Assessing the Integration of Building Science in Higher Education Curricula: Implications for Climate Change Adaptation in the Built Environment

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Abstract

This study critically examines the readiness of professionals in India to address the consequences of climate change. With a focus on architecture education, 15 institutes offering undergraduate courses were identified. The study solely assesses course syllabi on crucial building science topics related to climate change adaptation. The alignment of building science with the model curriculum guidelines provided by COA is also examined. The findings reveal certain building science topics are present in the syllabi only in a fundamental manner. However, there are gaps in in-depth coverage, integration with design studios, and practical skill development. The implications of these findings highlight the need for curriculum enhancements in architecture education, ensuring a comprehensive understanding of building science principles and their application in addressing climate change challenges. The study's application extends to guiding higher education institutions in revising their curricula to align with the urgent climate change impacts. Future research directions involve qualitative analyses and cross-country comparisons to enrich the discourse on integrating building science principles and climate adaptation into architecture education.

Keywords - Built Environment, Higher Education Institutes in India, Climate Change, Education of Building Science, COA.

1. Introduction

1.1. Background

Climate change poses a pervasive threat to our environment, economy, and societies, evident in rising temperatures, extreme weather events, and sea level rise. The year 2023 marked significant heatwaves worldwide, leading to the term "Global Boiling" [1]. Amid these changes, the built environment, where we live and work, is crucial [2]. Building science, encompassing physics, chemistry, engineering, and more, studies structures' impact on energy efficiency, durability, comfort, and air quality, guiding efficient design [3]. The reciprocal relationship between climate change and the built environment underscores their interdependence, necessitating cohesive approaches for mitigation and adaptation. As a COP 27 signatory, India faces pronounced climate risks, ranking nine states among the world's top 50 vulnerable regions [4]. This emphasizes the pressing need for India to actively address the implications of climate change on its built environment.

To effectively address the challenges of climate change, education plays a crucial role in enhancing our capabilities. By providing knowledge, promoting innovative thinking, and nurturing skilled professionals, it empowers individuals to understand and manage the consequences of the climate crisis [5]. In the context of architecture and the built environment, education has the potential to train professionals who can design and implement solutions that are both sustainable and climate resilient. Through these lenses, this research illustrates the critical role of the built environment and building science in shaping our response to the evolving global climate.

1.2. Literature Review

The literature review comprehensively explores climate change, the built environment, building science, and architecture education. Guzowski (2015) focuses on integrated luminous and thermal design for net-zero energy architecture [6]. Iyer-Raniga (2019) emphasizes sustainability education in the built environment curriculum for climate readiness [7]. Reid (2019) analyzes climate change education's potentials and issues Leal Filho et al. (2021) evaluates global climate change education approaches [8]. Iyer-Raniga and Andamon (2013) stress interdisciplinary sustainability education [9]. Manu et al. (2010) enhance architecture curriculum for clean energy economies [10]. Roy et al. (2022) examine disaster risk and climate change integration in urban planning curricula [11].

These studies reveal connections between climate change, the built environment, building science, and education, highlighting the need to bridge theory and practice to address climate challenges. However, there remains a lack of comprehensive studies examining the holistic integration of specific building science topics within architecture education, hindering a thorough understanding of how theory and practice are effectively interconnected to address climate change challenges. This study contributes to the scientific background by assessing the extent to which architecture institutes in India integrate subjects related to the built environment, building science and climate adaptation in their syllabi.

1.3. Aim and Approach

This study aims to examine and assess the capacity and readiness of higher education institutes in India to face future challenges in the context of climate change and the built environment. The study examined the syllabi of higher education institutes offering undergraduate courses in architecture. Based on NIRF ranking 2022 and institutes which have existed for more than 25 years, 15 institutes of National Importance have been identified for this study. For this study, the institutes are coded as Institute 1 (I1), I2, I3, and so forth.

1.4. Scope and Limitation of the Study

This research focuses on the assessment of syllabi accessible through the institute's websites. The scope of this study revolves exclusively around examining syllabi content and structure. It delves into the presence, coverage, and integration of specific subjects within the syllabi. It's important to note that this study is confined to the examination of syllabi alone, excluding discussions on pedagogical approaches, teaching methodologies, and classroom delivery. The study focuses solely on syllabi content limits insights into how the identified subjects are taught, discussed, or practically applied within the classroom environment.

2. Methods

2.1. Methodology of the study

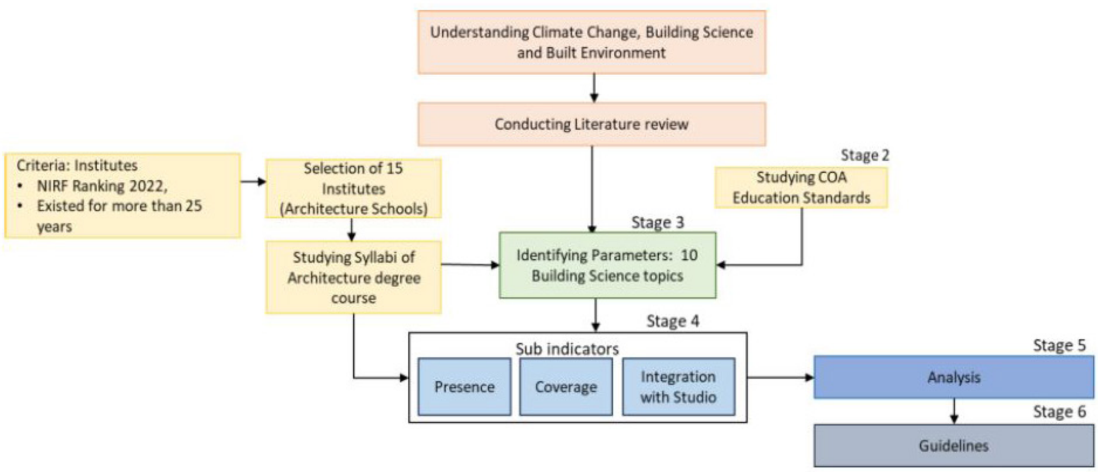

Figure 1: The diagram shows the methodology of the study.

The methodology (refer figure 1) consists of several stages. In Stage 1, the study reviewed climate change, building science, and the built environment, supplemented by a literature review. Stage 2 identifies 15 architecture institutes and examines and studies the model curriculum Council of

Architecture guidelines. Stage 3 selects 10 key building science topics for evaluation. Stage 4 assesses building science topics using sub-indicators as whether the topic is addressed or not, to what extent it has been covered, and its integration with the thrust area of the design studio. In Stage 5, the syllabi undergo comprehensive analysis using predefined benchmarks. Stage 6 integrates insights and study outcomes, leading to guidelines for enhancing subject integration. These guidelines aim to bridge theory-practice gaps, fostering comprehensive education that addresses climate change and building science implications within the built environment. This methodological framework offers a systematic means to investigate subject integration in architecture curricula, advancing educational practices aligned with evolving challenges.

2.2. Selection of Building Science Topics

Aligned with India's ambitious emission reduction targets of 33-35% by 2030 and net-zero emissions by 2070 [12], integrating these topics into architecture education gains vital significance. Equipping future architects with skills for designing in line with these goals contributes to sustainable, climate-resilient development. India's commitment to climate action is evident through international participation and the National Action Plan on Climate Change (NAPCC). This study identifies 10 key Building Science topics, carefully chosen based on Council of Architecture (COA) [13] criteria and global frameworks. These topics equip future architects to address climate complexities and create sustainable, resilient, energy-efficient architecture solutions.

2.2.1. Understanding the 10 Building Science Topics

The following 10 building science topics have been identified for examining syllabi, along with concise definitions:

1. Sustainable Design and Green Building Practices: Creating structures with a focus on minimizing resource consumption, maximizing resource reuse, optimizing site potential, and incorporating eco-conscious methods. Prioritizing energy efficiency, local and renewable energy sources, recycling, and minimizing emissions and waste throughout a building's lifecycle [14,15].

2. ECBC (Energy Conservation Building Code): A regulatory framework in India mandating energy-efficient design. Reduces energy consumption, and carbon emissions, and enhances sustainability by promoting insulation, efficient lighting, ventilation systems, and renewable energy integration [16].

3. Thermal Comfort: Ensuring indoor comfort by considering occupants' satisfaction with the thermal environment [17].

4. Green Landscape and Green Site Planning: Enhancing biodiversity, water efficiency, waste management, and quality of life through eco-friendly landscape and site planning [18].

5. Climate-Responsive Building Envelope Design: Designing building envelopes that align with specific climatic conditions, promoting occupant comfort and energy efficiency. Also, utilizes local materials and native technologies for minimal disruption to local microclimate [12].

6. Energy Efficiency in Services: Designing building systems for less energy consumption while ensuring occupant comfort. Focuses on energy-efficient equipment, smart controls, and system layout optimization [12].

7. Net-Zero Energy and Carbon-Neutral Building Concepts: Creating buildings that produce as much energy as they use, preferably from renewable sources. Balancing carbon emissions through energy-efficient technologies and strategies [12].

8. Integration of Renewable Energy Systems: Incorporating solar, wind, and geothermal power into building designs to reduce reliance on fossil fuels (Renewable energy sources) [12].

9. Energy Budgeting: Balancing energy needs and production throughout a building's life cycle by optimizing design elements and renewable energy sources [12].

10. Resilient Building Design for Extreme Weather Events: Designing structures to withstand extreme weather conditions and disasters, aligning with national policies and international frameworks [19].

By evaluating the integration of these Building Science topics into architecture curricula, this study aims to shed light on the preparedness of professionals undergoing training in Architecture Schools to effectively address the challenges posed by climate change.

2.3. Model Curriculum guidelines by the Council of Architecture (COA)

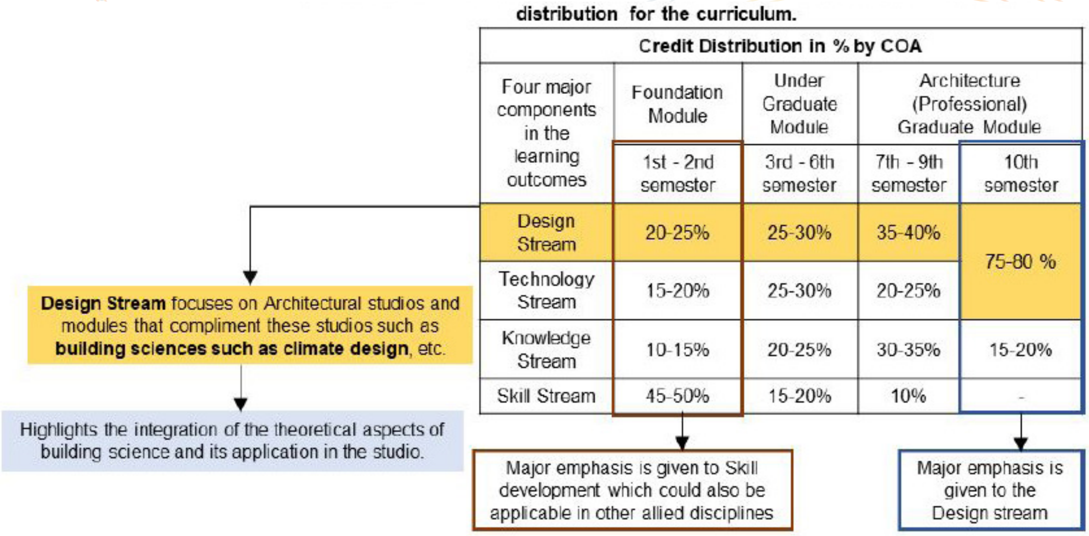

Figure 2: The diagram shows model curriculum guidelines by COA.

The Council of Architecture (COA) governs architecture education for both undergraduate and postgraduate courses. It sets minimum standards and guidelines for architecture education in India. According to the model curriculum, the five-year course is structured into three stages: a foundational module in the 1st year, an undergraduate module in the 2nd and 3rd years, and an architecture graduate module in the 4th and 5th years. Building science topics fall under the technology stream, which is part of the curriculum's technological aspect (refer figure 2) [13]. The curriculum highlights that the technology stream primarily revolves around the undergraduate module in terms of its distribution. This stream includes subjects like building services, construction, and structures. As a result, universities interpret the distribution and classification (Core/Elective) of building science subjects based on this framework.

Table 1: Alignment of Building science topics with the COA Curriculum guidelines.

Sr. no.	Building Science Topics	COA Suggested Building Sciences	Subject Title
1.	Sustainable design and Green building practices	No mention	-
2.	ECBC Codes (Building codes and regulations)	yes	Building Materials
		yes	Building Construction
		yes	Building Services
		yes	Environmental Lab (Non-Subject)
3.	Thermal Comfort	yes	Climatology
		yes	Environmental Lab (Non-Subject)
4.	Green Landscape/ Green site planning	No mention	-
5.	Energy Efficiency in services	yes	Building Services
6.	Climate-responsive building envelope design	No mention regarding building envelope design.	Climatology
7.	Energy Budgeting	No mention	-
8.	Net-zero energy and carbon-neutral building concepts	No mention	-
9.	Integration of renewable energy systems	yes	Building Materials
		yes	Climatology
		yes	Environmental Lab (Non Subject)
10.	Resilient building design for extreme weather events	No mention	-

Table 1. Alignment of Building science topics with the COA Curriculum guidelines.

Table 1 showcases the alignment between building science topics and the COA curriculum. Among the 10 building science topics identified for this study, four—ECBC, Thermal comfort, energy efficiency in services, and renewable energy systems—are addressed. However, topics like Net-zero energy concepts, energy budgeting, and resilient buildings are notably missing. These gaps could impact how institutes shape their syllabi.

3. Results

3.1. Overview of the Assessment

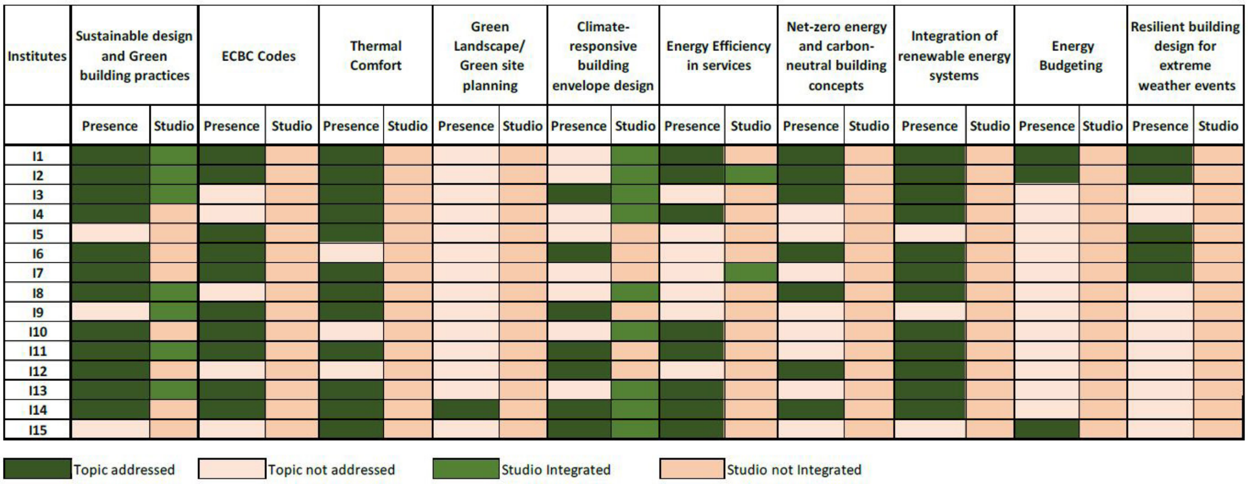

Figure 3: The matrix above shows the 10 building science topics covered by different institutes.

Figure 3 illustrates how various institutes incorporate 10 building science topics. The analysis reveals that several institutes prioritize subjects such as sustainable design, green building practices, ECBC codes, thermal comfort, and integration of renewable energy systems. In contrast, topics like net zero and carbon-neutral building concepts, energy budgeting, green landscape, and green site planning are less commonly addressed, often in a superficial theoretical manner without significant integration into design studios. The development of students' design skills through techniques and tools receives insufficient emphasis. Upon reviewing the building science topics, it becomes unclear whether students grasp the fundamental principles underlying these concepts.

Furthermore, the matrix depicting the integration of the 10 building science topics within design studios of different institutes indicates a distinct pattern. Sustainable design and climate-responsive design, albeit primarily limited to climatic considerations and energy efficiency, emerge as the predominant areas of focus. However, the incorporation of other building science topics within the studio environment is noticeably lacking. This matrix underscores the substantial disparity between theoretical knowledge and practical application within the context of design studios.

3.2. Inferences illustrating Coverage of the Subjects

This section focuses on the coverage of the 10 building science topics across different institutes.

The assessment of the integration of building science topics across different institutes reveals insightful patterns in their coverage and incorporation.

Sustainable Design and Green Building Practices (refer Figure 4a) are prominent in the curricula, with 12 out of 15 institutes including them. However, the treatment is mostly confined to basic theoretical exposure in early years. While a few institutions offer dedicated courses, these subjects generally lack integration with design and practical skill development. Similarly, ECBC (refer Figure 4b) finds coverage in 10 institutes, though primarily at a theoretical level, without significant application-based approaches or integration with design.

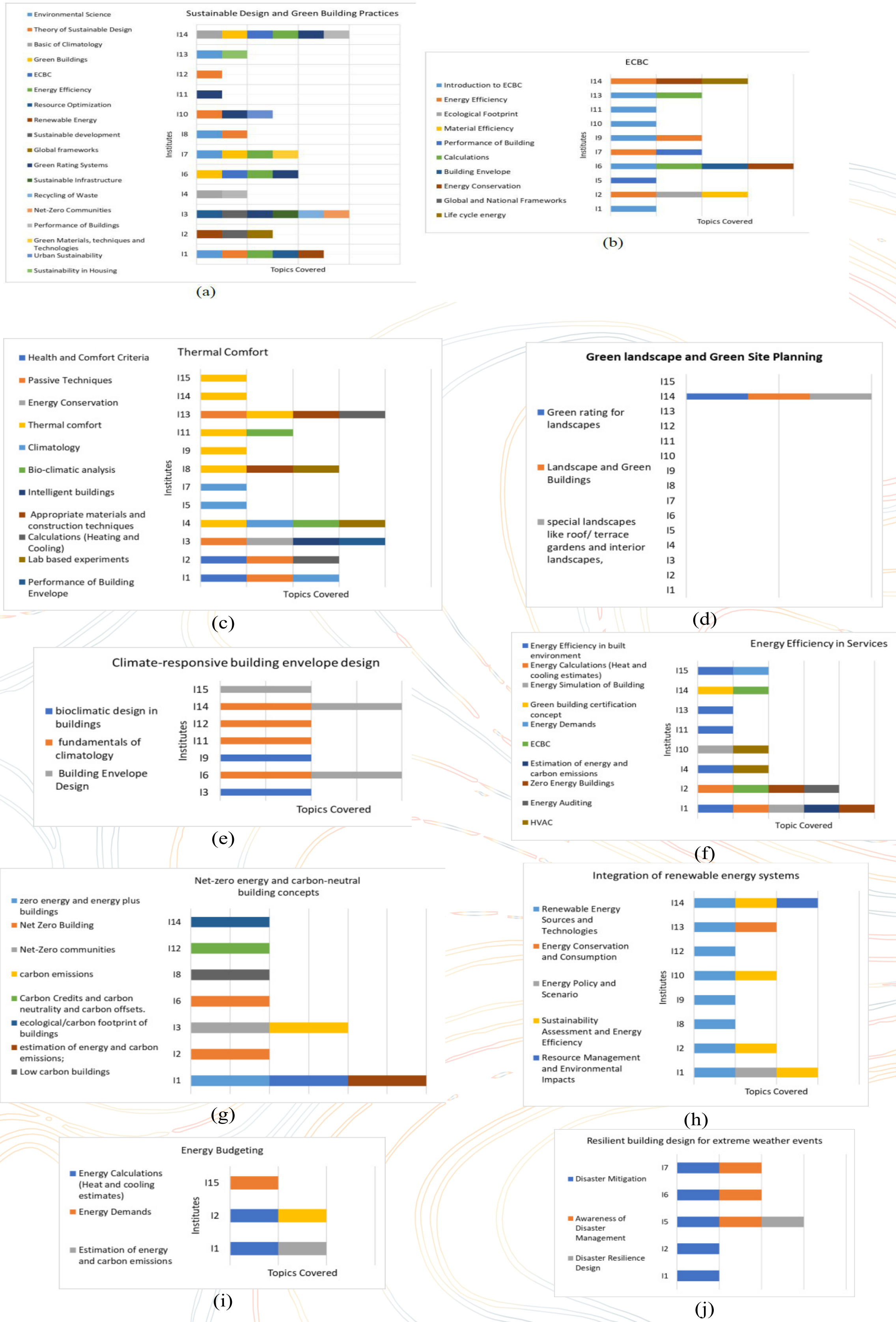

Figure 4: The diagram shows the theoretical topics covered under (a) Sustainable Design and Green building Practices, (b) ECBC, (c) Thermal Comfort, (d) Green landscape and Green Site Planning, (e) Climate-responsive building envelope design, (f) energy efficiency in services, (g) Net-zero energy and carbon-neutral building, (h) Integration of renewable energy systems,(i) Energy budgeting and (j) Resilient building design for extreme weather events covered by different institutes.

Thermal Comfort (refer Figure 4c) receives attention from 12 institutes, often addressed in foundational years through theoretical courses. Comprehensive integration with design is limited to a few institutions, underscoring a gap between theory and application. Conversely, Green Landscape and Green Site Planning (Figure 4d) suffer from limited representation, with only one institute offering an elective course, potentially hindering professionals' readiness to tackle climate change challenges.

Climate-responsive building envelope design (refer Figure 4e), covered by 7 institutes, imparts theoretical principles through core and elective courses. However, the focus remains predominantly theoretical. Energy Efficiency in services (refer Figure 4f) gets coverage in 8 institutes, providing a solid theoretical foundation, yet struggling to seamlessly merge with architecture design—an endeavour that requires interdisciplinary collaboration.

Net-zero energy and carbon-neutral building concepts (refer Figure 4g), while not explicitly covered, are touched upon in other subjects across the institutes. This rudimentary treatment underscores the necessity for in-depth understanding to create environmentally sustainable environments. Integration of renewable energy systems (refer Figure 4h) finds inclusion in 8 institutes, yet the syllabi emphasize basic theory and concepts over practical integration within architecture projects. Energy Budgeting (refer Figure 4i), despite its growing importance in the context of sustainability, remains largely absent from direct coverage within the curricula. Only a few institutes embed it within related subjects, revealing a potential gap in holistic energy management education. Lastly, Resilient building design for extreme weather events (refer Figure 4j) is considered by 5 institutes, with theoretical aspects explored in elective courses. While these courses provide foundational insights, they lack comprehensive in-depth coverage.

Collectively, these observations emphasize the need for bridging the gap between theoretical knowledge and practical design integration across a range of crucial building science topics. The study suggests opportunities for curricular enhancements to equip aspiring architects with comprehensive skills for creating sustainable, resilient, and energy-efficient built environments in the face of evolving challenges.

3.3. Integration with Design Studio

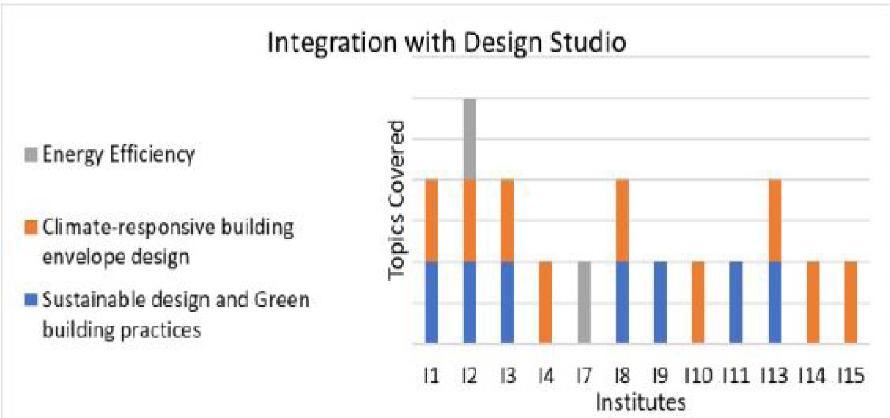

Figure 5: The diagram above shows the topics integrated into the design studio by different institutes.

Sustainable design and Green Practices, Climate-responsive building envelope design, and Energy Efficiency are integrated into Design Studios in just 12 institutes. The thrust area of the design studios primarily emphasizes site analysis, climatological factors (sun path, wind direction, orientation), and Sustainable design principles. Few institutes prioritize design studios centered on energy efficiency in services. Evident disparities between theory and design highlight a substantial gap in translating theoretical understanding into practical application.

4. Discussion

It's noteworthy that the results of the 15 institutes have implications for a broader educational landscape, as other institutions often look up to these top institutes. However, these findings reveal a concerning gap in incorporating the urgent needs of today's time.

4.1. Findings of this study

The outcomes reveal that certain subjects are included largely in theoretical manner, while others are visibly lacking from the syllabi. Several factors contribute to these results and offer explanations for the inferences drawn.

1. Emphasis on Theoretical Learnings: A significant reason for the outcomes is the syllabi's strong theoretical orientation. While some building science topics are covered, they often stay at a basic theoretical level with little focus on practical application or integration into design studios. This gap limits students' ability to apply theory to real-world situations, potentially leaving professionals ill-equipped to tackle climate change challenges practically.

2. Insufficient Focus on Key Issues: The assessment also highlights gaps in covering crucial building science topics. For instance, the absence of direct inclusion and integration of subjects like "Net-Zero Energy and Carbon-Neutral Building Concepts" and "Energy Budgeting" may hinder addressing India's sustainability goals.

3. Ambiguous Syllabus Guidelines: The ambiguity in Council of Architecture (COA) syllabus guidelines might contribute to the observed outcomes. Without clear directives that emphasize the integration of climate-related building science topics, educational institutions might struggle to design syllabi that adequately prepare students. This lack of a focused framework could result in fragmented teaching approaches, hindering a holistic understanding. The COA guidelines also miss out on providing a clear focus on the Technology stream, under which Building Science topics fall, further intensifying the issue.

4. Faculty Capacity and Expertise: Faculty expertise plays a vital role. Building science subjects require specific skills. Insufficient faculty knowledge might create a mismatch between curriculum intent and delivery. If faculties lack climate change training, academia might not meet evolving architecture needs.

5. Potential for Industry Marginalization: Limited education on climate-related building science could marginalize architects in broader design and construction fields. Engineers and sustainability experts might take a lead if architects aren't equipped to address these challenges. This shift could weaken architects' role in shaping holistic and integrated designs. \

6. Lack of Examination and Licensure: There is a need for a formal examination and licensure mechanism by the COA to evaluate architects' knowledge of climate change and building science, post degree completion. This examination would ensure that licensed professionals are well-prepared to address future challenges in their practice.

7. Scope and Limitation of the Study: It's essential to recognize study limits. Though the assessment focused on syllabi, it only scratched the surface of course and design studio structures. Pedagogy, teaching methods, and classroom effectiveness weren't explored. Thus, assessing actual knowledge transfer and skill development in classrooms falls outside this study's scope.

4.2. Recommendations

A set of recommendations and guidelines are proposed, aimed at enhancing the preparedness of future architects to address climate change challenges and contribute effectively to building a sustainable and resilient environment. The guidelines for Building Science Integration are as follows:

2. Fixed Percentage Allocation: Institutes should allocate a fixed percentage of their syllabi to building science topics related to climate change adaptation. This allocation ensures that these

crucial subjects are given due attention and prominence in the curriculum.

3. Compulsory Core Topics: Certain building science topics, such as Sustainable Design and Green Building Practices, Climate-Responsive Building Envelope Design, Energy Efficiency in Services, and Resilient building design for extreme weather events should be made compulsory core subjects in the curriculum. This ensures that all students gain a fundamental understanding of these critical areas. Practical lab-based activities and hands-on experiences should be integrated.

4. Application in Design Studio: Building science topics should be holistically integrated into design studios. This integration should focus on practical application, skill development, and real-world implementation. The orientation of the Design projects should be framed to challenge students to address climate change issues through innovative and sustainable design solutions.

5. Dynamic Syllabus Upgradation: The syllabi and course content should be regularly updated to reflect the evolving challenges and emerging issues such as climate change adaptation. A dynamic approach ensures that students are equipped with the most relevant and current knowledge in the field.

6. Skill Development for Climate Adaptation: The education system should emphasize skill development that equips students with the tools and techniques to design climate-adaptable and resilient structures. Practical exercises, case studies, site visits, and hands-on experiences should be integrated to enhance their ability to interpret theoretical knowledge into practical solutions.

The conceptual framework in Figure 6 shows the integration of 10 building science topics as theory subjects and design studio topics across different semesters, with some topics only being introduced.

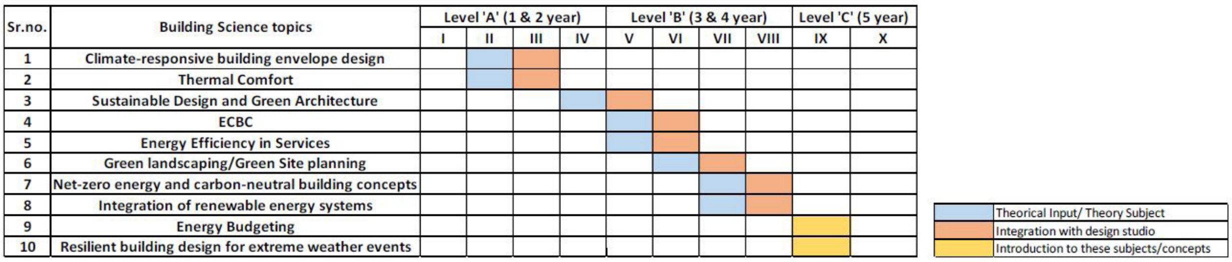

Figure 6: The diagram above shows a conceptual framework for integrating building science topics with the curriculum.

4.3. Application of the Study

The findings and recommendations of this study have practical implications for architecture institutes and the architecture profession as a whole. Institutes can use the results as a guideline to revise and enhance their syllabi, ensuring that their students are well-prepared to tackle climate change challenges in their professional careers. COA, in partnership with industry experts, professionals, and educational institutions, should endorse the proposed framework aimed at integrating building science into the curriculum. To ensure the successful implementation of this framework, it is imperative to focus on faculty training. Additionally, there is a need to establish hands-on learning labs in various educational institutions through a collaborative effort with COA. Furthermore, the paper suggests the necessity of implementing a structured mechanism for continuous review and curriculum updates. This approach will help ensure that the curriculum remains aligned with current industry standards and evolving future challenges.

4.4. Future Scope

Looking ahead, there is a scope for qualitative analysis to complement this study's quantitative assessment. Surveys and interviews with students, faculties, and industry professionals can provide deeper insights into the effectiveness of teaching methods, the perception of students on the integration of building science topics, and the real-world impact of education. Such qualitative data can enrich the understanding of the challenges and opportunities within architecture education.

Additionally, the methodology employed in this study can serve as a reference for similar assessments in other thematic areas, such as sustainability, urban planning, or heritage conservation. By adapting the framework to different contexts, researchers can explore the integration of diverse subjects in higher education curricula, ultimately contributing to the advancement of various fields. The recommendations and insights provided by this study pave the way for a more holistic and practical approach to educating architects who will play a pivotal role in designing a sustainable and resilient future built environment.

5. Conclusion

Through a comprehensive analysis of syllabi from 15 selected institutes, the research provided insights into the current state of education in this critical domain. The findings revealed both trends and notable gaps, shedding light on the preparedness of future architects to tackle the challenges posed by climate change in the built environment. The study's findings underscore the urgency for reforms in architecture education. To address the limitations identified, a set of comprehensive recommendations and guidelines were proposed. These include the allocation of fixed percentages for building science topics, compulsory inclusion of certain core subjects, seamless integration with design studios to emphasize practical application, dynamic syllabus upgradation, and a heightened focus on skill development for climate adaptation.
In conclusion, this research brings to light the focal role that architecture education plays in shaping professionals who are capable of designing sustainable and resilient built environments. The findings advocate for an educational paradigm that bridges the gap between theoretical knowledge and practical implementation, ensuring that future architects are equipped to address climate change challenges with innovative, effective, and holistic solutions.

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