation among second-grade students / weaknesses in expression techniques due to the lower division of students
tool experience	7a	challenges in using software in a limited time frame since it was complicated or not user-friendly
fragmentation	8a	inability to thoroughly master every subject for everyone, although everyone worked in every field

Table 11. Formulated meanings and emergent themes from partner experiences within the scope of the third research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Partners)
project coordination	2c	developing an uneconomical architectural project due to pushing the limits of off-site and modular construction systems / enhanced interactive industry collaboration to mitigate communication breakdowns / need to ensure that everybody is committed to the project schedule to achieve their increased contribution throughout / proposed closer process monitoring and meetings beyond official reviews
schedule management	3b	inability to solve the design in compliance with the project brief provided by the client / challenge of combining a competition project with a real problem
interdisciplinary representation	5a	suggested facilitation of peer learning by involving students from every discipline, achieving joint research in their field, and achieving explanation of the subjects to each other in the student's language / possible benefit of understanding what the other discipline does by involving students from different disciplines in the same team
	5b	suggested facilitation of students from various fields with a teacher from their discipline

A follow-up survey enlisting formulated meanings emerging from the interviews was shared with all students. Eight interviewees and an additional student responded to this survey. The follow-up survey results completed by nine student informants are presented in bar charts corresponding to three research objectives (Figure 3, Figure 4, Figure 5).

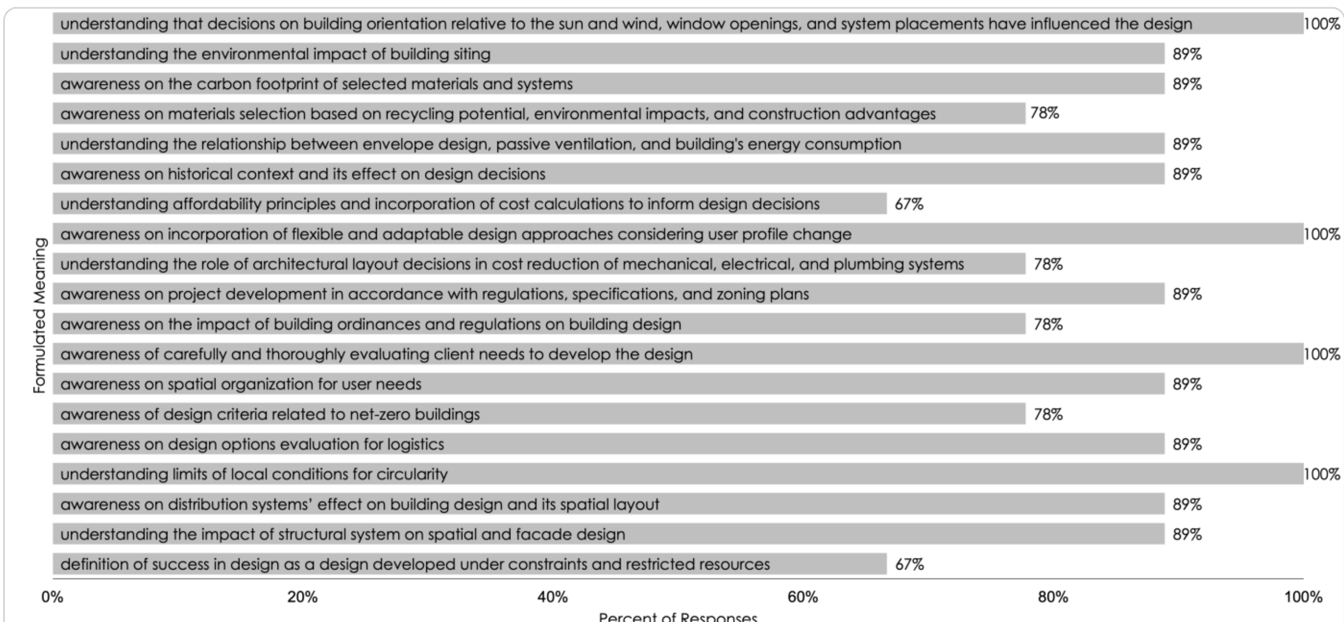

Figure 3. Percentage of students concurring with the first research objective's formulated meanings derived from peer responses (Source: Developed by Authors, 2024).

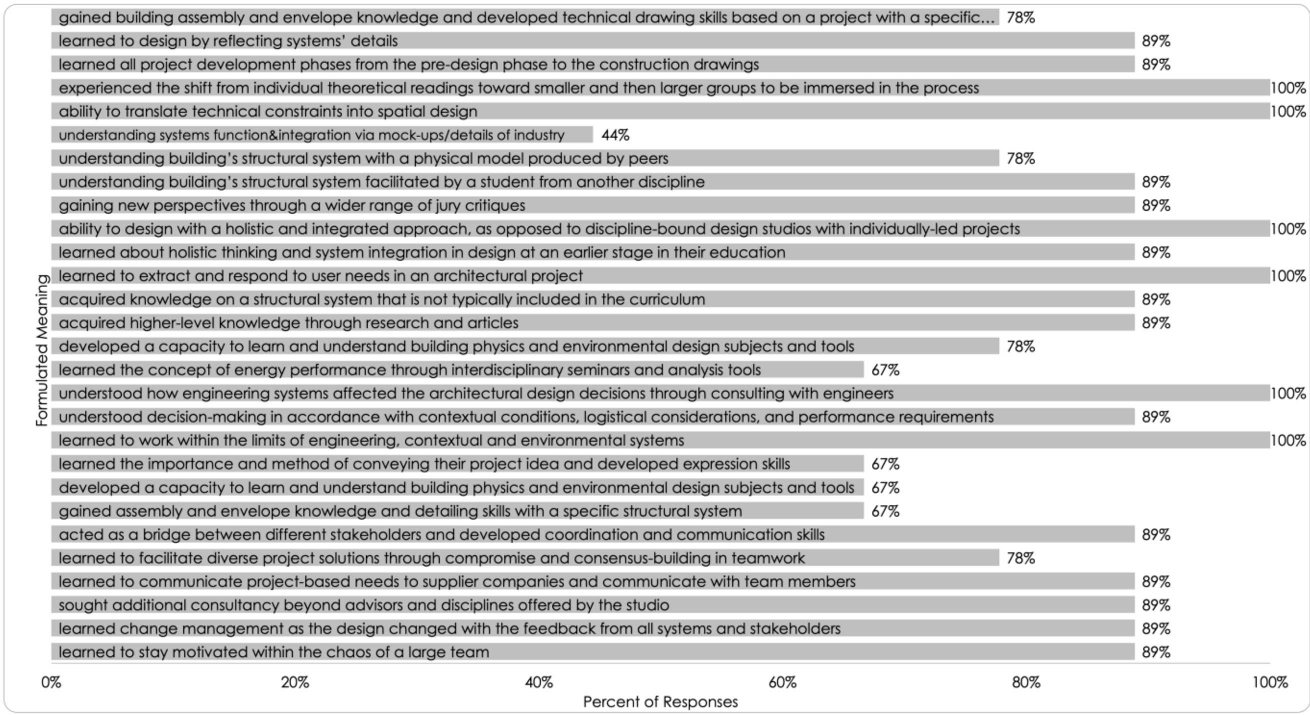

Figure 4. Percentage of students concurring with the second research objective's formulated meanings derived from peer responses (Source: Developed by Authors, 2024).

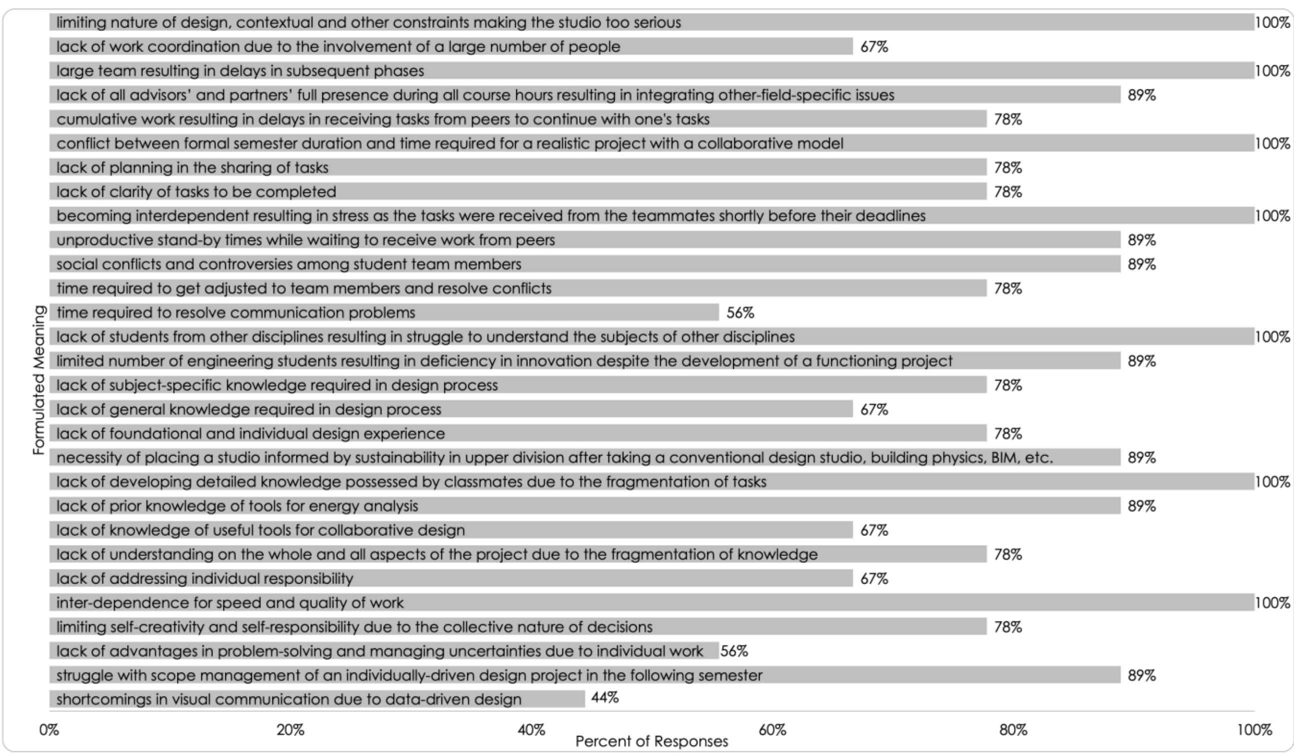

Figure 5. Percentage of students concurring with the third research objective's formulated meanings derived from peer responses (Source: Developed by Authors, 2024).

6. Discussion

Within the scope of the first research objective, an understanding of various interrelated frameworks of design and an awareness of complex design thinking come through statements that fall under the emergent themes of environmental, socio-cultural, socio-economic, and economic performance frameworks and constraints of demands and supply. All respondents reported having developed an understanding and awareness of passive systems, client factors, design adaptability, and building circularity, which are prominent subjects in contemporary scholarship on the built environment and central to sustainable development while most respondents have developed an understanding of siting-environment, design-carbon footprint, envelope-energy, form-energy, structure-form, facade-structure, design-resource, design-logistics, and several other relationships through collaborating with the other disciplines in a realistic project.

Several students articulated their unique experience in contrast to conventional studios and their grasping of design complexity and maneuvers to resolve the design:

> So, when we're designing architecture, we generally talk about it conceptually. But the action of turning it into reality goes through engineering. When this happens, of course, some of our decisions need to change. Maybe larger openings, maybe the materials on the facade changed, they weren't suitable, they didn't fit the calculations, or the static parts.

Based on their experience, one respondent underlined the grasping of complexity rather than design thinking reduced to form-making:

> I've learned that designing is a very complex thing. Because, you know, when we were doing a design in the first grade, it was always limited to what was in my head. But now, for example, I'm learning that cost is important. While dealing with engineering tasks, I realized how important the coefficient of a material used on a wall is. Or how important it is to calculate, for instance, the carbon emissions of a cooling system we use. The importance of this knowledge and skills has increased in my mind.

Parallelly, one of the team advisors, who has continued to teach the same group of students in the next studio, observed the reflection of complex thinking in the new studio:

> Most students think, 'What will be the structural system of this building? What will be the details of the structural system? How much span will be crossed? What will be the connection details?' When expressing their designs, they [other students in previous years] used to bring those volumetric things. They would bring one small cube for the initial concept. Currently, the work they bring includes structural details. They don't bring a closed volume, but they bring certain openings with structural carriers. They've started to think a bit more in detail, and their questions are in that direction. They started asking questions about the structure, about the engineering of the building, regarding their own structures. … They started coming to every class with their sketches, examples, analyses, everything. They [other students in previous years] used to just bring a sketch. They look at it more holistically now.

The research reveals an improved understanding of various design frameworks and complexities, including environmental and socio-economic factors, leading to an awareness of sustainable design principles among respondents. Students reported transitioning from conceptual to detail-oriented design thinking, influenced by interdisciplinary collaboration and real-world project experiences, demonstrating a holistic approach and a deeper grasp of design complexity.

Within the scope of the second research objective, the respondents reported learning outcomes on the 'content of knowledge acquisition,' 'method of knowledge acquisition,' 'integration of knowledge,' 'expansion of knowledge,' 'ability to design with limits and constraints,' 'technical skills,' 'personal and organizational skills,' and 'professional equippedness.' The findings underscore the profound impact of sustainable design thinking, collaborative teaching models, and interdisciplinary learning on students' architectural education. Students gained practical knowledge and technical skills by working on projects with specific structural systems, developing the ability to design with attention to detail throughout all project phases. They transitioned from individual theoretical readings to group immersion and learned to translate technical constraints into spatial designs and understand system function and integration through industry-provided mock-ups and drawings and interdisciplinary peer learning. One student noted their experience on that:

> Consera [industry partner] had sent us an AutoCAD file. We could look at a two-dimensional drawing plan at the same time. As we roamed around and looked at it, it became three-dimensional as well. And when Ali Osman, who was in our team, modelled it once, I said, 'Oh, this is how it really is, it connects like that.' That was one of the moments when it all came together, both when I looked at that AutoCAD file and when Ali Osman made that model.

They also gained new perspectives from diverse jury critiques. Furthermore, they developed a holistic design approach, responding to user needs and acquiring knowledge not typically covered in the curriculum, including higher-level concepts in building physics and environmental design. Architecture students learned to consult with engineers, make decisions based on contextual and logistical considerations, and work within engineering and environmental constraints while the engineering student learned the impact of various factors on building loads and learned to solve a new system by consulting with partners. Additionally, they improved their communication and coordination skills, acting as bridges between stakeholders and effectively conveying project needs to supplier companies. They also learned change management, motivation, and resilience within large teams, providing them professional career experiences.

Within the scope of the third research objective, 'complexity,' 'project coordination,' 'schedule management,' 'conflict management,' 'interdisciplinary representation,' 'foundational knowledge,' 'tool experience,' 'fragmentation,' 'diffusion,' and 'individual skill development' are the emergent themes. The research findings highlight various challenges faced in the collaborative studio setting, including the limiting nature of design due to contextual constraints, lack of work coordination in large teams leading to delays, and difficulties in considering interdisciplinary issues due to the absence of all advisors and partners during regular course hours. Additionally, issues such as cumulative work delays, conflicts between semester duration and project completion time, lack of efficient task planning and clarity, and social conflicts among team members were observed. Lack of subject-specific and general knowledge and foundational and individual design experience were noted, along with challenges in adjusting to team dynamics, resolving communication problems, and managing dependencies among team members. As a consequence of this studio approach, the collective decision-making process was found to limit self-creativity and self-responsibility, and the data-driven approach hindered the development of visual communication skills compared to individually-driven projects due to allocating more time to analysis skills than representation skills. Overall, the study suggests that collaborative studios informed by sustainability should be preceded by individual design studios and take place in the upper division after the relevant coursework to address these challenges effectively.

7. Conclusion

In conclusion, this study highlights the imperative for architectural and engineering education to adapt to the complexities of the 21st-century built environment. The sustainable design objective acted as a tool to respond to the need for complex design thinking facilitated by interdisciplinary collaboration. This study reveals an improved understanding of design frameworks and sustainable principles among students, facilitated by real-world project experiences enabled by the engagement of various stakeholders. The findings emphasize the importance of transitioning from conceptual to detail-oriented and integrated design thinking and developing holistic approaches to address contemporary challenges. Moreover, the study highlights the need for education to equip students with multifaceted knowledge, technical skills, and critical perspectives while addressing coordination, communication, and interdisciplinary integration challenges. Through this study, the authors shared a specific studio model that can be improved continuously for future implementation and adapted by other schools of the built environment.

Ultimately, the research contributes to ongoing discussions on integrating knowledge and bridging education and practice in architecture and engineering, advocating for interdisciplinary and collaborative models that prepare students for the dynamic and interconnected realities of professional practice and the world in general.

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The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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Conflict of Interests
The author declares no conflict of interest.

References

Ali, A. K. (2019). A case study in developing an interdisciplinary learning experiment between architecture, building construction, and construction engineering and management education. Engineering, Construction and Architectural Management, 26(9), 2040-2059. https://doi.org/10.1108/ECAM-07-2018-0306

Andrews, M., Erten-Unal, M., & Considine, C. (2020). Charting a path to trans-disciplinary collaborative design for adaptation to sea level rise. Journal of Higher Education Theory and Practice, 20(15). https://doi.org/10.33423/jhetp.v20i15.3948

Anfara, V. A. Jr, Brown, K. M., & Mangione, T. L. (2002). Qualitative analysis on stage: Making the research process more public. Educational Researcher, 31(7), 28-38. https://doi.org/10.3102/0013189X031007028

Badawi, A. M., & Abdullah, M. R. (2021). Interdisciplinary design education: Development of an elective course in architecture and engineering departments. Journal of Engineering and Applied Sciences, 68(19). https://doi.org/10.1186/s44147-021-00010-2

Bae, H., Polmear, M., & Simmons, D. R. (2022). Bridging the gap between industry expectations and academic preparation: Civil engineering students' employability. Journal of Civil Engineering Education, 148(3). https://doi.org/10.1061/(ASCE)EI.2643-9115.0000062

Borucka, J., & Macikowski, B. (2017). Teaching architecture: Contemporary challenges and threats in the complexity of the built environment. IOP Conference Series: Materials Science and Engineering, 245(8), 082058. https://doi.org/10.1088/1757-899X/245/8/082058

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Chang, T.-S., Wang, H.-C., Haynes, A. M., Song, M.-M., Lai, S.-Y., & Hsieh, S.-H. (2022). Enhancing student creativity through an interdisciplinary, project-oriented problem-based learning undergraduate curriculum. Thinking Skills and Creativity, 46. https://doi.org/10.1016/j.tsc.2022.101173

Deamer, P. (2020). Design pedagogy: The new architectural studio and its consequences. Architecture_MPS, 18(1). https://doi.org/10.14324/111.444.amps.2020v18i1.002

Freeman, M. (2011). Validity in dialogic encounters with hermeneutic truths. Qualitative Inquiry, 17(6), 543-551. https://doi.org/10.1177/1077800411409887

Gadamer, H.-G. (1988). On the circle of understanding. In J. M. Connolly & T. Keutner (Eds.), Hermeneutics versus science? Three German views (pp. 68-75). Notre Dame, IN: University of Notre Dame Press. ISBN-13: 978-0268010850.

Gadamer, H.-G. (2006). Truth and method (J. Weinsheimer, Trans.). London: Continuum. ISBN-10: 082647697X.

Geertz, C. (1973). The interpretation of cultures: Selected essays. London, UK: Fontana. ISBN-13: 9780465097197

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. The Qualitative Report, 8(4), 597-606. https://doi.org/10.46743/2160-3715/2003.1870

Hall, K. (2021). The Civil Engineering Education Summit 2019: Mapping a future for civil engineering education. In Association for Engineering Education - Engineering Library Division Papers. 2021 ASEE Midwest Section Conference, 13-15 September 2021, Virtual. American Society for Engineering Education, ASEE. https://doi.org/10.18260/1-2-115.1153-38333

Heinendirk, E.-M., & Cadez, I. (2013). Innovative teaching in civil engineering with interdisciplinary teamwork. Organization, Technology & Management in Construction, 5(2). https://doi.org/10-5592/otmcj.2013.2.6

Jin, R., Yang, T., Piroozfar, P., Kang, B.-G., & Wanatowski, D. (2018). Project-based pedagogy in interdisciplinary building design adopting BIM. Engineering, Construction and Architectural Management, 25(10), 1376-1397. https://doi.org/10.1108/ECAM-07-2017-0119

Leach, N. (1995). Fracture and breaks. In M. Pearce & M. Toy (Eds.), Educating architects (pp. 26-29). Academy Editions. ISBN-13: 978-1854903914.
Liang, C., & Yeh, H.-T. (2014). Engineering education: Curriculum, pedagogy and didactic aspects. J.P. Davim (Ed.). Chandos Publishing. ISBN-13: 978-1843346876
Liggett, J. A., & Etterna, R. (2001). Civil engineering education: Alternative paths. Journal of Hydraulic Engineering, 127(12), 1041-1051. https://doi.org/10.1061/(ASCE)0733-9429(2001)127:12(1041)
Livari, N. (2018). Using member checking in interpretive research practice: A hermeneutic analysis of informants' interpretation of their organizational realities. Information Technology & People, 31(1), 111-133. https://doi.org/10.1108/ITP-07-2016-0168
Moravánszky, Á. (2017). Metamorphism: Material change in architecture. Basel: Birkhäuser. ISBN-13: 978-3035610192
Navarro, I., Gutiérrez, Á., Montero, C., Rodríguez-Ubiñas, E., Matallanas, E., Castillo-Cagigal, M., Porteros, M., Solórzano, J., Caamaño-Martín, E., Egido, A. A., Páez, A. M., & Vega, S. (2014). Experiences and methodology in a multidisciplinary energy and architecture competition: Solar Decathlon Europe 2012. Energy and Buildings, 83(11), 3-9. https://doi.org/10.1016/j.enbuild.2013.03.073
Oliveira, S., Olsen, L., Malki-Epshtein, L., & Mumovic, D. (2022). Transcending disciplines in architecture, structural, and building services engineering: A new multidisciplinary educational approach. International Journal of Technology and Design Education, 32, 1247-1265. https://doi.org/10.1007/s10798-020-09645-3
Rifaat, S. I. (2019). The multidisciplinary approach to architectural education: Bridging the gap between academic education and the complexities of professional practice. IOP Conference Series: Materials Science and Engineering, 471(8), 082067. https://doi.org/10.1088/1757-899X/471/8/082067
Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. Policy Sciences, 4(2), 155-169. https://doi.org/10.1007/BF01405730
Salama, A. M. (2016). Spatial design education: New directions for pedagogy in architecture and beyond. Routledge. https://doi.org/10.4324/9781315610276
Sim, J., Saunders, B., Waterfield, J., & Kingstone, T. (2018). Can sample size in qualitative research be determined a priori? International Journal of Social Research Methodology, 21(5), 619-634. https://doi.org/10.1080/13645579.2018.1454643
Stock, P., & Burton, R. J. F. (2011). Defining terms for integrated (multi-inter-trans-disciplinary) sustainability research. Sustainability, 3(8), 1090-1113. https://doi.org/10.3390/su3081090
Stone, S., & Sanderson, L. (2022). Introduction. In L. Sanderson & S. Stone (Eds.), Emerging practices in architectural pedagogy: Accommodating an uncertain future (pp. 1-15). Routledge. https://doi.org/10.4324/9781003138843