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An Educational Framework for a Net Zero Future

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Highlights

- The primary objective of the paper is to evaluate the current state of education curricula to build capacity in students to design net zero resilient buildings with the literature review of formal education curriculum, continuing education programs, and competitions aimed towards building capacity for designing climate resilient buildings.
- This paper finds that building sector education needs to be interdisciplinary with competencies and knowledge in three areas - Climate Literacy, Climate Justice, and Climate Action.
- This paper also finds that among the curricula and education programs reviewed, the ten contests of the Solar Decathlon India and the education resources provided in the challenge form a robust framework that could be used in education curricula in India.

Abstract

This paper evaluates the current model curricula in India for architecture and engineering colleges as well as education policy documents that will influence the coursework taught across the country to determine if the undergraduate and post-graduate education system is aimed at creating future professionals who can respond to India's Nationally Determined Contributions and net-zero by 2070 goal. It uses literature review and survey data to identify gaps in graduate attributes and competencies that result from these curricula and policy documents. While over fifteen years of codes and rating systems, and longer for industry-led practices, have introduced standards and best practices, the market has not moved towards future-proof net-zero buildings. The findings show that the model curricula do not address climate change and that comprehensive frameworks, as well as transformative education at scale, are being done through other programs like Solar Decathlon India (SDI).

Keywords: Net Zero buildings, education, curriculum, Climate change, evidence-based design

Introduction

At COP26 in 2021, India committed to achieving net-zero by 2070 and followed it up with an update to the Nationally Determined Contribution in August 2022 [1]. It is a challenging task for India to manage the emission targets amidst population growth, rapid urbanization, increased manufacturing, mining, and infrastructure development activities, as well as unprecedented growth in energy demand over the next few decades. Amidst these challenges, ensuring climate justice becomes imperative, as marginalized communities should not bear the disproportionate burden of transitioning to net-zero while facing the impacts of industrial growth and urban development.

An integral aspect of urban development is embodied in buildings, and this sector alone contributes 33% to carbon emissions [2]. This presents an opportunity for the building sector to future-proof infrastructure in the decades to follow. Net-Zero Energy Buildings (NZEBs) can help reduce energy demand in buildings as they are energy-efficient and give back clean electricity to the grid. However, the uptake and enforcement of energy codes and rating systems are weak, and the building sector largely operates in a business-as-usual mode [3]. Therefore, it is crucial to tighten and target these codes and standards towards achieving net-zero energy and net-zero water to meet India's 2070 goal.

There is also a capacity gap among building professionals in designing and implementing NZEBs. Out of over 500,000 students graduating annually from courses related to the built environment in India, a meagre 50 receive formal training to deliver NZEBs [4]. To address this gap and foster sustainable development, climate literacy, climate action, and climate justice (henceforth called the climate trifecta) must be seamlessly integrated into the education system for building professionals.

A review of the current status of the education system for building professions shows that students are not given the training and resources necessary to address climate change in their careers [5]. In higher education, there is currently no coursework related to climate change or net zero energy buildings. Moreover, the coursework offered is not comprehensive and not mandatory [6]. The All India Council for Technical Education (AICTE) and the Council of Architecture (CoA), which are national statutory bodies responsible for the development of the technical educational curriculum for engineering and architecture, only offer coursework on concepts of climate, thermal comfort, and passive design for the architecture curriculum [7], [8], [9]. In engineering courses, coursework on energy efficiency in electrical systems is provided.

Other educational programs that are not formally a part of the curriculum, such as education modules provided by the green building rating system authorities and the Solar Decathlon India (SDI) challenge, may be able to fill the gap. Therefore, the objectives of this paper are to:

- Assess the state of the curriculum for higher education and its gaps through a literature review.
- Assess the capacity building efforts outside the formal undergraduate and post-graduate coursework.
- Identify a possible comprehensive educational framework for the climate trifecta.

Method

Our method contains five steps to research:

1. The first step is a literature review to identify any recent updates to higher education curricula internationally in response to climate change imperatives.
2. The second step is to review any changes included or proposed at a national level by the CoA or the AICTE. This review looks beyond changes to individual course content or new courses focused on climate change that were introduced in isolation. Rather, the review is conducted to identify structural changes in the curricula or systemic changes to the curricula related to the education of building design, construction, and operation.
3. Next, a review of the educational content provided for professional accreditation and continuing education in the building industry by various Green Building Councils and rating organizations. First, it was assessed if the content was intended for and accessible to students. If yes, then it was reviewed whether individual courses and the systemic curricula were relevant to climate change.
4. The fourth step is to assess distance learning or hybrid learning programmes and competitions that aid in building capacity toward net-zero building design. NPTEL, Green Rating for Integrated Habitat (GRIHA) Trophy, Indian Green Building Council (IGBC) Green Design competition, and the SDI Net-Zero Building Challenge are some of the platforms/programmes that enable capacity building for climate action.
5. Within these learning programmes, the paper identified SDI as the most comprehensive and accessible one and assessed its robustness and its role in building capacity for the climate trifecta. This is done in two parts:
    a. Assessing the scores given by the Jury members of SDI and analyzing if the scores of the teams meet the expectations of the Jury based on the evaluation criteria given by SDI.
    b. Assessing a self-evaluation test given to faculty on how they rate their areas of expertise before and after participating in the SDI program.

Results

1. Literature Review of architectural curriculum internationally

A recent study investigated architectural curricula in select international educational institutions outside

India, as directed by the CoA subcommittee, focused on integrating climate change syllabi into India's architectural education. Institutions studied included UCLA, Cornell University, MIT, University of Melbourne, University of Sydney, and National University of Singapore's College of Design and Engineering. Results indicated no dedicated climate change syllabi at the undergraduate level, though building science courses like passive environmental design, energy and water conservation, indoor environmental quality, and energy modelling were integrated across academic levels. Several governing bodies and institutions were reviewing their architectural curricula.

Notably, the Australian Institute of Architects recommended adding Climate Literacy and Action in Architecture Education. RIBA stated that climate change awareness is a core competence for chartered architects, while the Technological University of Dublin emphasized curriculum reform with climate-related subjects. Arch4Change, a collaboration supported by the Erasmus+ Programme, created a forward-looking climate emergency curriculum for 21st-century architectural education. Emphasizing restorative, inclusive design and climate justice, this curriculum aims for radical transformation toward carbon neutrality.

In conclusion, certain universities and institutions are already in the process of developing undergraduate architectural curricula that include climate change courses. These endeavors signify a growing recognition of the need to equip future architects with the knowledge and skills to address climate challenges in their practice.

2. Review of architectural curriculum in India

The CoA, responsible for architectural education standards in India, recently updated minimum standards in the 'Council of Architecture (Minimum Standards of Architectural Education) Regulations, 2020' [8]. These changes emphasize compulsory studies in building sciences and applied engineering.

Among the ten subject areas, only 3 are loosely related to climate action. The document also outlines 20 optional professional elective courses, with only 3 relevant to climate action - green buildings, sustainable cities, and building performance. While these courses offer insight into climate change mitigation, they lack a comprehensive understanding of its causes, impacts, and effects on vulnerable groups. This reveals a deficiency in the architecture curriculum's approach to addressing climate change in an integrated and multi-disciplinary manner. Similar to the CoA, the All India Council for Technical Education (AICTE), which is the national statutory body governing higher education for engineering courses, the coursework includes concepts of thermal comfort and passive design for those with an electrical and mechanical engineering background. These courses are, however, not comprehensive, nor are they compulsory.

Recognising the reform proposed in the National Education Policy of India 2020 (NEP 2020), the CoA prepared an 'Interim Report - Architecture Education Way Ahead, in Pursuit of Education Reforms' [10] to revamp architectural education in India. While the report proposed subject areas and competencies, it overlooked climate change as the biggest environmental, economic, and equity challenge. It lacked subject areas in context to climate action, climate justice, climate literacy, interdisciplinary collaboration, and building performance. A sub-committee has been established by the CoA to develop and prepare a syllabus for climate change to be added to the architecture curriculum and also to suggest ways and means to sensitise architects on the issue for achieving Net Zero Carbon Targets by India [11].

The sub-committee conducted an online survey with all registered architecture colleges in India to assess the gaps and strengths in their architectural education related to climate change. CoA curriculum reviews show that climate analysis, thermal comfort, passive design, and energy efficiency courses are not mandatory or comprehensive for architecture and engineering programs. Further, specific coursework related to Building Performance Simulations (BPS) is not offered.

Nalla et al. (2023) [12], in their review of curricula in India for adaptive pathways for resilient infrastructure for economic development, poverty reduction, and climate action, stress the importance of interdisciplinarity, critical thinking, and reflexivity, reflected in the elements of content, pedagogy, and delivery. They note that while some master's programs in Civil Engineering or Water Resource Engineering build an understanding of water distribution and result in requisite skills to design a drainage system to address the issue of flooding, their training only equips them to address the physical vulnerabilities. They argue that the education content does not build responsiveness and sensitivity to the vulnerabilities and needs of the most disadvantaged and marginalised communities and that education on climate action needs to be underpinned with an appreciation for equity and differential vulnerability in the form of climate justice.

3. Review of continuing education programs

Various green building rating systems like EDGE, LEED, GRIHA, and IGBC offer accreditation programs to professionals for a deeper understanding of the system and project facilitation. Accreditation exams evaluate broad green building comprehension and specific rating system knowledge. Only LEED's Green Associate (GA) credential is available to students. Preparing for the GA exam enhances green building knowledge within the rating system framework, particularly in site, water, energy, materials, and indoor quality aspects. However, it lacks comprehensive skills for designing net-zero energy-water buildings and resilient design and falls short on climate literacy and justice, limiting its climate action scope.

The United States Green Building Council (USGBC) provides over 1,000 e-learning courses for continuing education for LEED professionals, which are accessible to students too. Courses span basic, intermediate, and advanced levels, covering energy efficiency, materials, carbon, comfort, air quality, and more. While valuable for climate literacy and justice, these courses inadequately address skills crucial for climate action, especially resilient, carbon-neutral design. The platform's curated playlists by discipline and topic offer a starting point but lack a structured learning path.

Table 1. Review of continuing education programs aimed at capacity building for students and professionals

Organization	Program/platform	What is offered by the program/ platform
USGBC	Education@USGBC	e-learning platform of more than 1000 courses on green buildings and sustainability concepts aimed at continuing education for green building professionals, which is also accessible to students. 2 colleges in India have Campus subscriptions that give their students free access to all the courses on the platform
IFC	Design for Greater Efficiency (DfGE)	DfGE covers the fundamentals of energy and resource efficiency measures in building design from a technical and commercial perspective. The course also introduces the IFC EDGE online tool to assess the energy, water, and carbon metrics of a building. 5 day program to train the faculty, who will, in turn, train the students.

The International Finance Corporation (IFC) offers a Train-the-Trainer certification program for faculty of architecture, structural, and building services engineering colleges called 'Design for Greater Efficiency' (DfGE). The week-long program covers the fundamentals of energy and resource efficiency measures in building design, HVAC controls, lighting, and photovoltaics from a technical and commercial perspective. The program also introduces the IFC EDGE online tool to assess the energy and carbon emissions of a building design, using which the learners demonstrate their understanding of a sample project. When faculty train the students, it is expected to have a secondary effect in building capacity for climate action. DfGE is a good resource for faculty, but it too largely ignores climate literacy and climate justice while addressing climate action with issues that relate to the EDGE rating.

4. Review of the distance/hybrid learning programs and competitions

Massive Online Open Courses (MOOC) developed by seven Indian Institutes of Technology (IIT) under the National Programme on Technology Enhanced Learning (NPTEL) offer certified online courses to students across the country in various disciplines, including architecture and civil engineering (Table 2). These distance learning courses cover topics such as building science concepts, sustainable design guidelines, materials, daylight, and others. While the individual topics are relevant to climate change, they do not cover the entire gamut of skills required to design a net-zero building, such as building performance simulation and evidence-based approach to design, among others.

The Indo-Swiss Building Energy Efficiency Project (BEEP) organised an annual hands-on educational event for students called the BEEP Camp over the last several years to build capacity for designing energy-efficient buildings through an integrated design process. The program emphasises fundamentals of building physics, passive strategies, thermal comfort, cooling processes, ventilation, daylighting, building simulation, and monitoring in a hands-on, immersive learning experience. All these topics are relevant to building competencies for climate action related to net-zero buildings. However, it appears that there is less emphasis on resilient design and climate justice, which includes competencies in assessing vulnerability, risk, and resilience. The BEEP programme has now been turned over to the Bureau of Energy Efficiency, and its continuity in its past form is uncertain.

Table 2: Review of distance/hybrid learning programs for building capacity among students

Organization	Program/platform	What is offered by the program/ platform
National Programme on Technology Enhanced Learning (NPTEL)	MOOCs on various disciplines developed by seven Indian Institutes of Technology (IIT)	• *Courses under Architecture discipline:* Strategies for sustainable design • *Courses under Civil engineering discipline:* Sustainable Materials and Green Buildings, Sustainable Engineering Concepts And Life Cycle Analysis, Principles and Applications of Building Science Energy Efficiency, Acoustics and daylighting in Building Glass in buildings: Design and Application
Indo-Swiss Building Energy Efficiency Project (BEEP)	BEEP camp	• Annual hands-on educational event to build capacity in students. • Content covers fundamentals of building physics with multi-disciplinary working sessions. • Program brings leading practitioners and educators from the building energy efficiency sector to teach the students the latest and relevant skills and knowledge.

GRIHA, India's Green Building Rating System, hosts an annual net-zero design competition awarding the GRIHA Trophy. Held at the National Association for Students in Architecture Convention, it targets Indian undergraduates in Architecture. The design brief expects sustainable, climate-responsive designs, excluding resilience and climate justice. Organizers offer no resources, leaving students to self-learn climate trifecta aspects, excluding engineering students.

The IGBC organizes the Green Building Design competition for Indian undergraduates and post-graduates in architecture, planning, and design. It evaluates sustainable strategies, feasibility, and scalability, not requiring comprehensive or evidence-based entries. IGBC lacks green design resources, excluding engineers.

The SDI Net-Zero Building Challenge targets multi-disciplinary teams of Indian post-graduates and undergraduates, partnering with developers for real projects. SDI provides learning resources like modules, webinars, and mentors. They encourage various disciplines, providing education and competition criteria linked to the climate trifecta.

Table 3: Review of competitions for building capacity among students

Competition	Participating criteria	Learning resources offered
GRIHA Trophy	• Background: Undergraduates in Architecture • No. of participants: 2 Students per institution	-
IGBC Green Building Design	• Background: Undergraduates or pos-tgraduates in Architecture, Planning and Design • No. of participants: 2 per team + Faculty	-
Solar Decathlon India Net-Zero Building Challenge	• Background: Undergraduates or Post-graduates (all backgrounds) with at least 1 architecture, 1 engineering student • No. of participants: 5-15 per team + Faculty Lead + Real Estate developer	• Online Self-Learning Modules • Live Webinars • Simulation workshops • FDP

5. Assessment of SDI

Apart from the educational resources mentioned above, the SDI challenge has ten contests for participating teams, and these contests are the framework for evaluating student work. The ten contests include issues of energy, water, embodied carbon, resilience, affordability, building operations, and innovation, among others. These contests and their evaluation criteria have evolved over three years of the SDI challenge in the following key phases:

1. Year 1: Review of metrics to design net-zero buildings worldwide to develop the first version of the ten contests.
2. Year 2: Focus group discussions with experts, including industry and educators, and feedback from the Jury to revise the contests and develop detailed criteria for each contest.
3. Year 3: Learning from Year 2 and feedback from the Jury to refine the contests and and criteria.

The 10 contests in year 3 are shown in Table 4. SDI commnuciates the contests and their requirements to the participants as well as the Jury and revises its educational resources each year to ensure that students and faculty are supported in their learning to be successful in developing net-zero and resilient building solutions. Since each contest holds equal weightage and teams need to perform well across all 10 contests for a successful submission, SDI ensures a balanced approach to the climate trifecta at a team level.

Table 4: Ten contests and their evaluation criteria as of year 3

Contest Name	Contest Description	Evaluation Criteria
Energy Performance	Evaluates net-zero building design as a super-efficient building that generates renewable energy on-site as well as the capability of the building systems to interact with an electricity grid, with on-site or stored power. Teams are evaluated based on their solutions to achieve a low energy performance index and net-zero annual energy use.	• Reduction of loads demonstrated with annual energy analysis • Integration of low energy comfort systems • Integration of sufficient renewable energy generation on site • Smart grid interaction capabilities
Water Performance	Evaluates a net-zero water building regarding the design and management of on-site water resources towards a fully watersufficient development. Teams should provide a water-cycle design supported by detailed water calculations. Teams are evaluated based on their solutions to achieve low per capita water demand and net-zero annual water performance.	• Minimizing water usage • Sufficient use of harvested rainwater, recycled water, and treated wastewater returned to a public source • Optimisation of on-site storage and recharge of groundwater
Resilience	Evaluates the building's ability to adapt to changing environmental conditions and the ability to maintain functionality in the face of stress or disturbance.	• Assessment of potential risks • Improved physical integrity • Quantification of resilience demonstrated through calculations for passive performance and autonomy for critical functions • Improved operational continuity through a risk management and recovery plans
Affordability	Evaluates the building's financial costs for initial investment and ongoing operations. Teams must look at operations and maintenance costs that determine the total cost of ownership.	• Construction cost analysis for rightsizing, use of local or repurposed materials, and other strategies • Financing cost analysis for faster construction methods • Lifecycle cost analysis

Innovation	Evaluates the application of innovative techniques, technologies, or business models through creative approaches to enhance performance in other contest areas. It requires the team to identify specific problems in the region or the market and present their innovation as a solution to those problems and explore ongoing research and development activities within or disruptive technologies outside the buildings sector.	• Complete narrative based on the Innovation guidelines • Integration of innovation in the design
Health and wellbeing	Evaluates the building's capability to provide thermal comfort and good indoor environmental quality, which is essential for ensuring occupants' health and wellbeing. Teams are evaluated based on their solution to provide indoor thermal comfort for all occupied hours and desired indoor air quality and fresh air.	For thermal comfort • Provision of indoor thermal comfort based on a chosen standard • Annual simulations demonstrating thermal comfort • Strategies for reducing thermal stress in the outdoor environment and minimising thermal shock in transitional spaces. For ventilation and air quality
		• Provision of desired indoor air quality and adequate fresh air • Simulations or sizing calculations to achieve the above for natural and mechanical ventilation
Engineering and operations	Evaluates the effective integration of high-performance engineering systems and understanding of building operations. Teams are expected to provide an operation and maintenance plan for the building. The operation plan should include the key quantities that should be measured during the operation to ensure high performance.	• Engineering system design and right-sizing • Constructability at scale in terms of availability of material, technology, and labour For smart building operation: • Building operation narrative that lists the Do's and Dont's for the proposed building systems, along with a list of key parameters to measure the performance of the building • Building automation and control with control narratives and schematics
Architectural design	Evaluates the architectural design for its creativity, integration of systems, and ability to deliver functionality and aesthetic appeal desired by the market or client. Teams are encouraged to bring together aesthetics with sound building science, performance, comfort, affordability, and resilience.	• Use of an integrated, evidence-based, and creative process • Generation of an appropriate aesthetic and user experience for the end users at site, building, and interiors • Functionality and efficiency in terms of circulation, space allocation, servicing, adjacencies, densities for the site, building, and interiors • Integration of building systems and enabling their performance to respond to the other contests for the site, building, and interiors.
Embodied Carbon	Evaluates the design for the use of building materials and construction technologies that reduce embodied carbon emissions, which is essential for net-zero global emissions. Teams should demonstrate, through calculations, the reduction of carbon emissions in their design compared to a baseline.	• Narrative of the low embodied carbon materials and construction technologies • Reduction of embodied carbon • Construction details demonstrating the integration of low embodied carbon materials and construction technologies
Value Proposition	Evaluates the team's ability to convey the value proposition of the design and its performance to relevant audiences. Teams are encouraged to provide a succinct and compelling narrative with clear messaging and articulating the value proposition to relevant audiences.	• Completeness and clarity of the project • Compelling narrative for end users with clear messaging and articulation of the value proposition.

Table 4 is the contest requirements as of year 3. In the first 2 years, there were contest areas such as 'Presentation', 'Communication', and 'Market Potential and Scalability'. Based on the feedback that the organisers received from the faculty mentors and Jury experts in year 3, the 'Market Potential',

'Presentation' and 'Communication' contest areas were refined and added to the 'Value Proposition' contest area. Further, the 'Scalability' contest area was added to the 'Affordability' contest area. In year 3, a new contest area, 'Embodied Carbon,' was added for the participants to tackle construction methods and building materials.

Reviewing the score of the finalist projects in Year 1, on average, 56% of teams produced designs supported with evidence through Building Performance Simulation (BPS) and calculations. In Year 2, the number increased by 12% [13].

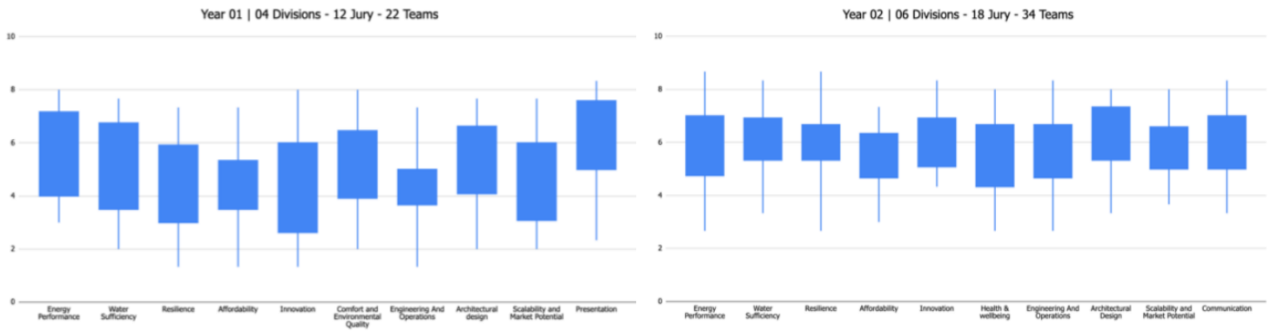

Figure 1: Based on feedback received by the Organisers, the presentation contest area was changed to 'Communication' in Year 2. In year 2, the competition guide was extensively refined to make it comprehensive for the participants

a. Review of Jury Scores

The authors of the paper analysed the scores given by the Jury members, who consisted of experts from the industry with deep expertise in designing and implementing net-zero buildings in the real world. Each contest area had a maximum score of 10. In the first year, the median score of the final competition entries (n=22) was in the range of 4 to 6 out of 10 for every contest area. The energy performance and presentation contest areas saw the highest scores by the Jury.

In Year 2, the median score for the final entries ranged between 5 and 6.5 out of 10 (n=34). In Year 3 (Figure 2), the median scores ranged between 5 and 6 out of 10 (n=36).

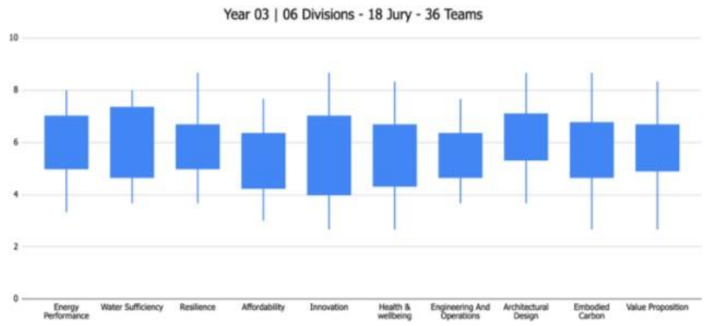

Figure 2: In year 3, the 'Market Potential' and 'Communications' were combined into 'Value Proposition'. 'Scalability' was merged with 'Affordability', and 'Embodied Carbon' was introduced as a new division.

The scoring rubric of SDI that is given to the Jury on a point scale of 1-10 [14] shows that scores between 5-6 are given when the student's work meets a minimum expectation of quality or is of very good quality.

b. Assessing Faculty expertise

In the SDI competition, each team is mentored by faculty members. At the beginning of year 3 of the challenge, the organisers conducted an FDP with the objective of training them to mentor the teams better. A self-assessment survey form was provided to the 40 faculty members at the program to document their expertise areas in the ten contest areas. While most faculty had expertise in Architectural design, their scores in other contest areas were lower. Another self-assessment survey was given to the faculty at the end of the challenge year after the finals. Figure 3 shows a comparison of their self-assessment scores at the beginning and the end of the challenge year. The data show a 10-30% increase in the scores of the faculty after they went through the SDI programme. The median scores of the faculty had improved by about 5% percent in contest areas like Energy performance, Engineering and Operations, and Architecture. The Embodied Carbon contest area saw the largest improvement in median scores, which was 15%.

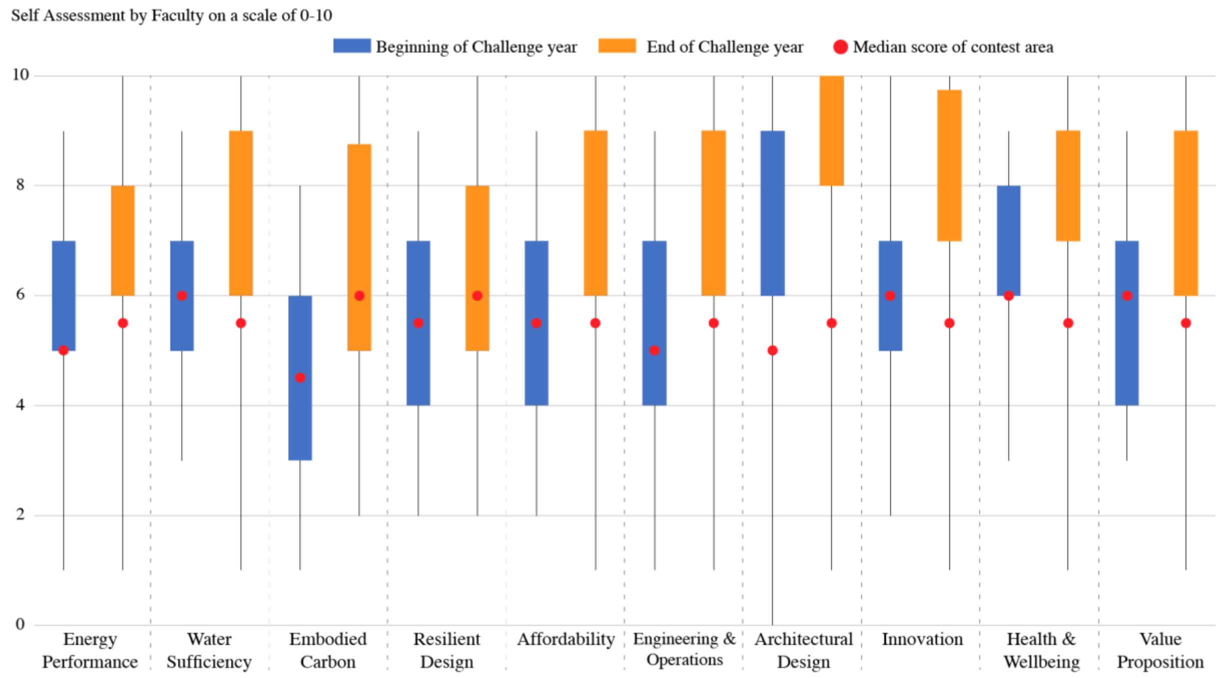

Figure 3: Self-assessment scores by faculty mentors in the SDI at the beginning and at the end of the SDI challenge.

From the scores given by the Jury members to the teams and from the self-assessment done at the beginning of the Challenge year by the faculty, it seemed like the teams did not do well in the subject areas in which their faculty did not have expertise. Contest areas such as Resilience, Affordability, Engineering, and operations, where the faculty lacked expertise (Figure 3), seemed to be the areas in which the teams also did not do well as per the Jury scores (Figure 2). This shows the importance of building capacity among faculty members as well as among students. Specific training sessions will be required in specific contest areas such as Resilience, Affordability Engineering, and operations.

Discussion

India's National Determined Contributions for the Paris Agreement entail a 45% reduction in carbon emissions intensity by 2030 and achieving net zero emissions by 2070. To attain these goals and mitigate emissions in the building sector, climate-resilient net-zero buildings are crucial. The building sector's long-term impact necessitates urgent enhancements in building performance due to its 150100-year lock-in effect.

This study asserts that interdisciplinary building sector education in architecture, civil, mechanical, and electrical engineering must cultivate competencies in the climate trifecta:

1. **Climate Literacy:** This encompasses comprehension of anthropogenic global warming, sectoral greenhouse gas contributions, climate change impacts on society and biodiversity, and relevant policies, including carbon credits and taxation.
2. **Climate Justice:** This entails recognizing regional and population vulnerabilities, equity issues, resilient infrastructure interconnectedness, and vulnerability assessment techniques.
3. **Climate Action:** This demands skills in crafting carbon-neutral buildings, zero waste strategies, disaster-resilient infrastructure, biodiversity enhancement, innovative product design, and evidence-based processes that align with regulations.

The faculty self-evaluation at the beginning of the SDI challenge indicates that the current higher education curriculum and the teachers are not ready to prepare for future building professionals for climate trifecta. The jury scores of the student teams and the faculty self-evaluation at the end of the SDI challenge provide evidence that large-scale improvement in abilities to address the climate trifecta is possible. The ten contests of the SDI challenge are broad enough to identify weaknesses or gaps in the curricula, and among the educational or training systems reviewed in the paper, these 10 contests seem to be comprehensive for the climate trifecta. SDI also appears to have a structured pedagogy with its combination of learning resources, faculty development program, and hands-on problem-solving for a real project. These elements can be included in coursework and curriculum, which also make the teaching more in alignment with the New Education Policy of 2020. Recently, the CoA of India has endorsed the SDI programme and has recommended that architecture schools across the country provide academic credit to participation in SDI. Stronger inclusion in the curriculum may result out of the work of the Climate Change Sub-Committee to the CoA. Meanwhile, another way to integrate the programme into the coursework is to include the 10 contest areas as learning objectives for courses that are taught in the curriculum. The self-learning modules and learning resources could be offered as learning resources or MOOCs to help the faculty to teach without having to create the learning materials themselves.

Conclusion

The current architectural undergraduate curriculum lacks focus on climate change and zero-energy buildings. Existing coursework, though not mandatory, lacks depth. National bodies AICTE and CoA recommend minimal energy-related courses. Some engineering programs address physical climate vulnerability. Climate literacy, action, and justice aspects are absent.

Certain international institutions are developing undergraduate architecture curricula incorporating climate change courses.

Continuing education in the building industry introduces learners to evidence-based design and climate literacy; however, NZEB design requires comprehensive, evidence-based design, and the SDI competition covers ten areas of expertise, enhances climate literacy, addresses climate justice, drives participants to practice climate action and provides the educational materials to achieve the trifecta. The SDI framework can help to revise technical higher-education and enhance faculty and student capacities for teaching and learning.

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