Integrating Building Energy Efficiency into Architecture and Engineering Academic Curricula – Phase II

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1 Background

India is the fastest-growing major economy in the world. It is the fourth largest greenhouse gas emitter, accounting for 5.8 percent of global emissions. India's emissions increased by 67.1 percent between 1990 and 2012 and are projected to grow 85 percent by 2030 under a business as usual scenario[1].

As one of the major steps towards climate change mitigation, India ratified the Paris Agreement in December 2015, committing to reduce its carbon emissions intensity per unit GDP from 33% to 35% below 2005 by 2030. This is now in preparation to be implemented as a nationally adopted goal. It is further estimated that India's building sector is expected to grow 4 to 5 times its current size[2], thereby increasing the energy demand and emissions. The cooling sector would be one of the main drivers of energy demand. Electricity consumption amongst commercial buildings in India is growing 11-12% annually[3]. The share of air conditioning in commercial building energy consumption in 2012 is 23% and is expected to grow to 55% by 2030. The amount of Window and Split ACs in operation in India is expected to grow from 32 million in 2015 to 225 million by 2035, which could emit approximately 338 MT CO2e (approx. 12% of India's total 2010 emissions) by the year 2030[4]. Furthermore, the production of energy required to run conventional ACs installed in Indian commercial and residential buildings are expected to require 1,010 additional power plants by 2030. The amount of energy (and related GHG emissions) necessary to cool Indian building interiors in the years ahead will depend on how they are designed and built today, and in the coming years, on which technology is used for cooling the residual heat load, as well as on how occupants operate their cooling equipment.

Considerable amounts of energy demand and GHG emissions could be avoided while maintaining comfortable interior temperatures, provided adequate technologies, know-how, information and behavior are transmitted and aimed at the key stakeholders. Hence, while there is considerable know-how related to indoor comfort conditioning and energy efficient building design in India, the rate of uptake of these approaches remains extremely marginal. Reduced uptake of efficient cooling technologies compounded by a rapid expansion of built spaces in India with a lack of attention to bioclimatic architecture locks-in the current useless and toxic surge in energy consumption.

Additionally, out of 2,888 architecture students graduating each year from India's top 55 architecture colleges, less than 25% of these colleges offer courses that embed energy efficiency or sustainable design knowledge into student's critical thinking and design skills[5]. Of these 25% colleges, only 3 to 4 courses out of the 72 courses over the bachelor's degree course require the student to think of the environmental impact of their designs (including orientation of the building; using building materials that provide better insulation; appropriate shading devices and ratio of window to wall area that allows daylight to enter without exacerbating the load on the air conditioner; natural ventilation methods; etc.). Less than 5% of the curricula of India's architecture colleges offer basic knowledge on sustainable design and the environmental impact of the buildings they will design. Out of the 423 registered Architecture colleges, a total of 17,000 students graduate with deficient skills.

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[1] India's Climate and Energy Policies – Factsheet, October 2015, Centre for Climate and Energy Solutions, (C2ES)

[2] Energy Conservation and Commercialization (ECO-III), 2010

[3] Energy Statistic 2011, Central Statistics Office, Ministry of Statistics and Programme Implementation, Govt. of India (Website: http://www.mopsi.gov.in)

[4] World Bank Data for India's GHG emissions in 2010: 2864.44 MT CO_2e

[5] Internal cBalance Study, 2016.

Furthermore, professors across architecture and engineering colleges are left to grapple with a dearth of high-quality teaching aids: physical scale-models and virtual (animations etc.). Even the professors that have realized the lacunae are faced with insurmountable administrative complacency from decision making executives in colleges and academic regulatory bodies. There are no punitive consequences, financial incentives, and peer-pressure amongst colleges to transform curricula.

Moreover, the Energy Conservation Building Code (ECBC) and the Bureau of Energy Efficiency (BEE) Commercial Building Energy Performance Benchmarking Programme have established the concept of '*Benchmark Energy Performance Index'* values (kWh/m2/year) for various building usages and climatic conditions. However, these concepts have not yet transformed the Indian building energy consumption scenario due to a lack of awareness, skilled-capacity and insufficient emphasis on increasing uptake of these codes. This diminished skilled-capacity can only be addressed by updating the existing architecturecurricula.

Today, most architecture and engineering students lack comprehension towards fundamental concepts of building physics; psychrometry; comfort cooling techniques & technologies; and localized, contextualized models of adaptive thermal comfort; such as the India Model for Adaptive (Thermal) Comfort (IMAC)[6] which provides a progressive alternative to the hegemony of the ASHRAE-55 which has perpetuated a problematic culture of sealed air-conditioned buildings that has permeated the mainstream of building and HVAC design thinking in India.

However, even if ECBC becomes mandatory, presently, there isn't enough workforce that will be able to adequately handle its implementation.

The only way to address the aforementioned concerns is to work upstream, by building capacity within India's architecture and engineering colleges (those that teach Refrigeration & Air Conditioning) design. What is needed is to focus on horizontal and vertical integration, where relevant subjects are infused, subtly so that the changes made are unnoticed, thematically expanding the breadth of knowledge imparted from a current two-dimensional focus of 'space' and 'structure', to a three-dimensional realm. Sustainability thus becomes an equal third-axis that shapes the building design process.

The intervention under this phase takes many vital cues, derives impetus and reaffirmation from clear recommendations articulated in an exhaustive study conducted under the USAID ECO-3 Project related to Architectural Curriculum Enhancement for Promoting Sustainable Built Environment in India[7].

Previous research and experiences validated the merit of the following areas of further work: Technical course content development & enhancement, skill(s) enhancement/continuous learning for faculty members, integration of theory/elective courses with design studios, and infrastructure improvement (laboratories and library). As is evident from the subsequent dissection of the effort currently underway, this program moves towards institutionalizing these structural reforms in academic institutions engaged in shaping architecture pedagogy in India. While there are many elements of the intervention described herein that can be directly correlated to recommendations made by this seminal study conducted in 2010, its metaphysical underpinnings are rather distinctly different. Unlike the general 'capacity, material support, and content' reform focus of the precedent study, this program draws upon the elemental idea that sustainability in the built form is not a missing 'component' in the pedagogy, it is the missing third pillar, along with space and structure, which ought to be part of the ontological preoccupation of the practice of architecture. It is, as postulated by this

[6] Developed by Centre for Advanced Research in Building Science and Energy (CARBSE) at CEPT University in India.

[7] Sanyogita Manu, Anurag Bajpai, Satish Kumar, Shruti Narayan, and Ankur Tulsyan, International Resources Group, Rajan Rawal, CEPT University, Sudha Setty, Alliance to Save Energy

program, a form of reasoning, a invisible lens through which the built form must be critically viewed, which needs to be reinstated in a manner that is so intricately enmeshed with the core of its pedagogy that it cannot be cognitively separated without unravelling it entirely.

2 Phase II Project Overview

Co-devised by Noe21 (Geneva) and cBalance Solutions Hub (Pune), the Fairconditioning project aims to help countries in tropical regions address their cooling demand with the highest level of energy efficiency and lowest carbon emissions. June 2013 marked the beginning of this program, with the Pilot phase focusing on phasing-out air conditioners using synthetic (fluorinated) refrigerants having very high global warming potential and phasing-in energy efficient ACs that use natural refrigerants (propane), having close to zero global warming potential.

Fairconditioning is now a Building-Cooling Demand-Side-Management (DSM) education, capacity building, and pilot implementation programme. It focuses to achieve behavior change amongst occupants of conditioned indoor spaces reduce building heat loads and reduce energy and GHG intensity of artificial cooling systems. The program aims to do this by improving energy-efficiency (EE) in the continuing building boom, integrating the most energy efficient-technologies to address cooling load in buildings, and, influencing corporate consumer behavior.

2.1 Introduction to Phase II

The academic leg of Fairconditioning, aims to deeply integrate sustainability and EE into architecture curricula. This was achieved through a series of training, retraining, troubleshooting andcourse-correcting session commenced with Training of Trainers (ToT) workshop for architecture professors. The Academic Curricula Integration Project (ACIP) has been specifically designed to enhance action-oriented understanding of sustainable cooling technologies and efficient building design centered around ECBC and other relevant sustainable design building guidelines to facilitate a two-way process of learning.

These semester-long pilot engagement sessions greatly enhanced pedagogy knowledge and skills amongst architecture professors, facilitated activity-based learning processes amongst students, as well as prepared for the subsequent (Fairconditioning phase 2) seamless syllabus integration of sustainability and energy efficiency into official University-defined curricula.

The academic project deliberately avoided creation of *'additive'* curricula content (i.e. separate courses) for architecture colleges and instead worked in an *'integrative'* manner. ToT workshops seeked to inform the entire five-year educational curricula spanning architectural theory, design and technical subjects.

ACIP 2015 – 2016 Metrics

- **Architecture Professor Workshops** – 96 professors from 26 architecture colleges were trained through 6 'selected cities' workshops (Delhi/NCR, Mumbai, Bengaluru, Pune, Chennai, andJaipur)
- **Engineering Student Certification Workshop** – 317 students from 10 colleges were trained through 6 'selected cities' workshops (Delhi/NCR, Mumbai, Pune, Chennai, and Jaipur, Bengaluru)
- Memorandum of Understanding (MoUs) to bring the organisations formally into the project with 9 colleges weresigned

2.2 Diagnosis: Lacunaeidentified

Phase 1 implementation with 28 colleges have led to a refined diagnosis of persistent lacunae that the program (in Phase 2 implementation, underway from February 2017 onwards) addresses in its most evolved form (2017). This is what we learned:

2.2.1 *Deficient Tech Support*

- Technical training 'tech support' for architecture professors post ToT workshop is required for Climatology, i.e.: Psychrometrics, Refrigeration Cycle; Sustainable Cooling Technologies such as Direct/Indirect Evaporative Cooling, Structure/Radiant Cooling, Solar Vapor Absorption; Comparative Life-Cycle GHG Emissions Assessment of Passive Design and Sustainable CoolingTechnologies.
- Feedback from attending professors suggested that more time should be spent on sustainable cooling technologies, current best practices in sustainable architecture, rethinking pedagogy, and building physics concepts, possibly extending the workshop from a 3-day format to a 4 or 5-dayworkshop
- They also pointed to the lack of high-quality teaching aids (physical) and virtual (animations etc.), needed to convey building physics concepts and electro-mechanical processes of active coolingsystems.

2.2.2 *Administrative-Complacency*

- No punitive consequences, incentives, or pressures – financial (taxation or increased revenue incentives), social (peers), market (competitors), or professional (regulatory bodies) in the academic ecosystem ensuring curricula is upgraded to integrate passive design and sustainable cooling across the spectrum of learning/teachingopportunities.
- Administrative and intellectual complacency towards augmenting the existing syllabi to integrate concepts of energy efficiency through sustainable cooling technologies/methodologies and building design in parent educational institutions of participating professors despite MoU's being signed and approved by senior management of educationalinstitutions.
- Dis-interest amongst non-participating professors as a result from inadequate participation by colleges, in most cases does not translate to uptake of curriculaintegration.
- Tepid (National Institute of Advanced Studies in Architecture, NIASA), or inconsistent (Council of Architecture, COA) response from national capacity building and regulatory bodies in the context of training program certification, outreach support and mainstreaming. Diffuse, hierarchical nature in conjunction with significant flux of executive body membersharmslong-term engagement and delivery upon promises made.

2.2.3 *Siloed Education*

Siloes of sustainable cooling knowledge libraries, well-documented performance-based case studies, capabilities and project opportunities in all 6 cities where the Program operates: tenuous or absent networks amongst Architecture and Engineering Academic Institutions, between practitioner's (Sustainable Design Architects and Sustainable HVAC Suppliers, Designers, Consultants) and professors/students.

Narrative Transformation

Formal surveying, roundtables and feedback from preliminary workshops by Fairconditioning staff underscored that sustainability, environmentally responsible architecture, and energy efficiency related knowledge, where it is taught, is largely seen as a 'dry technical subject' by students. It is a secondary, at best a tertiary concern in their design philosophy and praxis. Knowledge available through prescribed 'texts' for these subjects is seen as inorganic, uninspiring content. Content that must be plugged into one's intellectual repository of facts, figures, techniques, and mechanical operations leading to objective answers during exams in one out of four colleges where such courses are even offered.

It is also tacitly understood by students and professors that real-world practice of commerce-driven architecture for a paying 'client' requires only structural and fire-safety norms to be strictly obeyed, their violations considered to be deeply unethical and illegal. Climate change and energy-scarcity impacts of buildings they design (either for design studios or as professionals) comprise, at best, a final 'layer' of unrelated mechanically assembled systems that will 'make' their original design sustainable. A building can be converted to a 'green' rated building through a series of final 'polishing' steps to address only a few of the most acute impacts after their root causes have been inadvertently integrated in the core design itself.

2.3 Energy Efficiency Potential

The program is expected to transform curricula in 30 Architecture Colleges as part of its large-scale pilot leading to evidence-based policy change. The *'negawatt'* potential of the project was assessed by computing the energy conservation potential of project designed by 'transformed' graduates versus conventional students designing business-as-usual buildings. The parameters used in the assessment and outcomes are indicated in *Table 1*and assumptions are highlighted below.

It is estimated that the project can lead to approximately 208 MW savings per college by the year 2050 and the cost per MW for achieving this scale of negawatt generation is approximately₹4,614/MW only.

The above calculation assumes that each batch across all Indian architecture colleges consists of 40 architecture students in their graduation year, with a 30% graduation ratio. Hence, 12 students would be moving on from education to practice per year. Furthermore, each student starts practice after 4 years from graduation. Therefore, with 3,617 practicing years till 2050, 3,445 building projects would have been undertaken (0.95 projects per year).

These 3,445 projects/buildings would occupy an average area of 17,000 sq. ft. per project/building (approximate area of a 6 to 10 storey residential building, based on interviews with architects from small-medium sized firms enlisted in the Fairconditioning network.). Under the Business-as-usual (BAU) scenario, where a cooling capacity of 1 TR per 165 sq. ft. is seen to be prevalent in residential buildings, 103 TR cooling is required per project. Considering a 50% reduction of TRs required through energy efficiency enabled by enhanced passive design and sustainable cooling system skills and their application by 'default', the remaining 52 TR is being cooled through sustainable cooling technologies. This yields a peak-load power reduction 60.4 kW (based on 1.17 kW per TR for a typical system with a Coefficient-of-Performance of 3.0), which results in 208 MW of peak power reduction by year 2050 per college. Each architecture college intervention under the Fairconditioning programme costs ₹9.6 lakhs, hence, a net *'negawatt'* (amount of energy saved at source) cost equates to ₹4,614 perMW.

This is significantly lower than the cost of installing thermal or renewable power capacity in India in 2017 (approximately ₹5.3 crore per MW of installed capacity). Energy efficiency is still to become identified as the 'first fuel' to supply India's energy demand. It is also waiting to be identified as a vector for India to achieve its real-life independence.

Figure 1 | Generating Negawatts

Sr. No.	Parameter	Value	Units
1	Gradudating Batch/College/Year	40	students/year
2	% Graduates moving to Practice	30%	
3	Years between graduating and leading design	4	years
4	Projects per practicinng graduate/year	1	building projects
5	Projects/college till 2050	3,445	projects
6	BAU sq. ft. TR	165	sq. ft./TR
7	BAU TR/project	103	TR
8	Energy Efficiency %	50%	
9	Sustainable Cooling TR/project	52	TR
10	TR savings/project	52	TR
11	Power savings/project	60	kW
12	Power savings/college till 2050	208	MW
13	Project Cost (30 colleges)	4,50,000	USD
14	Cost per intervention	9,60,000	INR
15	Cost per negawattt	4,614	INR/MW
16	Cost per megawatt (thermal power)	5.3	Crore INR/MW
17	Negawatt-to-Megawatt Cost Ratio	0.009%	

3 The Intervention

The program's core philosophy is manifested in its communication tone and practice of embodying sustainability. These measures are enacted by staff during events to show how integrity can meet indoor comfort management: avoiding high-carbon travel options such as air travel and preferring to travel by railways instead; avoiding use of ACs and preferring natural or low-energy forced ventilation; setting room ACs at 24-26 degrees to address thermal comfort efficiently). This is a vital strategic tool used to convey the importance of viewing sustainability and environmental responsibilities as *'non-cosmetic values'* and empathically rejecting the parochial notion of it being merely a *'value added service'* or *'Unique Selling Point (USP)'* for a project.

3.1 Training Content Development

While the current architecture syllabi lack the opportunity to challenge conventional methods of cooling our built space and explore energy efficient cooling methods and technologies that are already mature, the unavailability of high-quality teaching aids to convey building physics concepts and electro-mechanical processes of active cooling systems make it even worse for the energy efficiency case.

Fairconditioning collaborated with several stakeholders to devise training content capable of building trainer capacity as well as integrate the same knowledge within existing architecture curricula through pilot integrations. Training modules encompass fundamentals of building physics such as: heat transfer; psychrometry; adaptive thermal comfort including The India Model for Adaptive Comfort Study (IMAC); passive cooling design strategies; climate analysis; solar geometry; and sustainable cooling technologies/techniques such as structure cooling, radiant cooling, evaporative cooling, and natural refrigerants.

3.2 Capacity Building and Pilot Scale Application

To this end, Fairconditioning developed and executed a wholesome program to integrate Building Physics, Passive Design, and Sustainable Cooling Technology' into undergraduate architecture curricula. The program's interventions at collegiate level commenced with securing explicit management buy-in to translate successes of the 1-semester pilot into transformation of the entire syllabus (while adhering to the rubrics of the university prescribed curricula) across all humanities, technical, and design studio courses comprising the 5-year undergraduate program to be aligned with principles and praxis of energy efficient building design that integrates sustainable cooling systems. This intervention manifested in the form of a kick-off 4-day deep-dive workshop conducted for the entire faculty for the given semester chosen for the pilot *(5thsemester in most cases)*.

These capacity building workshops included extensive training sessions that empowered, guided, and provided technical actionable-knowledge to professors to seamlessly deliver and subsequently be empowered to embed syllabus-content related to sustainable cooling strategies across courses.Seven core themes were developed: climatology, building materials, building technologies, structural design, and building services.

Training for professors started with extensive training on fundamentals of building physics, technology fundamentals and their working along with their real-world applications and benefits were further explored during the sessions.

Finally, technical training sessions formulated into extensive *'syllabus renaissance'* sessions on day 4 of the workshops, where working groups develop deployable sustainability infused lesson plans towards the pilot integration across a humanities, a design, and a technical subject of the chosen semester.

3.3 Sustainability Infused Curricula & Creation of Public Goods

The project seeks to execute and implement a horizontal *'Deep Curricula Integration'* across partner architecture colleges.

The 4-day deep-dive workshops were a precursor to a semester-long series of micro-engagements centered around weekly curricula-integration planning and review meeting/calls with college faculty to further enable them with additional technical and pedagogy techniques support, immediately prior to the respective learning session(s) (lecture, studio etc.) across the upcoming semester week(s).

Fairconditioning has been monitoring and evaluating the pilot integration for the 3 aforementioned courses *(1 technical, 1 humanities and 1 studio)* at 3 colleges *(details in section 4.3)*. Given the lacunae that exists in architecture education, Fairconditioning plans to continue its efforts beyond just building capacity, by providing resources and material that would potentially help achieve the pilot integration (refer to section 4.4 for details on public goods development).

3.4 EcosystemIntegration

Realising that there exists no platform to exchange valuable knowledge exchange on Energy Efficiency and Sustainable Cooling Methods & Technologies amongst academics, HVAC practitioners, architects, students, etc. Fairconditioning developed a Sustainable Cooling related *'Talent and Knowledge'* technology and human-engagement platform referred to as *'Freemarket' (discussed in section 4.4)*.

Fragmented *'ecosystems'* need much more impetus, reinvigorating, and trust-building between competing actors. This is why the program does not merely rely upon relatively *'passive'* methods such as online platforms. Creating local, human-scale links between the most promising professors in engineering and architecture colleges of a city (i.e. bridges spanning the architecture-engineering gap) as well as amongst their peers (professors from 'competing' institutions in their respective fields) is a deliberate strategy that is being experimented with. Its formal manifestations are: a) roundtables (2 per year in each city) that are anticipated to catalyse knowledge and experience-exchange between professors; anticipated to translate into human-level bonds and subsequent intensified use of the online platform to continue their informal association; b) formal arrangements, articulated through MoUs, between Mechanical Engineering (RAC course) and Architecture Design Studio to formally establish joint 3rd year design projects. These involve detailed passive and sustainable active cooling system design for a large-scale commercial, institutional or residential buildingproject.

The project further aims to create a local sustainable-architect network for each city and get colleges to formalize the inclusion of local practicing architects as mentors for design studios based on real-world sustainable design briefs. This would potentially mainstream energy efficiency within designs submitted by students. The programme seeks to implement this in its third phase of operations starting June 2018 (expected).

The Buddy Programme

Buddy programme was introduced as part of non-negotiable intervention to eliminate silos that inhibit a collaborative spirit between future HVAC/MEP Engineers and Architects during their formative academic development years. The Buddy programme will be a semester long collaboration between HVAC engineering students of Fairconditioning network colleges who have demonstrated explicit interest in pursuing HVAC engineering as their academic specialization, and application of knowledge to further studies (Masters or PhD), design (as a consulting engineer or manufacturer of cooling systems), or in research (working with research institutions, think-tanks, industry advocacy bodies etc.) and architecture students of Fairconditioning Network Colleges who's courses are part of the pilot curricula integration process. During the collaboration students would work together on a design project designed by their teachers which would directly underscore the requirement to integrate building energy efficiency through passive design principles and sustainable active cooling systems for multi-story residential or commercialbuildings.

Roles and responsibilities for architecture and engineering students as part of the whole-building design process would be clearly defined at the start of the semester. Architecture students could be responsible for integration of passive design features to reduce heat loads, make broad sustainable cooling technology selections based on thermal comfort requirements specified by the 'client' and climate analysis, make spatial provisions for integration of sustainable coolingtechnologies.

Engineering students could be advisors in the process of technology selection, articulate space requirements and other relevant specifications, and finally sizing various components of the sustainable cooling technology and projecting building energy, cost, and GHG emissions performance using Sustainable Cooling Technology Modelling Tools. The studio/class would hence culminate in a joint whole-building- design studio (project) with students of corresponding disciplines inthe'buddy-college', and final designs would be jointly presented and would be jointly assessed by student groups to a 'jury' including the Fairconditioning Management Team.

*MoUs with architecture and engineering colleges were revised in order to include the Buddy Programme intervention and are being signed, refer to **appendix 3.1** to **appendix 3.6** for existing MoUs with partner colleges. Click here to view appendices.*

3.5 PolicyChange

To ensure mainstreaming and successful integration of sustainability into architecture curricula nationally, the Fairconditioning programme has devised a set of engagements with the Ministry of Environment, Forestry, and Climate Change (MoEFCC), Ministry of Power (MoP) and the Ministry of Human Resource Development (MHRD). Enhancing the quality of existing architectural education implies a systematic review/re-think of syllabi of technical courses nation-wide. It also implies the development of a time-bound strategy to mainstream it into technical education, involving the following stakeholder/sub-stakeholder agencies: All India Council for Technical Education (AICTE), Council of Architecture (CoA) and Centre for Environment and Education (CEE). It would be naive to expect local, regional, and/or national policy level change without building evidence cases. This evidence base from experiments in curricula integration is being synthesized by the program from 2017 to 2020. These multi-semester pilot experiments in nuanced, integrative, and often implicit, curricula change to embed sustainable cooling ideas into the undergraduate pedagogy will be conducted in 24 colleges in India centered in 6 cities. Subsequently, policy recommendations will be derived from collective deliberation upon learnings in conjunction with government and academicstakeholders.

Engagement plan with All India Council for Technical Education AICTE

ACIP proposed AICTE the following possible areas of collaboration:

- Integration of sustainable cooling principles in all 5 years *(and across curricula for Humanities, Technical and Design Subjects)* of the *'Model Undergraduate Architecture Curricula'* that AICTE presents as a exemplary blueprint for accredited universities/colleges tofollow.
- Considering the ACIP program's aspiration to become a Quality-Improvement-Program (QIP) center-of-excellence cell so as to institutionalize the existing capacity building that the program has been performing amongst a small set of selected colleges and amplifying its reach to all Architecture Colleges in India as part of the routine practice of upgrading pedagogy and technical skills of professors on a periodicbasis.

ACIP is actively following up with the organization to present the program's aspirations to associates with the AICTE, through a comprehensive formal presentation to the board during its next routine conference arranged through mutual sources.

Engagement plan with Council of Architecture (CoA):

ACIP proposed a partnership with COAs Training and Research Center (COA–TRC) to mainstream energy efficiency in buildings through capacity building across architecture colleges in India. ACIP is following up with COA to get a MoU signed which describes the official engagement including:

1. Content Certification - ACIP is looking forward for COA-TRC to critically review and recommend edits to training modules and assessment examination(s) under the Academic Curricula Integration Project (ACIP). The mutually agreed upon edits would be incorporated to the training modules and assessmentexamination(s).

2. Awards Programme: Incentivizing EnergyEfficiency:

    - In an attempt to incentivize energy efficiency, ACIP will devise, develop, and support a new award as an extension of the existing annual thesis awardprogram.
    - Following the framework of annual thesis award program, the *'Building Energy Efficiency award'* will span across 5 zones in India wherein 5 colleges with50-100

entries from each zone participate in the awards. Out of all entries, 2 are selected for the final presentation, amounting to 10 thesis projects showcased at the national level. The award will seek to reward 5 students, 1 from each zone. Each of these 5 student(s) will get an opportunity to intern with FC and spend 3 months (with the possibility of an extension) working alongside the FC team. During the internship, students will learn and engage with sustainable cooling methodologies and passive cooling design practices, with a possibility of working on actual building energy efficiency projects that are under the Building Energy Modelling and Advisory Project (BEMAP) under the FC programme.

- The *'building energy efficiency award'* will target final year students with housing project designs as their thesis and will be evaluated on a set of criteria through building energy modellingsoftware.

3. Faculty Induction Programmes(FIPs)

    - ACIP will conduct FIPs in partnership with COA–TRC to harness critical support from college high-level management, thereby boosting interest amongst the faculty to attend the workshop and follow through with pilot integrations with ACIP support. COA will invite all associated institutions, asking for expression of interest for deep integration of sustainability in their curriculum. The first 5 to 12 institutions to express their interest will be selected forFIPs.
    - ACIP will train professors from all participating colleges at these FIPs on principles of building physics, energy efficient building design in compliance with ECBC 2017, sustainable cooling technologies, methods of horizontal integration of learning across humanities, technical and design studios, and the concomitant pedagogy techniques and aids to be incorporated in theirteaching.

4. Usage of Brand Identity - As collaborators on the programme, COA-TRC and FC logos will mutually use corresponding logos in all joint efforts, including cross-linking on their respective websites, project collaterals, certificates for successful completion of the FIPs, and the Energy Efficiency Award for the ThesisCompetition.

*Refer to **appendix 3.7** for the MoU expected to be signed with COA soon. Click here to view appendices.*

Engagement plan with the Bureau of Energy Efficiency (BEE) - Ministry of Power (MoP)

ACIP has seeked partnership with BEE in order to receive support for creating a robust dialogue and an organizational structure that engages key agencies such as the Indian Society for Heating, Refrigeration and Air Conditioning Engineers (ISHRAE), Alliance for an Energy Efficient Economy (AEEE), University Grants Commissions (UGC) and Global Initiative of Academic Networks (GIAN) to work in compliance with the Ministry of Human Resource and Skill Development (MHRD). The purpose of this engagement will be to receive accreditation and systemic support to develop a capacity building program for architecture and engineering institutes in India focusing on Refrigeration & Air Conditioning (RAC) design. Under the official engagement a mechanism to engage Council of Architecture (CoA), Ministry of Human Resource and Skill Development (MHRD) and Centre for Environment and Education (CEE), to initiate changes in the architecture and engineering syllabi by integrating concepts of sustainability could be set up. Such a mechanism could also provide for periodic monitoring and evaluation, coupled with review of new lesson plans.

The augmentation of curricula and resulting built capacity will set motion to rapid implementation of Energy Conservation Building Code (ECBC) and the Bureau of Energy Efficiency (BEE) Commercial Building Energy Performance Benchmarking Programme. BEE has informally recognized this programme as a vital resource for improving their effort to mainstream ECBC knowledge assimilation into bachelor's level curricula in Architecture Colleges.

To provide a clearer understanding of the FC program BEE authorities have been invited to all the Deep Dive Training of Trainers and Engineering Students Certification workshops. Attempts are also being made for engaging with joint collaboration of BEE- COA and including training on sustainable cooling technologies in workshops held by BEE- COA across India to mainstream Energy efficiency.

*Refer to **appendix 3.8** for the detailed engagement plan with BEE. Click hereto view appendices.*

Engagement plan with the Ministry of Environment, Forestry and Climate Change

*(MoEFCC)*ACIP has approached the Ministry of Environment, Forestry and Climate Change

(MoEFCC), the

Ministry of Human Resource and Skill Development (MHRD) with the purpose of enhancing the quality of existing architectural and engineering education to ensure that a systematic review/re-think of syllabi of technical courses nation-wide is done to update the body of knowledge. A time-bound strategy to mainstream it into technical education would be developed, involving the following stakeholder/sub-stakeholder agencies: Ministry of Human Resource and Skill Development (MHRD), All India Council for Technical Education (AICTE), Council of Architecture (CoA), and Centre for Environment and Education (CEE). Support and approval from MoEFCC, MHRD would allow for interventions and changes in the architecture and engineering syllabi by integrating concepts of sustainability. A national exchange network between technical agencies like CoA and CEE could be established, allowing collaboration of both architecture and engineering streams in order to work together and understand concepts of energy efficient building design and modelling thereby strengthening capacity and skilled development through enhanced pedagogy.

*Refer to **appendix 3.9** for the detailed engagement plan with MoEFCC. Click hereto view appendices.*

3.6 Impact& KeyMetrics

Conducting customised and targeted workshops for key stakeholders to build capacity is a means to the end and a highly integral catalyst at that for a broader yet systematic curriculum change. The end goal is for sustainable building design specifically, in this case through energy efficiency interventions, to become an ingrained and organic standard practice through policy change across colleges/institutions/universities across major Indian cities to begin with. That said, while the number of: workshops conducted; participating academic institutions; professors & students trained; and MoUs signed are key programmatic metrics to assess its impact, unless these translate into cohesive curricula integrations, the effort would be futile. Therefore, the number of pilot integrations and assessing its success/failure is the project's key metric and helps assess its true impact. These metrics and impacts will be highlighted in the followingsection(s).

4 Project Activities - February 2017 to April 2018

4.1 Deep-dive Architecture ToTworkshops

Eminent partner architecture colleges, most suited for the pilot integration were identified in each selected city, that are renowned for their progressive teaching methods and vibrant faculty. These institutions were deemed/renewed as *'HUB Colleges'*. Colleges in selected city signed/renewed a MoU to affirm their intent to support curricula upgrading through efforts by trained professors' post-conclusion of workshops.

The ACIP team executed *'Architecture Training of Trainers (ToT)'* capacity building: 3/4-day (3 cities, 1 workshop per semester per city) deep-dive workshops that primarily catered to architecture professors teaching *'technical'* subjects for lecture support-mechanism. The college steering committee identified most suited professors *(refer section 5 for challenges faced)*, that participated in the deep-dive workshop(s). These workshops were conducted on the following dates:

1. Dr. Banuben Nanavati College of Architecture (BNCA), Pune: 30th May – 2nd June2017
2. Sushant School of Art and Architecture (SSAA), Delhi: 12th – 15th June2017
3. Smt. K. L. Tiwari College of Architecture (SKLTCA), Mumbai: 21st – 23rd Aug2017
4. Dr. Banuben Nanavati College of Architecture (BNCA), Pune: 30th October – 3rd November 2017
5. Sushant School of Art and Architecture (SSAA), Delhi: 21st - 22nd December2017

The deep-dive workshops included extensive training sessions that empowered, guided, and provided technical actionable-knowledge to professors to seamlessly deliver and subsequently be empowered to embed syllabus-content related to sustainable cooling strategies across courses covering seven core themes: climatology, building materials, building technologies, structural design, and building services.

The workshops were a 3/4-day journey for professors that started with extensive training on fundamentals of building physics such as: heat transfer, psychrometry, adaptive thermal comfort, passive cooling design strategies, climate analysis, and solar geometry, followed by sustainable cooling technologies/techniques such as Structure Cooling, Radiant Cooling, Evaporative Cooling, and Natural Refrigerants where in principles behind the working of these technologies along with their applications were discussed. Along with imparting technical knowledge, to teach these technical concepts through new & improved pedagogical exercises, activities, and methods was also carried out. This allowed for internal integration across each module describing activities fordeep-sensitisation, best practices in integrating sustainability within curricula, and teaching aids that encompass physical scale models for climatology and building physics, software tools, animation videos, testing and evaluation aids, etc.

The training content further seeked to rethink the existing pedagogy methods and challenges the status-quo by introducing (re-introduce in certain cases) Kolb's experiential learning cycle and Bloom's Taxonomy of learning domains along with the proposed adapted learning system. Finally, technical training sessions formulated into extensive *'syllabus renaissance'* sessions on day 4 of the workshops, where working groups develop deployable sustainability infused lesson plans towards the pilot integration across a humanities, a design, and a technical subject of the chosen semester.

As the project evolved, feedback from architecture professors necessitated the need to create and update existing modules to focus on sustainability concepts targeted towards the selected semester for integration. Therefore, through these tailored workshops, technical concepts and teaching techniques necessary to *'teach'* these concepts were targeted. Syllabus for each subject targeted for intervention was studied in-depth, and ideas for sustainability-integration in current syllabus were chalked out before the workshop. The final two days of the workshop(s) focused on co-creating final lesson plans with architecture professors.

Key Metrics *- February - April 2018*

- 70 professors from 4 architecture colleges were trained through 3 *'selected cities'* workshops. The number of Participants from each college is asfollows:
  - Dr. Banuben Nanavati College of Architecture:28
  - Bharti Vidyapeeth College of Architecture:2
  - Sushant School of Art and Architecture:24
  - Smt. K. L. Tiwari College of Architecture:6
- Memorandum of Understanding (MoU) to bring the organisations formally into the project with all colleges has beensigned.

Figure 2 | Still from the Deep-dive ToT for Architecture Professors at Sushant School of Art & Architecture, Ansal University.

Figure 3 | Still from the Deep-drive workshop for Architecture Professors at DrBhanuben Nanavati College Of Architecture For Women (BNCA), Pune

Figure 4 | Still from the Deep-dive ToT workshop for Architecture Professors at Smt. K.L. Tiwari College of Architecture, Mumbai

Click here to view a few all photographs from the workshops. Refer to ***appendix 4.1*** *for the detailed outline for one of the Thoughtful Cooling Architecture Deep-Dive ToT Workshops. Refer to* ***appendix 3.1*** *for a MoU signed with one of the architecture colleges. Click here to viewappendices.*

4.2 Engineering Student Certificationworkshops

Eminent partner engineering colleges, most suited for the pilot integration were identified in each selected city, that are renowned for their progressive teaching methods and vibrant faculty. These institutions were deemed/renewed as 'HUB Colleges'. Colleges in selected city signed/renewed a MoU to affirm their intent to support curricula upgrading through efforts by training engineering students and professors' post-conclusion of workshops.

The ACIP team executed 'Thoughtful Cooling' Engineering student certification capacity building: 4-day (2 cities, 1 workshop per city for 3 colleges) that primarily catered to engineering students, seeking to highlight the most efficient mechanical cooling techniques outside of traditional ACs, State-of-the-art information and system level design considerations, energy and GHG emissions performance parameters, Building Energy Modelling on Smart Energy software, and cost-benefitanalysis techniques related to efficient/sustainable Cooling Technologies including Radiant Cooling, Evaporative Cooling (Direct and Indirect), Vapor Absorption, and Natural Refrigerant based cooling.

Students from the Mechanical Engineering department who have RAC subject as mandatory of their curriculum (MESCOE, NCET), students who are interested in RAC subject as elective (SVIT) and the professors in charge of RAC subject (refer section 5 for challenges faced) participated in the workshop. The workshops were organized on the following dates:

1. Modern Education Society's College of Engineering (MESCOE), Pune: 15th – 18th March 2018
2. Nagarjuna College of Engineering and Technology, (NCET) and Sai Vidya Institute of Technology, (SVIT), Bengaluru: 10th – 13th April2018
3. A 3rdworkshop for the 4thcollege was planned at Mukesh Patel School of Technology Management & Engineering (MPSTME), Mumbai in March 2018, however, needed to be cancelled owing to unavailability of days. Therefore, the workshop and pilot integration with MPSTME has been scheduled for the upcoming semester in September 2018, along with another receptive and interested engineering college in Mumbai. An MoU has been signed for this engagement.

Refer to the MoU signed with MPSTME in ***appendix 3.5****.*

The 2 deep-dive workshops included extensive training sessions that empowered, guided, and provided students, technical actionable-knowledge, tools and technologies that promote energy efficiency in the building construction and the indoor cooling sector with a view to mitigate the climate change impacts caused by direct and indirect GHG emissions from these industry sectors. The ultimate goal is for engineering colleges to subsequently augment their existing RAC subject in the upcoming semester(s) to include principles of sustainable cooling and enriched pedagogy as a *'pilot'*.

The workshops were a 4-day journey for students that started with extensive training on fundamentals of building physics such as: heat transfer, psychrometry, adaptive thermal comfort, passive cooling design strategies, climate analysis, and solar geometry, followed by sustainable cooling technologies/techniques such as Structure Cooling, Radiant Cooling, Evaporative Cooling, and Natural Refrigerants where in principles behind the working of these technologies along with their applications were discussed.

The workshop concluded with empowering participants with hands-on training on the upgraded Smart Energy tool, where participants calculated cooling requirements of a building through modelling exercises provided by the ACIP team. A parallel session was conducted with engineering professors discussing areas for intervention across the RAC curricula, sharing relevant best practices in integrating sustainability within curricula, ideas to sensitize students about the subject, discussing engaging teaching aids (physical models, software tools, testing and evaluation aids). Session for hands-on syllabus modification to imbibe sustainability within the core of their teaching was proposed before commencing pilot integration next semester. The workshop also seeked to enhance existing pedagogy skills and imparted techniques for sustainability-integration in technical courses.

Key Metrics *- February - April 2018*

- Out of 106 students who attended the workshop, 59 students were trained and certified and 26 professors from 3 engineering colleges were trained through 2 *'selected cities'* workshops. The number of Participants from each college is asfollows:
    - Modern Education Society's College of Engineering (MESCOE), Pune: 53 students (registered and attempted test), 49 students (certified), 14professors
    - Nagarjuna College of Engineering and Technology (NCET), Bengaluru: 35 students (registered), 20 students (attempted test), 7 students (certified), 11professors
    - Sai Vidya Institute of Technology (SVIT), Bengaluru: 13 students (registered) 3 students (attempted test and certified), 1professor
- Memorandum of Understanding (MoU) to bring the organisations formally into the project with MESCOE and NCET has been signed, SVIT isunderway.

Click here to view a few photographs from the workshops. Refer to ***appendix 4.2*** *for a detailed outline of the Engineering Student Certification Workshop. Refer to* ***appendix 3.4*** *for a MoU signed with an engineering college. Click here to view appendices.*

Figure 5 | A group debate session at M.E.S. College of Engineering, Pune for Mechanical Engineering Students

Figure 6 | A still from the 'Rethinking Pedagogy' session for Engineering Professors at Nagarjuna College of Engineering & Technology, Bengaluru.

4.3 PilotIntegrations

'Pilot Integration' is a strategically laid out action plan to implement a sensitisation centric lesson plan framework that is unique to each architectural institute, that seeks to integrate sustainability within the confines of the prescribed university curriculum.

Our extensive research and field experience highlights that the majority of architecture professors lack learning-centered teaching techniques and are largely oblivious to the spectrum of teaching methods now used by progressive academic institutions that have dismantled the traditional and failed method of unidimensional lecture teaching. Professors in architecture and engineering colleges face a hard time explaining technical concepts without high-quality teaching aids: physical scale-models and virtual (animations etc.), therefore, students are unable to comprehend and/or retain fundamental concepts and hence these concepts remain unapplied throughout their future projects. Professors realise this disastrous lacuna across architecture and engineering pedagogy, however, are unable to bring about curricula change due to lack of support from the management/administration, decision making executives in colleges and academic regulatory bodies. There are no punitive consequences, financial incentives, or and peer-pressure amongst colleges to transform curricula. Training student's directly is also not sufficient. The magnitude is so vast that the professors of colleges must be tooled to deliver the required training on sustainable design principles and this effort must be institutionalized through curricula change.

The only way to address this magnitude of poorly trained and empowered students is by building capacity and deeply integrating sustainability and efficiency into architectural and HVAC-engineering higher education curricula, building capacity within India's Architecture and Engineering Colleges (those that teach HVAC design). Once capacity is built, students are endowed with an understanding of energy efficient building design, thereby developing buildings that have a reduced energy demand. Reduced energy consumption through energy efficiency adoption would eventually lead to increased supply in rural areas, strengthening energy access and security. Building capacity enables students to reduce emissions, increase India's energy security and thereby, combat climate change.

Hence, in an attempt to deeply and meaningfully embed sustainability across subjects, technical, humanities and design subjects were identified for each HUB college. As part of the syllabus renaissance session during the Training of Trainers workshop (ToT), professors with assistance from the ACIP team modified existing lesson plans for courses in the university mandated curricula, and augmented the existing semester-long lesson plans; by identifying essential teaching methodologies, determining physical, virtual and or or classroom teaching aids, by defining key educational objectives (Bloom's taxonomy) and systems of learning (associative, indirect + interactive, experiential, collaborative, and project-based). Detailed structure and implementation of each pilot is discussed in the following subsections.

Figure 7 | Screenshot from the Pilot Integration Matrix. Refer to appendix for details.

1							To track for integration	To track for integration	To track for integration	To track for integration	To track for inte
2	College Subject	Week	Lecture Number	Date and Day	Focus Area	Syllabus Topic	Deliverable Mode	Intervention Description	Concept Taught	Teaching Aids	Application/Asse
3		0	0	1st week after the Workshop		**Formalizing Integration Plan**		**Formalizing Integration Plan**			
4	Architectural Design : Madhur	1	1	Monday, 5 June 2017	Dc 01 - Design Methodology; Dc (	Introduction, Design Process, Theme for the year, Groups and Faculty coordinators; Introduction to Design Exercise 1; Identification of Antecedents; Briefing on Abstract Exercise. Abstract Exercise					Abstract Exercise
5		2	2	Friday, 9 June 2017	Dc 01 - Design Methodology; Dc (	Abstract Exercise; Preliminary Discussion on Antecedents - Information; Briefing on Activity Study					
6		2	2	Saturday, 10 June 2017	Dc 01 - Design Methodology; Dc (	Site Visit for Exercise 1, Case Study Visits - Studer	Site Visit	Site Analysis, Climatic conditions, geographical	Microclimate Analysis	Climate Consultant Software	
7		3	3	Monday, 12 June 2017	Dc 03 - Site Analysis	Predesign Module B - Antecedents preliminary ana	Lecture & Discussion		Passive Design Strategies		
8		3	4	Friday, 16 June 2017	Dc 03 - Site Analysis	Predesign Module C - Activity studies; Briefing on Site Analysis & Planning					
9		4	5	Monday, 19 June 2017	Dc 04 - Codes and Design Standa	Predesign Module D - Site Analysis & Planning; Contextual responses, Students Case Study Presentations					Students Case S
10		4	6	Friday, 23 June 2017	Dc 04 - Codes and Design Standa	Predesign Module D - Site Analysis & Planning; Bri	Lecture & Discussion	Climate module, Sun path: Form and Orientatio	Climate Analysis	Sun Path Chart Program	
11		4	6	Friday, 23 June 2017					Effect of Heat gain on Building Envelope	Climate Consultant Software	
12		4	6	Friday, 23 June 2017					Form and Orientation		
13		5	7	Monday, 26 June 2017	Dc 05 - Ideation	Design Module 1 - Stimulant Idea, Design Philosop	Lecture & Discussion	Explorations in Form: Passive Cooling Strategie	Climate Analysis	Natural Ventilation	
14		5	7	Monday, 26 June 2017					Passive Design Strategies	Air flow inside the building	
15		5	8	Friday, 30 June 2017	Dc 05 - Ideation	Design Module 2 - Studio Explorations in Form; Briefing on Figure Ground, Adjacency Plan, Grid Geometry,Adjacency, Figure Ground					
16		6	9	Monday, 3 July 2017	Dc 06 - Form & Function	Design Module 2 - Alternatives in Explorations with significance of form makin, Submission of form exploratory models alongwith figure ground, Adjacency plans and sections					
17		6	10	Friday, 7 July 2017	Dc 06 - Form & Function	Design Module 2 - Alternatives in Explorations with	Lecture & Discussion	Light, Ventilation: The students should be enco	Psychrometry	Natural Ventilation	
18		6	10	Friday, 7 July 2017					Daylighting		
19		6	10	Friday, 7 July 2017					Natural Ventilation	Air flow inside the building	
20		6	10	Friday, 7 July 2017					Passive Design Strategies		
21		7	11	Monday, 10 July 2017	Dc 07 - Form & Structure	Design Module 2 - Identifying Geometry, Appropriate Grid for framing; Briefing on Service Systems, Lifts, Staircase & Ramps					
22		7	11	Friday, 14 July 2017		SPARE STUDIO - INSEM EXAM - IF PAPERS ARE SCHEDULED ON THE DAY OF DESIGN STUDIO; OTHERWISE STUDIO 12 SHALL BE SCHEDULED					SPARE STUDIO
23		7	12	Monday, 17 July 2017	Dc - 08 External Elements	Design Module 3 - Concverting Adjacencies to Floo	Lecture & Discussion	Briefing on Explorations in Envelope: Concepts	Energy Use/Consumption in Buildings		
24		7	12	Monday, 17 July 2017					Envelope Load		
25		8	13	During 8th week of Pilot Integration		**Semi Annual Workshop - 1**		**Semi Annual Workshop - 1**			
26		8	13	Friday, 21 July 2017	Dc - 08 External Elements	Design Module 3 - Explorations in envelope; Architectural character 3d models; with significance of Architectural character, Basements and Services					
27		8	13	Saturday, 22 July 2017		Time based Task for Exercise 3 on July 21, 2017 and July 22, 2017 resolving the design configuration in basic outline format of P			Passive Design Strategies		
28		9	14	Monday, 24 July 2017	Dc - 09 Light, Texture	Design Module 4 - Design Development; Detail Plans, Sections and Elevations, Design Modules 1 - 3 Submission					
29		9	15	Friday, 28 July 2017	MEP Services Integration	Design Module 4 - Design Development; Detail Plans, Sections and Elevations with Structural, Service Systems, MEP Services Integration					
30		10	16	Monday, 31 July 2017	Dc 10 - Art and Architecture	Design Module 5 - Site Development; Exterior grading; ancillary services; Movement systems etc, Submission of Detail Plans, Sections and Elevations along with Site Plan					
31		10	17	Friday, 4 August 2017		Design Module 5 - Site Development; Exterior grading; ancillary services; Movement systems etc, Site Development; External Services					
32		11	18	Monday, 7 August 2017		HOLIDAY - RAKSHABANDHAN					
33		11	18	Friday, 11 August 2017		Design Module 6 - Narrative Development; Narrative on Significance of Form, Architectural Character and Process followed, Narrative as a way of Design presentation					
34		12	19	Monday, 14 August 2017		Design Module 7 - Design Synthesis; Validation of Design for Integrity of Function, Structure, Service Systems and Process; Area Statements for the Final Design, Narrative and Graphics on the Conceptualization of the Product					
35		12	20	Friday, 18 August 2017		Design Module 7 - Design Synthesis; Validation of Design for Integrity of Function, Structure, Service Systems and Process; Area Statements for the Final Design, Draft Design Portfolio					
36		12	21	Monday, 21 August 2017	Identifying Critical students based	Design Module 8 - Design Presentation - Verbal & Graphical Presentation, Table Jury					
37		13	22	Friday, 25 August 2017		GANESH CHATURTHI - HOLIDAY					
38		13	22	Saturday, 26 August 2017		Site Visits for Exercise 2 and 3, Site Analysis, Jury	Site Visit	Site Analysis: The microclimate analysis of the E	Climate Analysis	Climate Consultant Software	
39		14	23	Monday, 28 August 2017		Jury Comments and Further Design Development,	Review Comments with Final Design				
40		14	24	Friday, 1 September 2017		Time based Design Assignment - Exercise 2					
41		15	25	Monday, 4 September 2017		Introduction to Short Term Assignment - Exercise 3; Identification of Antecedents; Site Analysis; Concerns and Strategies, Assess Final Portfolio - Exercise 2					
42		15	26	Friday, 8 September 2017		Stimulant Idea; Explorations in Form and Envelope; Design Development, Site Development and Narrative.Review Form and Envelope					
43		15	27	Monday, 11 September 2017		Design Development, Site Development and Narrative Preliminary Submission: Assess Preliminary Sketch Design - Exercise 3					
44		16	28	Friday, 15 September 2017		Design Development, Site Development and Narrative; Time Assignment submittal as Sketch Design document at the end of Saturday Studio					
45		16	29	Saturday, 16 September 2017		Time based Task for Exercise 3 on September 15, 2017 and September 16, 2017 resolving the design configuration in form of Plans, Sections and Elevation with functional and Structural integrity. (Total Time 12 Hours)					
46		17	30	Monday, 18 September 2017		Design Presentation - Portfolio; Critical Review of Individual Works, Final submission for Exercise 3 at 0930 hrs					
47		17	31	Friday, 22 September 2017		Design Presentation - Portfolio; Critical Review of Individual Works, Review					
48		18	32	Monday, 25 September 2017		Term End: Final submission for Exercise					
49		20	0	2 weeks after Pilot Integration is Complete		**Semi Annual Workshop - 2**		**Semi Annual Workshop 2**			
50	Contemporary Architecture	0	0	1st week after the Workshop		**Formalizing Integration Plan**		**Formalizing Integration Plan**			
51		1	1	Wednesday, 7 June 2017		Subject Overview: A general overview of the subject with timeline. Schedule with List of Assignments.					Assignment 01 :
52		2	2	Wednesday, 14 June 2017		Revivalism, Neo-Classicism, Neo-Gothic: To unders	Lecture & Discussion	To understand the factors responsible for reviva	Thermal Comfort		Assignment 2: Mas
53		2	2	Wednesday, 14 June 2017					Climate Justice		
54		2	2	Wednesday, 14 June 2017					Climate Zones		

TEMPLATE | BNCA_SemV | SSAA_SemV | BNCA_SemIV | SKLTCOA_SemIV | SSAA_SemVI | Lists&Tables | +

Ready 100%

*Refer to **appendix 4.3** for the detailed pilot integration lesson plan matrix for all pilot integrations**.***

4.3.1 *Dr. Banuben Nanavati College of Architecture, BNCA, Pune*

4.3.1.1 *Semester V (April - September 2017)*

At BNCA, the fifth semester was selected for the pilot, from which Building Services III (Technical), Contemporary Architecture V (Humanities), and Architectural Design V (Design) were selected for the integration. Prevalent lesson plans for each subject were studied in-depth and topics suitable for integration were identified, furthermore, existing lesson objectives were revised to compliment sustainability concepts.

*Refer to **appendix 4.3** for the integration plan for semester V, BNCA.*

Architectural Design V

This subject focuses on learning the basics of design methodology. Students were asked to design a leisure center as part of their design project. Throughout the design discourse spanning sixteen weeks, intervention points were identified to target sustainability integration. The intervention focused on making microclimate analysis and geographical survey of the site before design and site planning a standard practice. Students were encouraged to create climate responsive, and climate harmonious designs, by considering the passive design strategies at the preliminary stages of design and planning.

To initiate the architectural design discourse, students were encouraged to analyse the geo-climatic characteristics of the building as part of the site analysis, in order to appraise architectural designs through the lens of sustainability. Butterfly diagrams and sun path diagrams prepared during the site visit were used to identify site limitations and consider solar heat gain on the building and building design interventions (for example, reducing solar heat gain from the southern façade with help of advertising panels) were worked out accordingly.

Students were then introduced to passive design strategies for lighting &ventilation and learned to incorporate the passive cooling strategies in design with the help of building energy efficiency guidelines for natural ventilation and space cooling. Moreover, students were encouraged to use natural ventilation for cooling common spaces in the leisure center design plan and active cooling systems were only adopted for areas where natural ventilation was not possible. Students were explained the concept of wind loads, and strategies to enhance or obstruct wind flow in the building design. While discussing the explorations in building envelope, the effect of solar heat gain on the envelope and the resultant energy consumption for cooling was touched upon. In the last weeks of integration, the external elements of the building design such as light, texture, service systems and area statements were finalized, and students developed their detailed design plans.

Contemporary Architecture V

For the humanities subject in the semester five, students studied the history of socio-political, cultural and other influences, philosophies, styles, purposes, and contributions of notable architects, national and international on contemporary architecture.

The integration plan explored means to make students aware of the impact that the changing architectural styles and materials had on the environment. It further encouraged students to consider how and where climatic conditions and thermal comfort of the occupants influenced the architectural style and the building elements. Students were asked to study and analyze the works of two master architects as a group assignment. Students were additionally asked to prepare a comparative matrix of these architects and their unique approaches i.e. purpose of the building, client-specific design, aesthetic value, environment-friendly, climate responsive etc. This comparison was made between four buildings, two buildings by the same architect and one building each (of the two architects) that served the same purpose.

The industrial revolution and its impact from new age building construction materials on the environment was also discussed. While new international styles, innovations and pioneer architects along with their work were further discussed. Students were asked to note whether the new inventions were environment-friendly, climate responsive, or whether the designs were only based on client requirements. Students were asked to document and study a modern project and critique it on the basis its climate-friendly characteristics and compare it with a sustainable, climate responsive project. Students were also asked to study similar contemporary buildings in the city to analyze and compare their individual energy performances, lighting, and ventilation strategies.

Building Services III

For this subject, students obtained knowledge of technical and design aspects of natural ventilation and HVAC and learn to build services as an inclusive part of architectural design process. The objective for integration in building services was to sensitize students to understand environmental issues created by mechanical ventilation and air conditioning and stimulate them to incorporate energy efficient, environment-friendly building services in their designs.

It was proposed that the discourse will open with a discussion on thermal comfort, followed by an introduction to Indian model of adaptive comfort developed by CEPT University, and Givoni and Milnes bioclimatic charts. During this discussion, students were urged to realize that the purpose of ventilation is not to cool spaces but to cool people. Passive design strategies for natural ventilation such as form and orientation, apertures, fins, windcatchers, chimneys, stack effect, infiltration, cross ventilation, Venturi effect, and Trombe wall were discussed in detail to make students aware of the alternatives to Mechanical ventilation and Air conditioning.

As an alternative to air conditioning, evaporative cooling technologies (indirect, direct, & 2-phase indirect-direct) and passive strategies revolving around the principles of evaporative cooling such as water bodies, fountains, water curtains, wet jaalis, roof ponding, etc. were explored. Students were then trained on the psychrometric chart, and its ability to help decide passive design strategies and cooling technologies with respect to different climatic zones. Evaporative coolers and their working, along with the advantages and disadvantages w.r.t different climatic zones was also discussed. To assess the students understanding of natural & composite ventilation systems, they were asked to prepare a brief case study that would enable them to understand and analyze the correct application of natural and/or composite ventilation systems within their design strategies.

In the next unit, while discussing mechanical ventilation systems, students learned that similar to other active cooling systems, mechanical ventilation systems are energy intensive. The building energy consumption, as well as the energy requirements for each component of mechanical ventilation systems, were addressed in detail. Material eco-friendliness, fan selection criteria, space requirements, architectural provisions and location for setup for each mechanical ventilation system were also identified. Students were then given an exercise to calculate the cooling i.e. fan requirement for a design problem, and then based on the above characteristics were asked to do an online cooling equipment survey with the help Searcho.org(an industry specific search engine developed by ISHRAE, a database for equipment manufacturers, contractors, labor consultants, system integrators, retailers, dealers and service providers in HVAC&R industry). The students also conducted a local market survey to identify the most suitable energy efficient fan according to the cooling requirements of their design.

Air conditioning was introduced in the next unit wherein principles of HVAC, the use of refrigerants, natural and artificial types of refrigerants, Global Warming Potentials (GWP) of refrigerants and their hazards were explored. With the help of a passing-the-parcel game, assuming that heat is the parcel, students were explained the working principle of an air conditioning system.

Refer to the video of the exercise here.

Energy requirements in detail of each component i.e. evaporator, compressor, condenser, expansion devices, refrigerants and their purpose in the refrigeration cycle was also highlighted. As different types of conventional air conditioning systems was discussed, a conscious effort to address the energy consumption, selection criteria, space and design requirements, architectural provisions and identification of climatic zones for each air conditioning system was made. Similarly, when chiller systems and their components were discussed, emphasis was given on using energy efficient chiller systems, increasing energy efficiency by using chillers with higher set points, and reducing the bends in ducting for energy efficient cooling. Along with non-conventional AC systems (hybrids & packaged units), sustainable cooling technologies such as radiant cooling and structure cooling were also introduced and trained upon.

Through the discussions, it became clear that air conditioning systems are energy intensive and environmentally hazardous, and that there are effective, already mainstreamed, energy efficient as well as environmentally safe alternatives to air conditioning. To evaluate students understanding of air conditioning systems, and its use, students were then given an exercise to calculate the cooling i.e.
AC requirement for a design problem.

4.3.1.2 *Semester IV (November 2017 - April2018)*

The fourth semester was selected for the pilot, from which Building Technology and Materials (Technical), History of Architecture (Humanities), and Architectural Design (Design) were selected for the integration. Prevalent lesson plans for each subject were studied in-depth and topics suitable for integration were identified, existing lesson objectives were revised to compliment sustainability concepts. Furthermore, training modules were tailored to strictly limit to the concepts covered in the syllabus, and teaching aids, activities for lesson for each subject were prepared. In the last two days of the workshop, lesson plans were co-created with the professors based on these ideas for integration.

A test was designed to gauge students understanding of science and engineering principles, spark curiosity for sustainable design ideas, and foster critical thinking skills amongst them. The tests were decided to be conducted at the start of the semester (pre-test) and then again at the end of the semester (post-test) to understand the extent of impact and understanding achieved after sustainability interventions.

Refer to ***appendix 4.4, 4.5*** *for the pretest with and without answers conducted at BNCA. Refer to* ***4.6*** *for pretest evaluation scores of Div. A.*

Building Technology and Materials

In BTM, the focus areas selected for integration were theory of materials, Ferrocement, RCC construction and Windows. In theory of materials, students learnt the basics of dense concrete as a building material. The lecture opened with a discussion on the social and environmental impacts of material extraction (limestone), processing and use in construction. The building physics concepts of heat transfer through building materials like conduction, radiation, thermal mass was explained with help of quality measurements of temperaturesfrom various building surfaces. Then the importance of reducing heat gain in buildings (i.e. to avoid excessive AC energy consumption and refrigerant use) was discussed, concepts related to Conduction: U value, R value, thermal capacity were taught.

The same exercise was carried out for lightweight concrete and ferrocement building materials. Students were supposed to perform a building physics experiment comparing the temperature and thickness of 5 building material models made of dense concrete blocks, AAC blocks, lightweight concrete blocks, red bricks, and wood, all of them partially exposed to the sun. The exercise aimed to help students compare and analyse conductance & resistance of various building materials, with and without aid of insulation, and ultimately select the most suitable building material for construction. The experiment was only possible to be carried out for red bricks due to unavailability of sufficient building materials for entire batch.

Refer to the brief of the building physics exercise here.

While learning about Ferrocement in the next lecture a debate on should contemporary buildings in Pune have thick walls with high thermal mass or thin walls with low thermal mass + insulation, was supposed to be conducted to assess students understanding of concepts of thermal mass, insulation. In RCC constructions students learnt about RCC slabs and RCC lift shafts. While the theoretical physics principles related to passive cooling techniques to shield (from solar radiation) & drain heat from concrete structures were taught, building physics experiments of measuring surface temperature measurements using low emissivity radiant barriers was not conducted. The experiment for understanding principle behind structure cooling, by measuring slab bottom temperatures of RCC slab+ embedded water pipes/ wet gunny bags(evaporation)+ insulation assembly was not conducted due to shortage of time.

History of Architecture

For history of architecture, this semester focused on learning about tribal, folk, high style architectural structures in India. Aiming for sensitization about Climate Change and the impact of built space on Climate Change, students were shown images of contemporary buildings in various climatic zones (appropriate and inappropriate) and a debate was planned, with a discourse on limits, balance, and causality (consequences of actions) as articulated in historical texts and its relevance in our current context, a discourse about how shelter was built to combat environment, now environment has to combat shelter. In depth discussions on these points was tried, but it was observed that the students were in a very nascent stage learning to form critical opinions about these topics.

Students learnt concept and use of shading devices while learning the topic of movement in a traditional city, in which the street shading by buildings was highlighted. In the next lecture students learnt about the concept and necessity of thermal comfort, achieved in India architecture with the help of transition elements like Buffer Spaces - Verandahs, Sabhamandap. In the next session, a field visit was planned to experience urban environment. The field visit was conducted in two batches, where one batch visited a stone temple, while the other visited a brick temple. As part of the visit students took qualitative and qualitative temperature measurements at 2-hour intervals, for comparing the thermal comfort experience in both structures. While discussing student's observations, the impact of shaded streets, thermal mass, openings, architectural design on thermal comfort was reiterated.Students were asked to draw measured drawings of the sites they visited for assessment at the end of the semester.

After their midterms, a joint lecture (HOA + AD) on passive design strategies was planned for students to learn element of Living (tribal, folk and high style). This lecture focused on the strategies required for achieving thermal comfort through building design while living various types of climates, i.e., for:

1. Hot and Dry climates - thermal mass, use of Bernoulli's principle to design openings, thermal mass and night sky cooling,and
2. Hot Humid climates - cross ventilation andconvection.
3. Composite climates -courtyards,
4. Cold climates-insulation.

In the next lecture, architecture was addressed as an element of worship (tribal, folk and high style). Places of worship, Sahn, Garbhagriha were discussed in relation to thermal comfort. The passive design strategies, use of thermal mass, structure cooling, and evaporative cooling in places of worship to achieve peace and thermal comfort were addressed.

Architectural Design

The discourse on Architectural design started at the settlement tour. Out of the four divisions for this semester, two divisions visited the Auroville village, Bengaluru, and the other two visited Melukotte village, Mysore. Before the tour students were given 'thematic words- shade, insulate, ventilate' related to which they conducted desktop/secondary research and were asked to find, understand and analyse examples of those concepts during the settlement tour structure. During the settlement tour students also did climate analysis exercise, noting measurements for temperature, wind speed, precipitation, humidity and other climate parameters. Once back from the settlement study tour students started to consolidate their observations for the study tour in presentations. During the presentations it was observed that students had forcefully tried to correlate or fit said concepts/ strategies of shading, insulation and ventilation in their presentations. An apathy for learning and correlating concepts was observed. Hence the need for galvanizing students was felt by the professors. The first design assignment for Div. A and B. was to design a primary school in Auroville, providing climatic comfort to occupants with the help of passive design strategies. While for division C and D, the second design assignment was based on climatic comfort where students were asked to design a Indology and Research Institute at Melukotte.

To assist the design projects, students were given case studies to understand the purpose, functions and space requirements of schools and Indology. Students were explained climate specific passive design strategies for achieving thermal comfort during the joint lecture conducted for HOA and AD. Horizontal integration of sustainability concepts was tried to be achieved; students learnt passive design strategies in history of architecture and building materials and properties in building technology and materials, students tried to apply their learning in their assignments for design subjects. Even though students could not perform in depth life cycle and GHG emissions analysis for their designs, it was observed that students tried to incorporate climate specific design strategies to achieve thermal comfort in their designs.

*Refer to **appendix 4.7** for design brief and student outputs for design assignments.*

As the semester is nearing conclusion, student outputs have not been shared by BNCA yet, students' design outputs will be shared once received from BNCA.

4.3.2 *Sushant School of Art and Architecture, SSAA,Delhi*

During the monitoring and support communications with BNCA college for sustainability integration in semester IV, it was observed that there is a necessity to create a positive pull or willingness amongst the students to learn sustainability concepts. Hence, at SSAA, for semester V, sensitizing students on the importance of sustainability was experimented. Building Services III (technical), and Architectural Design (Design) were identified for the integration.

4.3.2.1 *Semester V (August 2017 - November 2018)*

Building ServicesIII

As an introduction to the course, it was planned that students will be sensitized about energy generation, primarily, the massive amounts of energy resources required to produce energy, and the immense amount of emissions released during production of energy. Based on which students were asked to write a research paper on renewable sources and energy efficiency guidelines in green building rating systems. In the next lecture, students learnt systems of electricity generation, transmission and distribution, and wastage of energy during transmission by doing an analysis of own residential electrical system by understanding the local source of energy, per person and per appliance energy consumption and per unit expenditure of electricity. Furthermore, while discussing components of the electrical transmission, generation of heat during conversion from AC to DC was emphasized and the major electricity guzzlers in the building sector were identified. Students were then asked to draft an electrical layout plan for a residential building. Following which the norms and standards for electrical layout i.e. national electric code, legislative and code of practice, green building norms - Griha, LEED were discussed in detail with respect to the importance of the codes in building construction and the shortcomings of various 'greening' codes. Students were then to be taken to a site visit to TERI Retreat, Gwal Pahari, to study renewable energy systems and understand sustainable habitat.

In the following weeks, along with the preparation of electrical layout plan, students learnt electrical load calculation in a residential space, and then compared the electrical load of energy efficient appliances and conventional appliances. In the final weeks of the integration, students learnt about firefighting systems. The emissions generated by fire disasters and behavior of efficient appliances in face of a fire were highlighted.

Students also learnt about firefighting systems and network, and the possibility of using recycled water for firefighting was discussed. In the last week of integration, students learnt about building automation system, and basics of Building Information Modelling (BIM) software. Students were asked to write a paper on Energy Management Systems (EMS) or Building Automation (BA) as their final assignment.

Architectural Design

The discourse for architectural design was proposed to start with a brainstorming session mapping idea for designing an institution. While introducing the design problem for this semester students were sensitized about the environmental implications of building design. Students were then distributed case studies to study orientation, fenestration and shading strategies. The purpose of this exercise was to make students understand the physical context, environmental responsiveness of building design, and various kinds of spatiality’s and architecture. Discussion on the case studies was continued in next week and students were encouraged to study shadows, envelopes, lighting, orientation, wind & comfort through time & place mapping. After the case studies were presented, site study methodology was introduced, and site brief was given. During the next three weeks, students carried out site analysis, by doing site mapping and climate analysis with the help of bioclimatic charts and Climate consultant software and presented their observations with drawings and site models. Site mapping exercise aimed to help students learn how a contour site affects microclimate of the building structure and its surroundings.

During the Architectural conceptualization lecture, students learnt the concepts of area, and dimensions, volumes with the help of building illustrations on Sketchup software. During the same exercise, students also learnt concepts of solar exposure, solar orientation of the building with the help of Sketchup illustrations. In the next lecture after learning Solar orientation and geometry, students discussed the solar exposure, wind direction of the site and formulated the shading strategies and site level services that could be provided to exploit or counter the climatic conditions of the site. A site visit to DLF Square, Gurgaon was proposed to understand shadow masking and ventilation in detail.

It was decided that in the following weeks as site layouts are finalized, emphasis will be given on design features such as Window Wall Ratio, natural lighting, daylighting instead of artificial heat gain, and possible passive design strategies that could be incorporated in the design with the reference of a bioclimatic chart.

4.3.2.2 *Semester VI (December 2017 - April 2018)*

At SSAA, for semester VI, Building Services IV (technical), Research Methodology (Humanities), and Architectural Design (Design) were identified for the integration. Prevalent lesson plans for each subject were studied in-depth and topics suitable for integration were identified, existing lesson objectives were revised to compliment sustainability concepts. Furthermore, training modules were tailored to strictly limit to the concepts covered in the syllabus, and teaching aids, activities for lesson for each subject were prepared. Professors were then asked to create lesson plans based on these ideas for integration.

Building Services 4 (HVAC)

The discourse for building services started with an overview of the need for cooling, energy efficiency, environmental considerations of Heating, Ventilation, and Air Conditioning (HVAC). In the next lecture fundamentals of heat transfer in buildings, were explained with the help of FC presentations. Students experienced their studios, corridors, and places in the building using touch and memory with respect to building materials: glass vs brick walls, impact of opaque vs non-opaque materials, U values, SHGC and VLT. Based on their previous experiences a discussion about thermal comfort experiences in glass and enclosed environments, and assessment of thermal comfort of own studio with the help of day to day experiences, sensory experiences was done. Thermal properties of material: glass was explained through ACIP presentations and discussion on how various types/ thickness of glass affect the heat gain of the building with the help of touching glass surfaces. In the next lecture students learnt how to do sun path analysis, with the help of stereographic diagrams and shadow mask exercise and learnt how to design shades based on azimuths and altitudeangles.

Students then learnt fundamentals of ventilation and air movement, by mapping wind direction using a handkerchief. To understand that wind is a dynamic concept, students carried out a time study in an open-air theatre. Students stood at 3 places in the same building, to relate the impact of architectural volume on the wind speed, and the deflection of the handkerchief was used as an indicator to detect wind flow. In the next lecture, students learnt the basics of Psychrometry, use of Psychrometric charts, and bioclimatic charts for climate analysis using ACIP presentations. These concepts were then correlated to the cooling loads of the buildings and to introduce sustainable cooling technologies and passive design strategies to tackle the cooling requirements in a sustainable manner. In the following two weeks, guest lecture was conducted on HVAC: principles and working of AC systems, refrigeration cycle, system types, components, cooling towers, AHU as supplementary solutions to passive cooling technologies and/or sustainable active cooling technologies. In the final week of integration, ECBC 2017 norms for building services were to be discussed emphasizing the idea of ECBC, its applicability, components of ECBC, covered through a BEE-UNDP-GEF presentation on ECBC 2017.

*Refer to **appendix 4.8** for students lecture notes, answers for test on building services concepts (assignment 1), presentation on sustainable living, and analysis of passive design strategies for project site (assignment 2).*

Architectural Design

The design course for semester VI was divided into three stages, namely design ideation stage, analytical design, and design stage. The project brief for this semester was to design a commercially viable, environmentally responsive, mixed-use building, with a good balance between commerce and hospitality with an interesting insert of an X-Factor program, for the students to explore intensive mixed use, environmental issues and responses, vertical stacking of services, bye-laws and basement design. Once the site study analysis stage of the project site was complete, students were given 3 case studies – a hotel project, seen and studied during study tour, an internationally well published and critiqued hotel project and one different case situation, designed by an internationally renowned architect or practice, focus of which which was either of the following – sustainability and environmental concerns, greatness of a design idea and its further resolution, responsiveness to context and the design idea etc. Students then studied, discussed and analysed the design measures, responses taken by the architect to combat, exploit geo climatic conditions of the case study. Students then tried to relate and find the design responses required to make their own project site climate responsive.

In the next lecture, the process of ideation was explored: where students were given a list of elements under the themes, site-based ideas, Architectonics based ideas, and role/purpose-based ideas. The individual breakup of each theme is included in the lesson plans. Students were then asked to choose and base their design focusing on any two idea elements. Students were then asked to articulate their design responses for said ideas as built form, carving, programmatic distributions (sheets and process models). To facilitate and conclude the process of design ideation, a two-day workshop was held, in which students were supposed to get all their idea iterations, discuss them with the expert, and formulate a singular design idea out of them. The lecture presentations and the workshop discussions, were helpful for evaluating, reiterating and developing student's ideas towards strategies and manifestations. The actual design stage spanned across the next 12 weeks, which included individual work and one on one mentoring of the students for creating site plan, all floor plans, sections, each unit details including internal layouts, services including structural plans, relevant service shafts, core details, open space, public space details, basement parking details and ramps. In the sixth week, students were assessed under Midterm review, during which students were evaluated based on (indicativerubric):

1. Uniqueness/originality in designidea
2. Design Iterations to developappropriate
3. Design Strategies to actualize Design Idea while retaining uniqueness andvalue.
4. Ability to address environmental, economic & amp; functionalefficiency.

5. Zoning and stacking diagrams to distribute all programs, based on the designstrategies.
6. Presentation - coherence in drawings and verbalpresentation.

*Refer to **appendix 4.9** for the midterm assessment rubric**.***

After the midterm review, across the next six weeks students addressed the comments made during evaluation, and prepared single line plans, lower/upper ground floor plans, upper floor plans, structural grid plans, support services, building services, parking + working and Double line floor plan with columns, cantilevers, shear walls, pergolas, space frames, critical structural members. Once all floor plans and sections were complete, students underwent final design review and jury, assessing:

1) Completion of deliverables(quantity)
2) Quality of content & Plancohesiveness:
    - Ideation & conceptdesign
    - Programmaticdesign
3) Studentsprepare
    - Concept sheet to explain ideation &intent.
    - All floorplans:
        - basement, site/roof plan, ground floor (lower/upper) plan withcontext,
        - typical floorplans
    - Sections: two critical sections(minimum)
    - One key elevation: 3D views from computer model to explain the outside form/inside spaces.
4) Individual written feedback to be shared with the internal faculty - which shall become the comprehensive feedback for the student for the design finalisation in the run-up to the external jury.

Research Methodology

Learning objective of the Research Methodology subject was to explain students the purpose and method of carrying out scientific research, and how to present it as scientific proposal. During research orientation and significance lecture, students were introduced to basics of research - why research; standards of research: truth value, applicability, consistency, neutrality; and scope of research in Architecture. During Reasoning, Logic & Literature Review: Data Collection & Collation lecture, students learnt How to gather and collate data and evidence - quality & substance, Reading/Writing as Reasoning, Reasoning as the linking together of claims- Broad Types of reasoning (deductive, inductive and abductive); What/Who is an authentic (claims are reasoned in an academically credible way) source? - Peer reviewed- Journal/conference/authority etc.; and Kinds of sources- Primary/Secondary- Kinds of Primary & Secondary sources. In the next part of Reasoning, Logic & Literature Review, i.e. Text Comparison lecture, students learnt about Relative mapping of arguments, facts & figures, quality of citations, opinion validation etc. in 3 texts on a single topic/theme. In the following 4 weeks students learnt about quantitative research methods: quantitative questionnaire, survey, empirical, scientific, statistical, simulation-based researches and visual research methods; as well as qualitative research methods: value-laden nature of enquiry, nature of reality, experience, interviewing, focus groups, ethnography, phenomenology. During these weeks a two-day capsule workshop on epistemology & methodology epistemology was also carried out, which focusedon:

1. How is it that we come to know what weknow?

2. What are the underlying assumptions of this pursuit?
   What is our process ofinquiry?
3. What are our disciplinary, sub-disciplinary and personal expectations abou what information is valid for what purposes? Development & application of avenues of inquiry - qualitative & quantitative.
4. Exploring ways to employ tools and techniques in the field to generate rapport and gather data.

In the next three weeks, students focused on making a research proposal by identifying the combination of:

1. Topic/subject/theme of their choice (from an exhaustivelist)
2. Argument making:Issue/concern/idea/finding
3. Methodology chalk out: methods ofresearch
4. Limiting & scopingresources
5. Ensuring data eclecticism & variation ofsources.

Since the academic semester has not ended at the time this report was prepared, sample research proposals focusing on sustainability issues related to architecture haven't been received. Once received, the report will be revised.

Frequent rigorous review calls to monitor the integration was not possible despite persistent follow ups and review requests perhaps owing to resistance from professors who had not attended the workshop as well as tight schedules, clearly suggesting the importance of the deep-dive workshops as a precursory sensitisation instrument.

4.3.3 *Smt. K. L. Tiwari College of Architecture, SKLTCOA, Mumbai (Nov 2017 to Apr 2017)*

At Smt. K. L. Tiwari College of Architecture, sustainability integration for the fourth semester was addressed in the creative elective course, as a horizontally integrated design module. The module integrated Humanities, Building Services, and Architectural Design subjects. As per original lesson plans, students were given small tasks every week to help them gain knowledge about sustainable design concepts and at the end of the semester,students took an assignment to apply their knowledge and create retrofitting solutions for the project site.

The module stretched across 16 weeks starting from the last week of November, planned to sensitize students and embed sustainability concepts and perquisites within the students' thought processes before they are taught about building services and could create their own building design. The lesson plans created during the workshop had to be changed as the design syllabus did not include concepts of refrigeration and cooling in this semester as well as due to inadequate efforts of other subject faculties to gather knowledge on sustainability concepts, owing to syllabus commitments to be fulfilled in a short period of time. Therefore, lesson plans were realistically re-designed as per the beliefs of what could be achieved in the current semester. The discourse began with sensitization of students on Climate Change and the impact of built space on the environment through a documentary screening.

To make students practice climate analysis before planning as a standard procedure for every design project, students were briefed on the basics of climate analysis and were asked to take field measurements on college campus on their own. Once the climate analysis of the site is complete, as a homework activity, students were asked to conduct a climate analysis of their own house, to understand how building designs are influenced by the climatic conditions of anarea.

Students then learnt the basics of Psychrometry, how to use a Psychrometric chart and its relation with the climatic zones. While discussing the climatic zones the concept of solar radiation and its effects on heating and cooling loads on a building was introduced. Students learnt how different shading devices affect the solar heat load on a building. It was demonstrated how to calculate the heat gain through different building components such as wall, window, roof, and students were asked work on a simulation exercise to calculate heat gain of their previous semester design project (a weekend bungalow).

In the next lecture students learnt about daylight simulation with the help of presentation and simulating daylight penetrating through hypothetical installation of a window in their classroom. The simulations were run on Rhino, LUX values, VLT, SHGC and U values of the assemblies were also calculated. As homework, students were asked to do similar calculations for their own bungalow project from last year.

*Refer to **appendix 4.10** for the climate analysis brief and **4.11** for climate analysis data sheet**.***

Since the academic semester has not ended at the time this report was prepared, sample research proposals focusing on sustainability issues related to architecture haven't been received. Once received, the report will be revised.

It was observed that students comprehended the concepts easily and took more interest in learning the concepts of heat loads and daylighting as they could calculate the parameters for their own project and improve upon the outputs.

Students learnt the importance of natural ventilation and passive design strategies used to enhance natural ventilation in a building. Applying their learnings students were supposed to create building models to represent all the passive design and ventilation strategies that could be used for different climatic zones. This activity was not possible due to shortage of time. Instead, students were divided in groups, given a device, a passive design strategy aiding natural ventilation and asked to present the principles, components and mechanism behindit.
As application of their learnings throughout the semester, as conclusion of the integration, students were supposed to learn how to select appropriate design strategies to minimize heating loads for their project but was not possible due to insufficient time for the project activity.

Since the academic semester has not ended at the time this report was prepared, sample research proposals focusing on sustainability issues related to architecture haven't been received. Once received, the report will be revised.

*Refer to **appendix 4.3** for the pilot integration details from all three colleges.*

4.3.4 *M.E.S. College of Engineering, MESCOE, Pune*

At MESCOE, during the engineering student's certification workshop, parallel sessions were held with RAC professors on rethinking the engineering pedagogy. As part of the rethinking pedagogy session, professors were given examples of the possible integration of sustainable cooling technologies within the university mandated RAC curricula. Participating teachers were briefed on essential teaching methodologies, sensitization ideas, physical, virtual & classroom teaching aids, how to define key educational objectives (Bloom's taxonomy) and systems of learning (associative, indirect + interactive, experiential, collaborative, and project-based) for given curricula. The discussion included understanding teachers expectations from current curriculum, and the problems they face while delivering the topics covered under current curricula.

The teachers pointed out that current RAC curriculum is very extensive and contains outdated technologies. Professors also highlighted that due to the voluminous syllabus, too much time is spent in explaining the concepts theoretically rather than allowing students to do numerical, simulation and practical exercises on them. This causes poor practical knowledge across students towards the application of learnt technologies, leading to under developed skills for the industry. During discussions the need for tailoring the syllabus according to industry standards, sequencing it in a problem-solving approach, and need to include practical training was underlined and stressed upon.

It is proposed that during the next phase of the programme, efforts will be made to approach the syllabus designing committee of Pune university for including Sustainable Cooling Technologies across the RAC syllabus along with pilot integrations for next semester.

4.3.5 *Nagarjuna College of Engineering and Technology (NCET), Bengaluru and Sai Vidya Institute of Technology, SVIT, Bengaluru*

Similar to the MESCOE workshop, during the engineering student's certification workshop at NCET parallel sessions on rethinking pedagogy were held with RAC professors from NCET, SVIT colleges.

It was decided that to take the discussions on sustainability integration further, training of teachers (ToT) workshops will be held for Mechanical and Civil engineering professors from interested colleges affiliated to Visvesvaraya Technical University (VTU), Bengaluru. Once pilot integrations are complete, the syllabus designing committee from VTU could be approached for including sustainability concepts in RAC syllabus.

4.4 Public GoodsDevelopment

4.4.1 *Teaching Resource Kit*

The teaching resource kit that seeked to help achieve the pilot integration consists of:

4.4.1.1 *Scaled Models for Building Physics 2*

Phase I

Two sets of physical model prototypes of building physics along with an illustrative manual was developed by Mr. Suresh Vaidya Rajan to ensure better understanding of the concepts. The scaled models' sets are complete.

*Refer **appendix 4.12** for the MoU and list of teaching aids that have been developed.*

Phase II

In addition to the aforementioned aids, the ACIP team along with Mr. Suresh Vaidya Rajan developed 2x22 teaching aid kits that were redesigned and fabricated using tougher materials for durability for consumption by colleges. The 22 teaching aids in the kit were:

A. SolarGeometry

1) Pedestal for locatingNorth
2) Earth-Sunmodel
3) Solar dialprotractor
4) Solar protractor for29N

5) Sundial
6) Solarscope
7) Solar scope withdial
8) Heliodon
9) Climatic zones of India (superimposed onmap)

B. Solarradiation-lighting

10) Inverse square law -1
11) Inverse square law -2
12) Pinhole camera withviewer
13) Plywood racquet with cutout (collated and scatteredlight)

C. Solarradiation-heating

14) Plywood cutout for studying windowsshades
15) Thermoscope - for comparing radiation of horizontal/verticalsurfaces
16) Thermoscope - for comparing radiation of black/whitesurfaces
17) Thermoscope - for comparing absorption of radiation ofshapes
18) Thermoscope - for comparing absorption of radiation of with/withoutglass

Airmovement

19) Candle powered wind tunnel to understandsuction
20) Cistern with bottle for studying chimneyeffect
21) Model to study Venturieffect
22) Model room to study airflow

Moreover, based on internal recommendations, feedback received from architecture professors and from other stakeholders, the ACIP team further developed video graphs to explain the use of 17 key teaching aids and 3 core concepts. This activity was primarily implemented by Mr. Suresh Vaidya Rajan, who prepared the scripts and explained the use of these aids through videos. These videos were also added as training material for the online MOOC (also available as a free learning resource) on the Freemarket platform.

Models covered in videos:

A. SolarGeometry

1) Pedestal for locatingNorth
2) Earth-Sunmodel
3) Solar dialprotractor
4) Solar protractor for29N
5) Solarscope
6) Solar scope withdial
7) Heliodon
8) Climatic zones of India (superimposed onmap)

B. Solar radiation-heating

9) Plywood cutout for studying windowsshades
10) Thermoscope - for comparing radiation of horizontal/verticalsurfaces
11) Thermoscope - for comparing radiation of black/whitesurfaces
12) Thermoscope - for comparing absorption of radiation ofshapes
13) Thermoscope - for comparing absorption of radiation of with/withoutglass

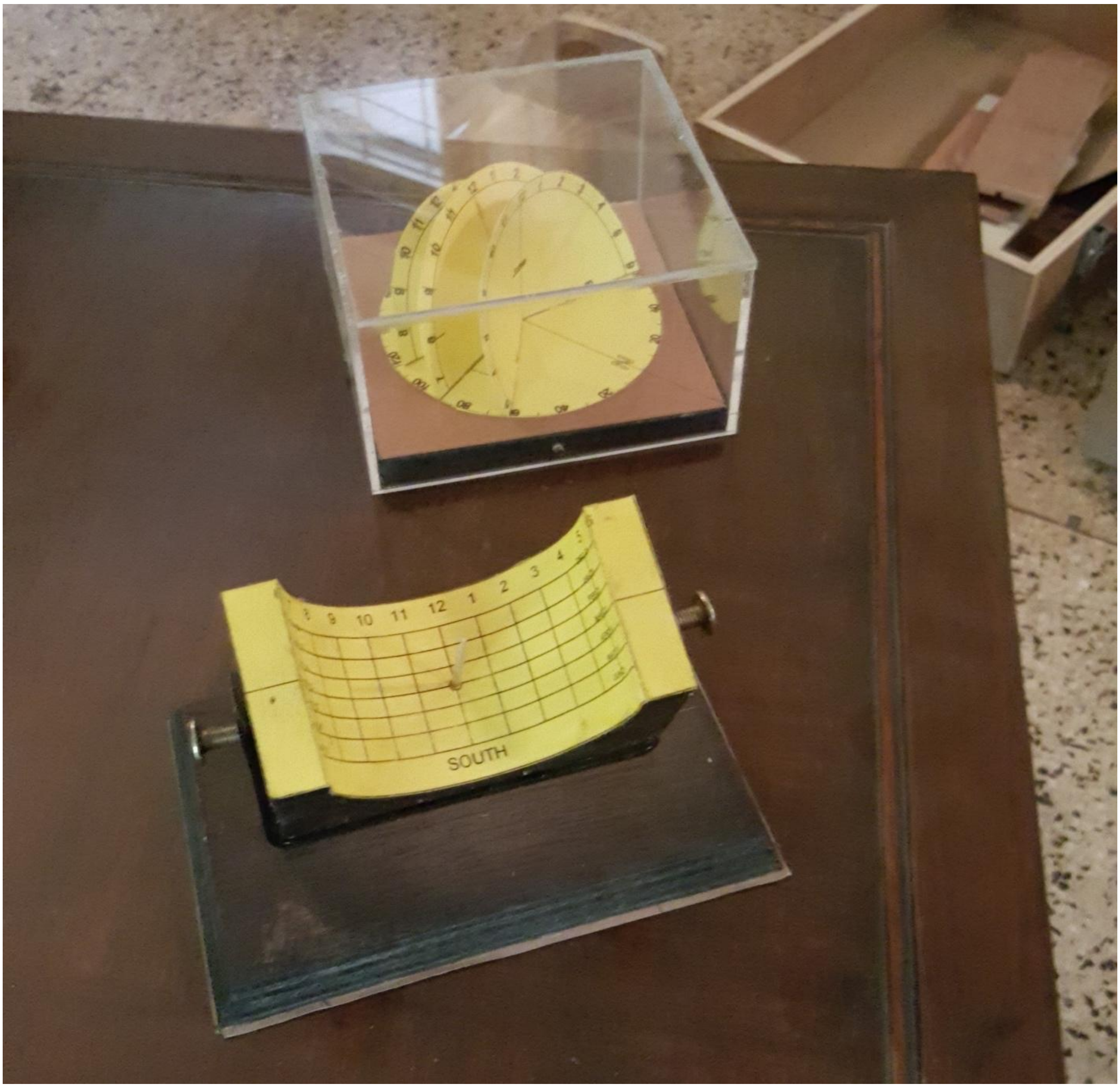
C. Air movement

14) Candle powered wind tunnel to understandsuction

15) Cistern with bottle for studying chimneyeffect
16) Model to study Venturieffect
17) Model room to study airflow

Figure 8 | Solar Scope teaching aid, prepared by Mr Suresh Vaidya Raja

Figure 9 | 3D Solar Protractor model prepared by Mr. Suresh Vaidya Rajan



Refer to this link to view/download all teaching aid videos.

4.4.1.2 *College Resource Kit*

A college resource kit to aid pilot integrations was devised, that consists of:

- Training content delivered during workshops was made freely available through the Freemarketplatform.

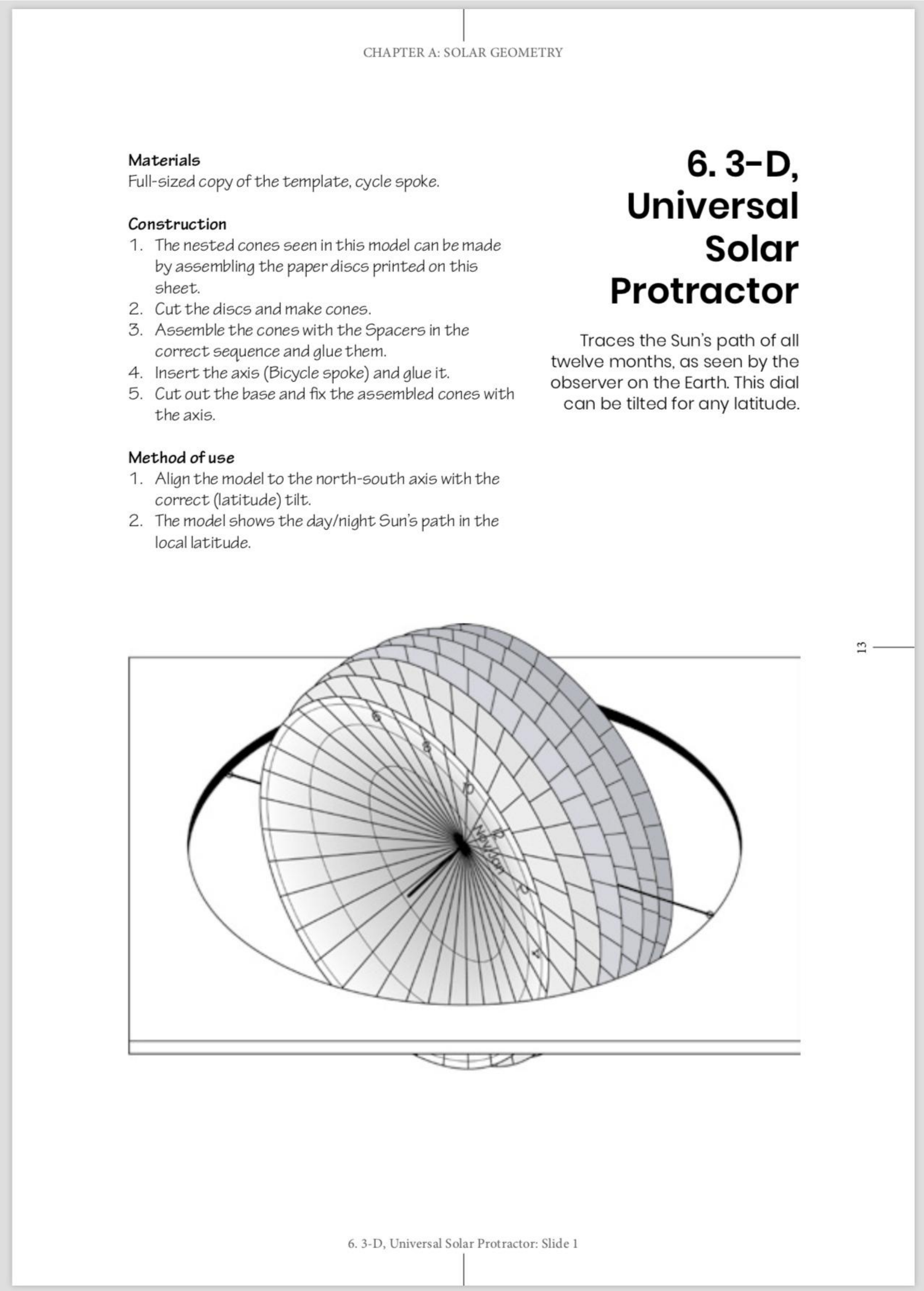
*Refer to this linkto view/download all **training module PPTs**.*

- The ACIP team throughout the pilot integrations with partner college has prepared a plethora of *'other'* resources, that can be used by professors to better explain technical and non-technical concepts and fundamentals that include: videos, software's, articles, journals, case studies,etc.
  View other resources here.
- A concept's textbook that elucidates upon topics such as: 1) Climate Change, Ozone Depletion and Cooling Systems; 2) Energy Efficiency, Thermal Comfort and Cooling Systems; 3) Sustainable Cooling Technologies (End-of-PipeSolutions)

  *View/download **concepts textbook** here.*

- An easy to understand Do-It-Yourself (DIY) kit that is a comprehensive step-by-step booklet/manual which supports along with building, the usage of these tools and clearly lists the proposed experiments (wherever applicable) and learnings that can be implemented by professors during lectures. It willinclude:
  - A Do-It-Yourself (DIY) kit that professors/students/others can use to replicate across their respective coursedelivery
  - Instructions supporting the usage of thesetools
  - Experiments and learnings for eachaid

Figure 10 | A screen-grab from the DIY Manual



CHAPTER A: SOLAR GEOMETRY

6. 3-D, Universal Solar Protractor

Traces the Sun's path of all twelve months, as seen by the observer on the Earth. This dial can be tilted for any latitude.

Materials

Full-sized copy of the template, cycle spoke.

Construction

1. The nested cones seen in this model can be made by assembling the paper discs printed on this sheet.
2. Cut the discs and make cones.
3. Assemble the cones with the Spacers in the correct sequence and glue them.
4. Insert the axis (Bicycle spoke) and glue it.
5. Cut out the base and fix the assembled cones with the axis.

Method of use

1. Align the model to the north-south axis with the correct (latitude) tilt.
2. The model shows the day/night Sun's path in the local latitude.

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6. 3-D, Universal Solar Protractor: Slide 1

*View/download **DIY Handbook** here.*

4.4.1.3 *Models & Animation Videos for Sustainable Cooling Technologies*

Along with providing 3rd-party animations on conventional cooling methodologies that enable students to deconstruct the demerits of using air as a refrigerant, the project developed self-explanatory animation videos for the 4 sustainable cooling animations: 1) Structure Cooling, 2) Radiant Cooling, 3) Solar VAM, and 4) Evaporative Cooling. These freely available videos can be used by any stakeholder to deeply understand and/or mainstream sustainable ways of cooling built space. These animations are also part of the MOOC (discussed later).

Figure 11 | A still from the Structure Cooling animation

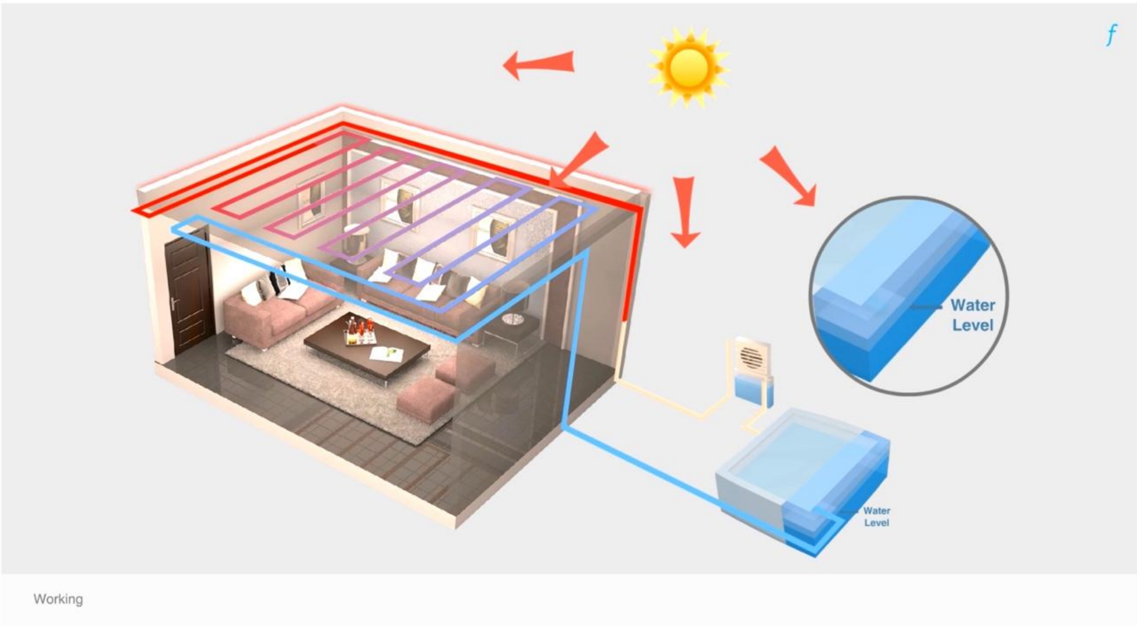
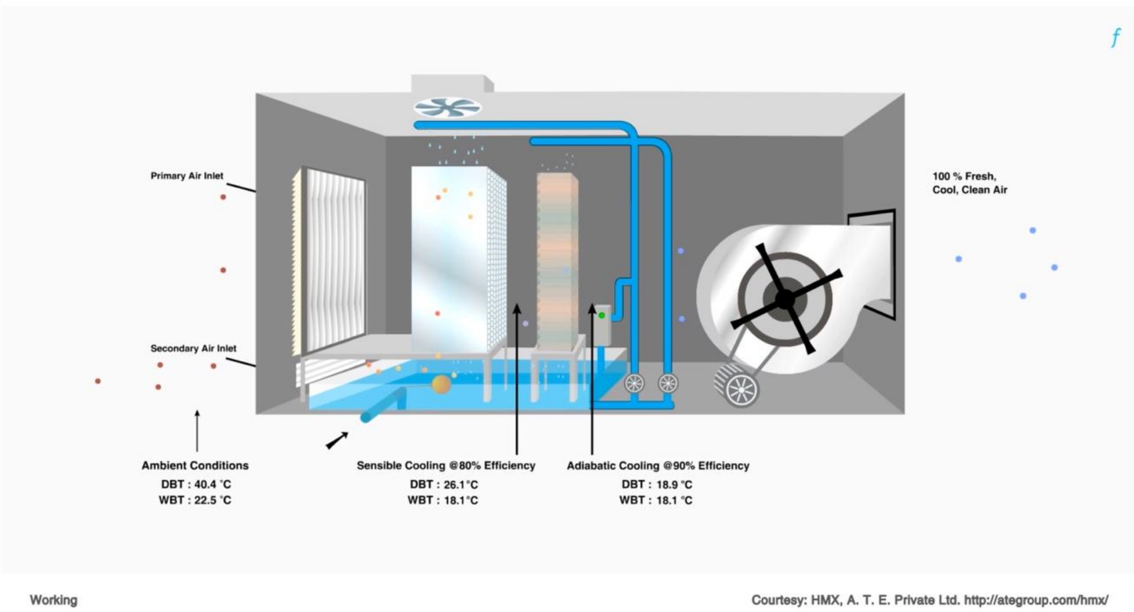


Figure 12 | A still from the Evaporative Cooling animation



*Refer to this link to view/download the **animations**.*

Physical model prototypes of Sustainable Cooling Technologies and building physics concepts enabling deep understanding were developed for: a) Indirect-direct Evaporative Cooling, b) Structure Cooling, and c) Radiant Cooling. The purpose of deploying these models at BNCA is for the students at BNCA (and beyond BNCA) to deeply understand and be able to embed the concepts of SCTs in their educational and future designs. These models will also be open for use by any other college within/not-within that region to be studied in-depth at no cost. These models are constructed in a manner that allows for easy data logging and understanding of the principles that constitute these technologies.

The scaled model for Indirect Direct Evaporative Cooling (IDEC) has been developed in collaboration by HMX-A.T.E., India and the unit were delivered to and installed at Dr. Banuben Nanavati College of Architecture (BNCA), Pune during the first week of October 2017. The scaled model for structure cooling was developed in-house and was also installed at BNCA towards the end of October 2017.
Lastly, scaled model for the radiant cooling system was developed by Oorja Energy Engineering, and was delivered to and installed at BNCA towards the end of October.

*Refer to this link to view photographs of all the three **models**.*

4.4.2 Smart-energy Tool Upgrade

Under the current phase of ACIP, the Smart Energy tool was upgraded to include the ability to model sustainable cooling technologies as an enhanced feature in the software. In addition to this, the tool now provides simulation results for sustainable cooling technologies and compares it to the use of conventional HVAC technologies. Furthermore, it is able to promote and encourage the diversification of HVAC activities in India in order to reduce the GHG emission and energy consumption through hands-on practice of using this tool.

Figure 13 | Screengrab from the design-day report of a Solar VAM modelling exercise.

SMARTENERGY
Web Based Energy Modelling Software

Design Day Report
12, Apr 2018 10:32 AM

Project Details

Project Name :	fairconditioning2
Submitted By :	Nagarjuna College of Engg
City State :	Pune, Maharashtra
Design Range :	1.0 %

Zone Name ***P ZONE***

Climatic Condition

	Outside			Inside	Difference
	Summer	Monsoon	Winter		Summer
DBT	37.1	29	10.9	24	13.1
WBT	19.600	24.200	10.900		
RH %	18.83	65.76	100.00		
GR/LB	56.738	129.131	60.734	67.895	-11.157

Ventilation

Ventilation air or Treated fresh Air Qty. (CFM) :	0	Zone Area (sqft) :	8110.46
Ventilation (ACH) :	0	Zone Volume (cuft) :	31045.47
Infiltration (ACH) :	0.066	Zone Height (ft) :	3.83

Dehumidified CFM

Dehumidified CFM/sqft :	1.69	RSHF :	0.863
Dehumidified rise (deg F) :	12.51	ERSHF :	0.865
Dehumidified Air Qty (CFM) :	13,715.51	ADP (deg F) :	61.299
		By-Pass Factor :	0.1

Sensible Gains

Gains	Units	Value	Summer (Btu/Hr)	Monsoon **(Btu/Hr)**	Winter **(Btu/Hr)**
Windows, Glass Doors			7258.583	5948.137	0
Walls, Partitions, Doors, Roofs, Floors			44043.956	5457.847	0
People			32111.196	32111.196	32111.196
Equipment			46993.869	46993.869	46993.869
Lights			33863.454	33863.454	33863.454
Bypassed Ventilation Air			0	0	0
Infiltration Air			785.485	308.516	0
Sensible Heat Sub-Total			165056.542	124683.019	112968.519
Sensible Load Safety, Supply Fan Heat Gain	%	5	8252.827	6234.151	5648.426
Effective Room Sensible Heat			173309.369	130917.170	118616.944

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*Refer to **appendix 4.13** to view details on the upgrade and the MoU for the upgradation.*
*Refer to **appendix 4.14 to 4.18** to view design day reports of actual simulations from the 5 SCTs.*

4.4.3 *Freemarket Platform*

The online *'Freemarket'* platform was developed as part of the current ACIP phase, which seeks to intensify ecosystem interactions and breed organic connectivity amongst the sustainable cooling ecosystem and enhance quality of architecture education. The platform further aims to act as a forum and support group on sustainable cooling technology issues, environmental science and building technologies. It further seeks to promote research towards improved pedagogy, creative activities that seek to engage students and improve learning, etc. Information pertaining to maintenance, site installations, specific technology info, MOOCs, lecture videos, wiki and research papers will other features of the *'Freemarket'*.

Freemarket includes a variety of resources such as a *'knowledge'* section which includes very detailed pages for all Sustainable Cooling Technologies and Passive Design Strategies. The knowledge section also includes a MOOC. Fairconditioning in collaboration with Environmental Design Solutions, an organisation based out of Delhi, that looks at reducing GHG emissions across the building sector in India, developed a 9-module online course that helps establish a thorough foundation in scientific and technical concepts that are related to Building Physics, Passive Design Strategies and Sustainable Cooling Technologies. It has benefited professors by acting as a platform to re-learn fundamental concepts, motivating and encouraging them to teach these concepts to the students in a simpler, yet effective manner. Moreover, it is a prerequisite since the ToT workshop intensely focuses on imparting pedagogy related training through the technical and design concepts discussed in the MOOC. While all users would have the rights to take the MOOC, only specific user types will be given the right to add MOOCs (if required infuture).

Freemarket further includes an *'Events'* section that would list any workshops and/or events in the sustainable cooling space. While all users will have the ability to register for an event(s) online, only specific stakeholders such as Freemarket administrators, Institutes, Architecture Firms, etc. can be given the rights to list events. All external event listings will be subject to approval by Freemarket administrators/content managers.

Additionally, a *'Talent'* module was also developed that lists jobs from the Sustainable Cooling Industry. Only specific user types will be given rights to upload a job. For e.g. Institutes, Firms, Freemarket admins, etc.

The platform also features a *'Showcase'* section that lists case studies of live projects that feature Sustainable Cooling Technologies or Passive Design Strategies. The showcase section has the ability to filter down to specific case studies as per the user's criteria. Moreover, as other sections, only specific users will be able to add case studies.

Lastly, the Freemarket platform has an extensive *'Collaborators'* section that lists approximately 2,500 users that consists of Students, Professors, Architects, Architecture Firms, Engineering Firms, Sustainable Cooling HVAC firms, etc.

Figure 14 | A screengrab from the Freemarket homepage

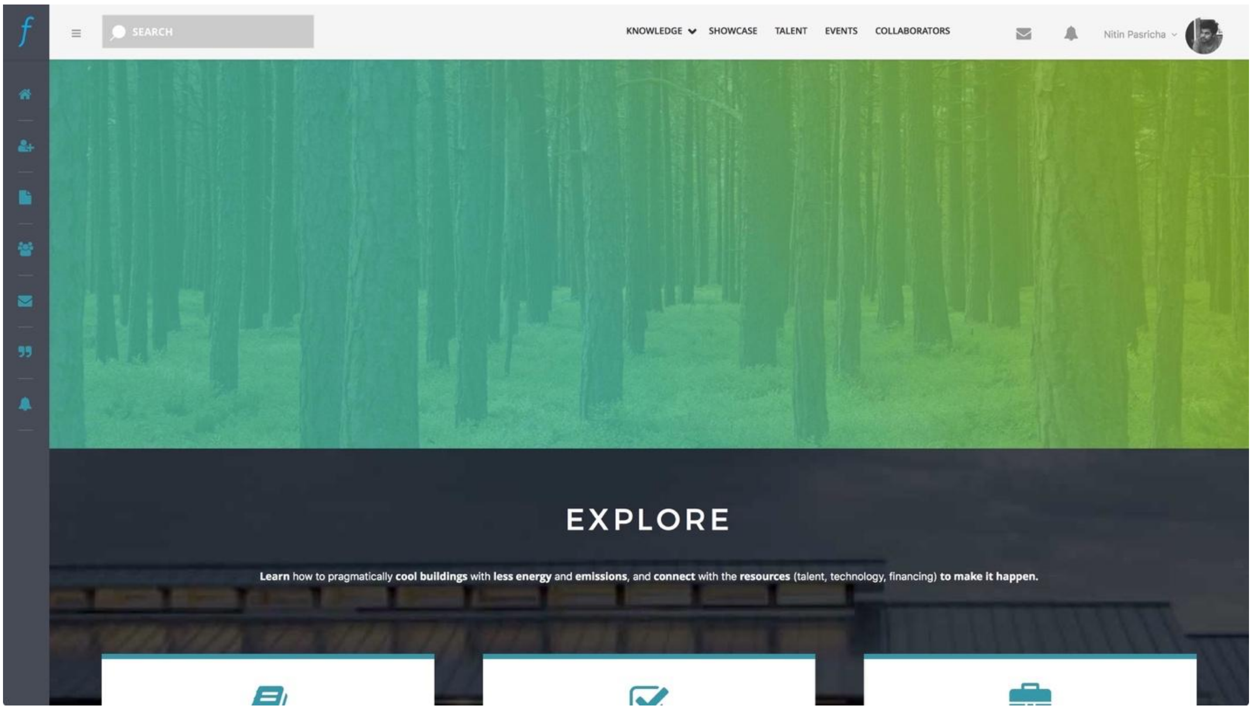


Figure 15 | A screengrab from the Freemarket homepage

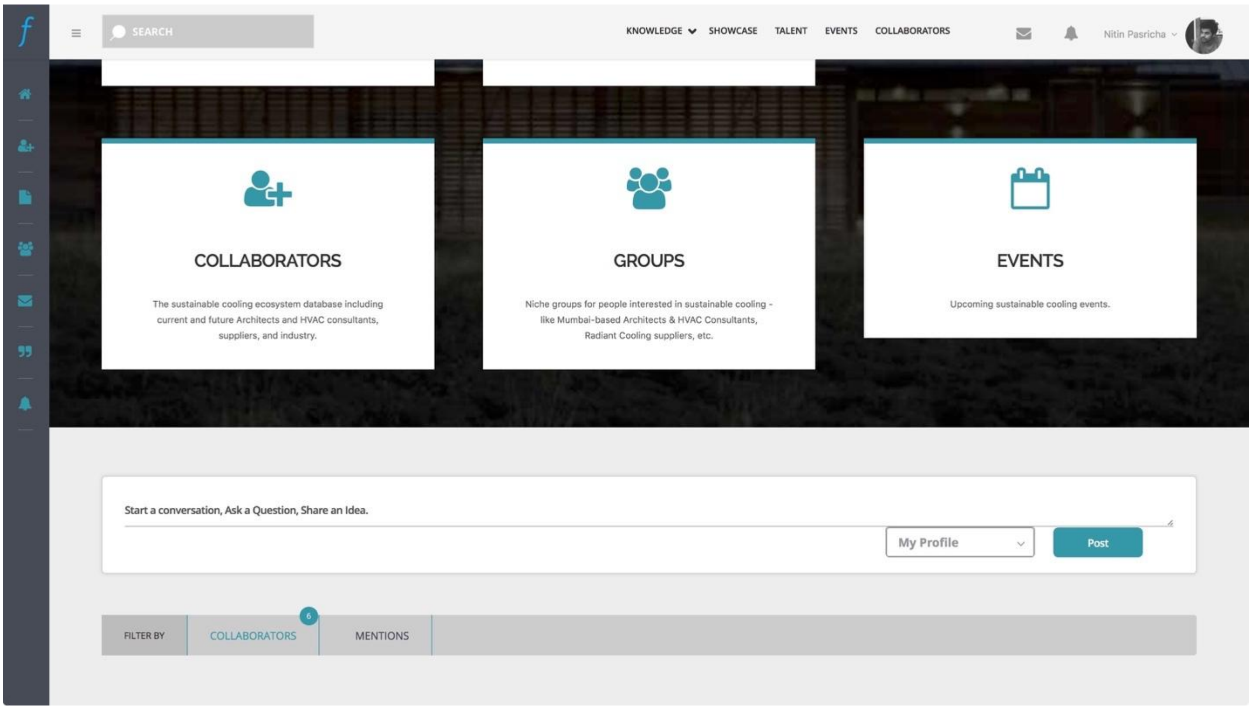


Figure 16 | A screengrab from the Structure Cooling 'Knowledge' page

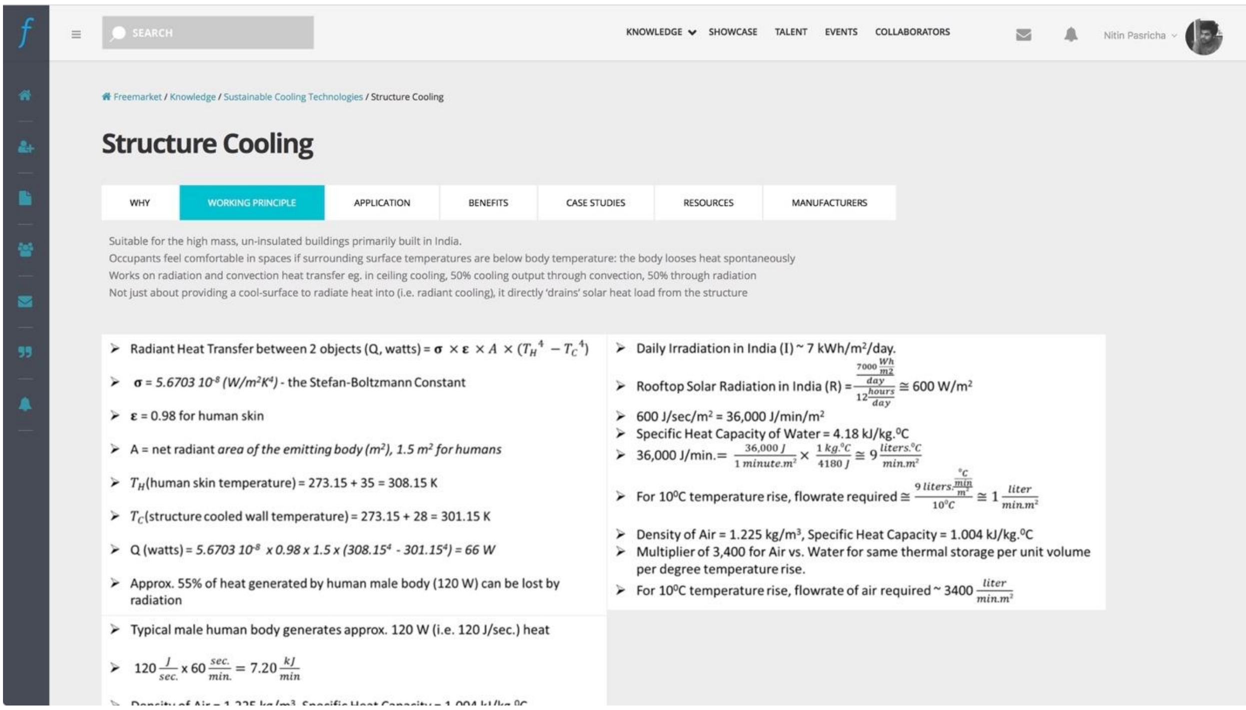


Figure 17 | A screengrab from the Freemarket 'Collaborators' section

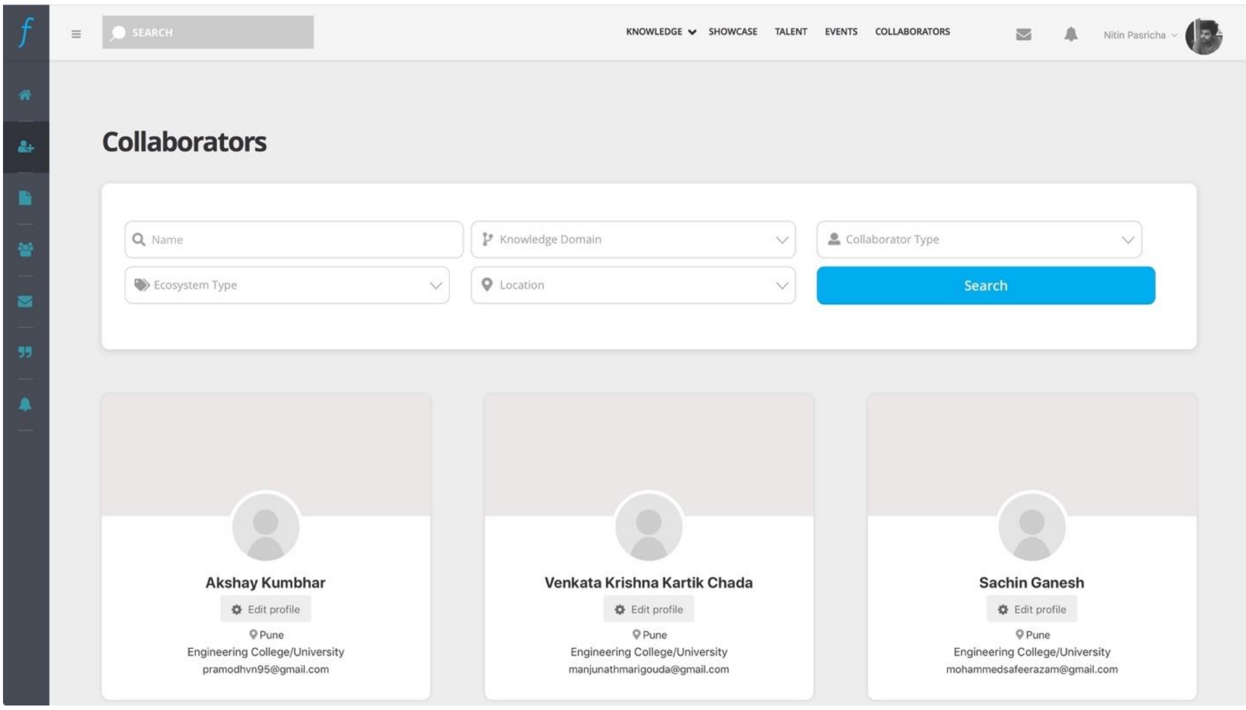


Figure 18 | A screengrab from the Freemarket 'Events' section

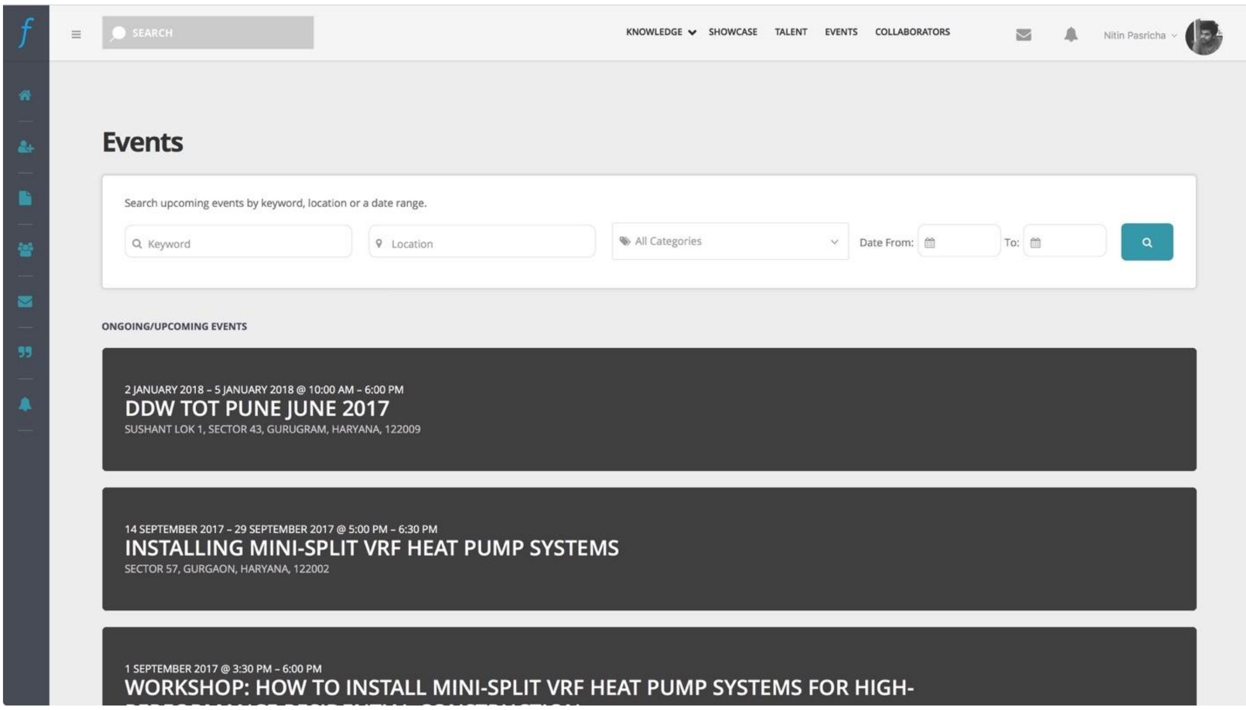
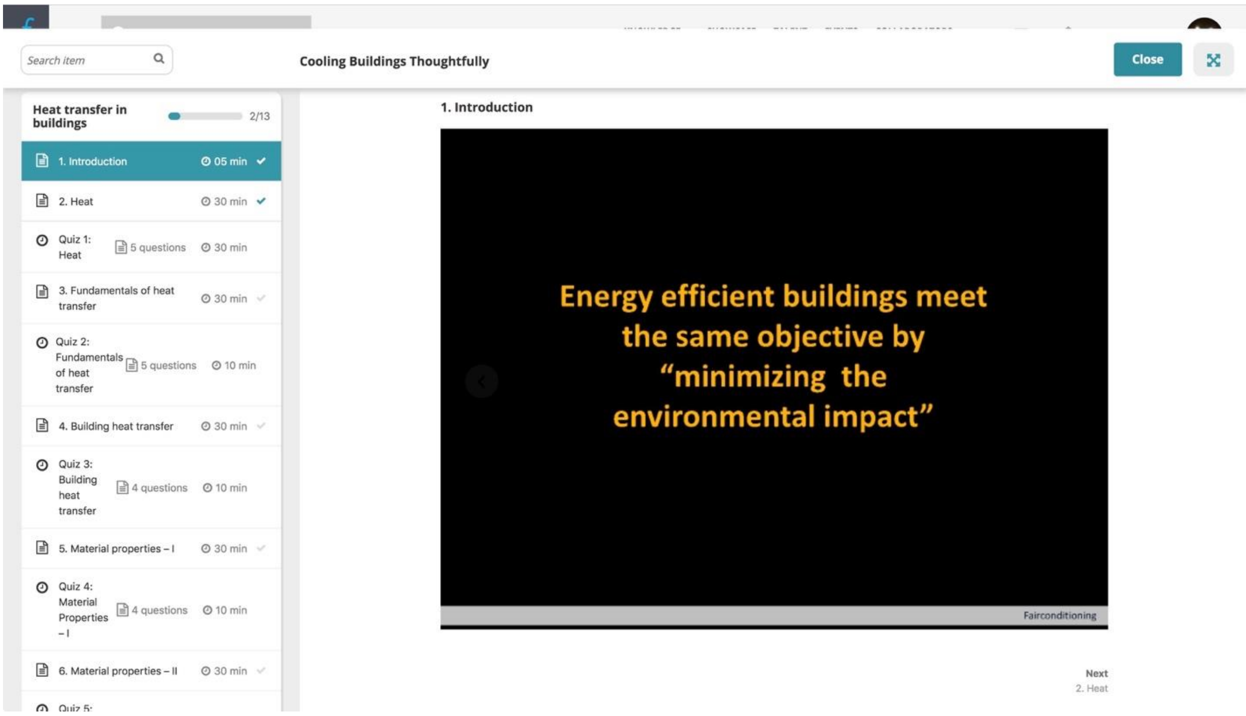


Figure 19 | A screengrab from the Freemarket 'MOOC' section



*To view the **Freemarket platform**, click here.*

4.4.4 *Training Modules*

The ACIP team collaborated with several stakeholders to devise training content capable of building trainer capacity as well as integrate within existing architecture curricula. Training modules encompassed fundamentals of building physics such as: heat transfer; psychrometry; adaptive thermal comfort including The India Model for Adaptive Comfort Study (IMAC); passive cooling design strategies; climate analysis; solar geometry; and sustainable cooling technologies/techniques such as Structure Cooling, Radiant Cooling, Evaporative Cooling, and Natural Refrigerants.

These training modules have constantly evolved during the course of the programme. Until their most recent form, the technical concepts were devoid of internal integration where, relevant teaching aids used to explain the concept were discussed after the module. However, all technical modules are now integrated with activities for deep-sensitisation, best practices in integrating sustainability within curricula, and teaching aids that encompass physical scale models for climatology and building physics, software tools, animation videos, testing and evaluation aids, etc.

The training content further seeks to rethink the existing pedagogy methods and challenges the status-quo by introducing (re-introduce in certain cases) Kolb's experiential learning cycle and Bloom's Taxonomy of learning domains along with the proposed adapted learning system.

Training modules include:

A) Engineering StudentCertification

- Group Debate: Personal position mapping and articulation in the context of ClimateChange
- Climate Justice and the Built Space: An Introduction toFairconditioning
- Thermal Comfort and Indoor AirQuality
- Psychrometry
- Climate Analysis and Passive DesignStrategies
- Active Cooling: Efficient HVACSystems
- Sustainable Cooling Technologies - Natural Refrigerant AirConditioning
- Sustainable Cooling Technologies - Direct/Indirect EvaporativeCooling
- Sustainable Cooling Technologies - RadiantCooling
- Sustainable Cooling Technologies - StructureCooling
- Introduction to EnergyModelling
- Smart Energy Tool - Modelling Sustainable CoolingTechnologies
- Case StudyDetailing
- Rethinking EngineeringPedagogy

B) Architecture Professors Training ofTrainers

- Nexus between Climate Justice, Built Space and ArchitectureEducation
- BuildingPhysics
- ThermalComfort
- Psychrometry
- Climate Analysis & Passive DesignStrategies
- Solar Geometry & ShadowMasking
- Active CoolingPrinciples
- Sustainable Cooling Technologies – NaturalRefrigerants
- Sustainable Cooling Technologies – StructureCooling
- Sustainable Cooling Technologies – RadiantCooling
- Sustainable Cooling Technologies – EvaporativeCooling
- RethinkingPedagogy
- SyllabusRenaissance

Additionally, the ACIP team along with 3rd party vendors videographed brief training lectures that would not only greatly assist architecture professors in the future during pilot integrations but will also be an integral training resource for various stakeholders as part of the online MOOC on the Freemarket platform. This activity also stems from feedback from professors who face difficulties addressing technical concepts.

*To view **Architecture ToT training modules**, click here. To view **Engineering Student Workshop training modules**, click here. To view the **training lectures**, click here.*

5 Challenges, Learnings & Outlook

5.1 Summary of Feedback fromParticipants

5.1.1 *Architecture Professors*

- Participants found the Nexus between climate change and built space, Sustainable Cooling Technologies, Pedagogy related sessions to be outstanding.
- Most of the participants agreed that the sessions were well spread out. They also suggested spending an entire day on the interactive sessions (lesson plan co-creation sessions) in order to fully comprehend all concepts and apply them to the reworking of the lessonplans.
- Most participants agreed that the theory part of the workshop (building physics, thermal comfort and sustainable cooling technologies) were intensive but well spread out. Professors who felt that the workshop was rushed and saturated were assured and given support throughout the semester by arranging retraining sessions as and whenrequested.
- Participants were extremely satisfied with the structure of the workshop and stated that they found the workshop to be extremely informative, inspiring and resourceful. They also stated that the workshop allowed them to introspect on their teaching methods, discover new ideas for sensitisation and teaching about they could introduce and emphasize on the importance of each of these concepts of sustainability to their students andclients.
- Participants suggested that making the workshop less technical and more practical, by spending more time on the syllabus renaissance sessions and having more group discussions would bebeneficial.
- Most of the participants wanted the rethinking pedagogy, syllabus renaissance sessions to be longer, requesting a break of few days' time between the workshop and finalising the lesson plans, to chalk out detailed lessonplans.
- Participants felt a need to conduct more tailor-made workshops, focusing only on concepts that would be focused on the current semester syllabus, suggesting deep sensitization activities, and interactive learningtechniques.
- Professors proposed creation of videos for each session, so its more easily accessible to them. Creating these videos would further help trainers understand how they can improve and would be easier for refreshing concepts to from time totime.
- Professors raised concerns with respect to getting the students more involved in sustainable building design, due to university regulations and how those policies need to change in order to effectively integrate sustainability into their syllabus.
- Time constraint pertaining to meet the university deadlines was identified to

be a critical concern, highlighting that the existing syllabus compels them to focus on the end-result more than ensuring a sufficient understanding of concepts. They further raised concerns as to how they could change their teaching style in compliance to the university regulations, so as to ensure that the thought-process of the students are developed to think sustainably when it comes to building design.

*Refer to Arch. ToT Deep Dive workshop feedback report in **appendix 5.1. Refer to** Arch. ToT Deep Dive workshop consolidated feedback in appendix **5.2***

5.1.2 *Engineering Students*

- All participants agreed that the objectives of the workshop were clearly communicated, and the workshop met theirexpectations.
- Most students found the presentations to be outstanding, especially, the sessions on Climate justice and build space, Psychrometry, Thermal Comfort and Indoor Air Quality and Sustainable coolingtechnologies.
- Most students agreed that different pedagogical, interactive and group activity-based sessions were well spread out. Students proposed that more time should be spent on psychrometry and software training, so they could use the software to understand all aspects whilemodelling.
- Students highlighted that they would like to spend more time on sustainable cooling technologies and active cooling, however, this contradicts with the tight schedule provided by collegemanagement.
- From the feedback received, it was incurred that, students agreed the workshop was good, and sensitized them about sustainable cooling technologies, which they hadn't explored before. Students requested the workshop to be spread out over the period of a week, hence giving ample break time and even workloads for assimilating the learnings from the workshop.
- Students also felt the need for including more problem solving, modelling and practical sessions, in that order to understand and apply sustainable cooling technologies and energy modellingbetter.

The aforementioned feedback has been noted down and further in-depth analysis of the feedback forms will be carried out. The report will be revised to include key learnings and strategies for changes to be be carried out by the ACIP team during the next phase of operations.

*Refer to Engineering Student Certification workshop feedback report in **appendix 5.3.** Refer to Engineering Student Certification workshop consolidated feedback on in **appendix 5.2.** Refer to detailed feedback summary of Engineering students workshop at MESCOE and NCET in **appendix 5.4** and **5.5** respectively.*

5.2 EvaluationResults

To assess and be able to certify students, an evaluation to gauge comprehension of skills was conducted by the ACIP team on the last day of the respective workshops. The assessment consisted of 50 MCQ's including concepts of Building Physics, Thermal Comfort and Indoor Air Quality, Sustainable Cooling Technologies and Natural Refrigerants. Students were allowed to refer to all presentations and a concept book was shared with them. Students that score 50% and above were granted a certificate of completion. The results are:

1) **MESCOE, Pune** - Out of 53 students that took the assessment, 49 students scored over 50% and received certificates. The average score for MESCOE was60%.
2) **NCET, Bengaluru** - Out of 20 students that took the assessment, only 7 students scored over 50% and received certificates. The average score for NCET was47%.
3) **SVIT, Bengaluru** - All 3 students that took the assessment were certified. The average score for NCET was65%.

A total of 59 Mechanical Engineers were certified by ACIP in phase II.

*Refer to **appendix 5.6** for the consolidated answers from the 2 engineering workshops. Refer to **appendix 5.7 and 5.8** for an assessment report for each workshop evaluation. Refer to **appendix 5.12** for the evaluation MCQs withanswers.*

5.3 Key Learnings &Outcomes

1. Learning-centric pedagogy is a new idea amongst most Indian teachers and architecture pedagogues specifically. This evolved approach requires unlearning and de-centralizing the role of the *'teacher'* who till now essentially used *'teaching content'* as an object of exchange with the student. The relative *'power structure'* is being deconstructed and the material and student are being placed in proximity and learning is being stimulated. This perceived *'displacement'* of the teacher's role was sometimes resisted by those who felt insecure about their relevance in the revised order that is beingestablished.
2. The elemental question of explicit calling out sustainability in the design studio briefs is being constructively debated by some of the colleges and the program is considering running control studies to determine the relative efficacy of *'invisible'* integration. For e.g. Professors at SSAA and BNCA felt that the mention of sustainable design and passive cooling strategies in the design brief might take away the creative freedom ofstudents.
3. Unlike horizontal integration, which is greatly embraced by most academics, vertical integration that links successive taught and applied subject over the 5 years of undergraduate education is proving to be challenging and there is adequate skepticism amongst academics of its possibility within the rubrics of the current curricula framework which strictly separates *'semesters'* from each other and within them, into discrete thematic elements. Thus, the vision of formalizing the establishment of common design-studios which cultivate and simulate the working environment of a real architecture practice (wherein experienced *'mentors'* guide and advise less experienced practitioners) is still unrealised and might require rethinking as a major thrust element of the program's experimentalmatrix.
4. Enhancement of training material must include specific teaching/learning methodologies for specific subjects/topics, examples of integration practiced in other Indian architecture colleges,andevaluationmechanismsforthosespecificelements(i.e.waysinwhichitmight manifest itself in the design and hence be considered a successful instance of integrated learning).
5. While the general response to interventions and change by academics has been encouraging, regional variations in attitude are clearly discernible and the conventional ostensible causes,

for instance autonomous/deemed university versus those following a university syllabus or private versus government-supported colleges, are insufficient explanations for the disparate responses and levels of resistance to change. In general colleges in the Delhi NCR region have been recalcitrant while colleges in Mumbai have displayed a greater proclivity to embrace change. Professors from Delhi/NCR region usually echo the view that they would not have enough time on their hands to integrate *'everything'* with respect to sustainability. They expressed the view that they are extremely short on time with just the bare minimum curriculum and integration needs to be minimal, at least initially to get buy-in fromprofessors.

6. In spite of relentless communication and support extended by the ACIP team, architecture professors showcased disinterest towards participating in the workshop and the subsequent pilot integration. Even though reasons for disengagement, cited as: previously scheduled commitments and lack of interest. This is being remedied in next semester's integration plan by mandating the idea of sustainability integration to the entire faculty across the identified semester of intervention prior to the workshop and proceeding with integration only after unanimous agreement for full support and involvement by professors andmanagement.
7. Few professors have articulated their concern that while it is desirable for architecture students to acquire an instinctive and tactile understanding of key sustainable design principles e.g. climatology, through experiential learning, etc. without necessarily quantifying benefits (like engineering pedagogy would be engaged in) and understanding the implications in terms of energy saved, etc., this might precipitate the situation whereexpectedskill-development and climate-literacy benefits might not be achieved.
8. The strategy and benefits of altering architecture theory (e.g. theory and method) vs. more well-defined humanities subjects (e.g. history of architecture) remains to be resolved, appraised, and refined. Does the program select only 'easy' receptacles for integration or strive for nuanced and powerful integration, but proportionally arduous, in even these less defined and nebulous courses is a profound subject to be explored with evidence-creation and localized, contextualized debate for the specific conditions prevailing in acollege.
9. Architecture professors have expressed concern over students refusing to learn beyond the bare minimum syllabus. To ensure sustainability integration is seamless and incohesive with the syllabus, care is to be taken to only target topics relevant to sustainability for intervention. Any sort of content addition to the current syllabus was strictly avoided. Ideas were suggested for sensitizing students about each subject at the start of the semester, to make the students want to know more about the subject. Exercises that factor sustainability principles were given to the students to create a pull for sustainability knowledge. For e.g. History professors at BNCA included climate responsive buildings as a criterion to analyse buildings of various architecturalstyles.
10. Complete consent from decision making authority, management and all professors teaching subjects selected for intervention was reiterated as, a) It was observed that professors who did not attend the workshop (after confirming they would) were not exposed to the sensitisation and need for the integration, hence resisted the idea of integration and b) Since they did not fully understand the goal of the integrations, they rejected the idea of integrated sustainability in their respective subjects stating it is not possible to do so. However, the integration was achieved with other institutes thereby suggesting that it is achievable and reassuring the importance of sensitisation of professors as well as students. Some participants also suggested conducting the same 4-day workshop, specifically for each college,toensurethatallfacultyfromthatcollegeistrained,easingtheprocessofintegration.

11. Majority of participants voiced their concerns about starting the process of integration coming from a purely technical background thus having minimal knowledge pertaining to the different passive design strategies and sustainable cooling technologies. Participants thus felt they couldn't do justice to the sustainability concepts to be imbibed through the intervention and hence were hesitant about sustainability integration. Along with video recording of the lectures it was suggested if possible to employ a *'sustainability coordinator'* in hub colleges in each region for full time pedagogy support. As requested during feedback videos of sustainability concepts were created and put up on Freemarketwebsite.
12. As requested by participants during feedback collected in middle of phase II, tailor made workshops were conducted, with updated modules focusing only on concepts that would be focused on the current semester syllabus, charting and suggesting deep sensitization activities, and interactive learning techniques in the current lessonplans.
13. Upon completion of pilot integration(s) a self-assessment feedback form was circulated amongst professors to elucidate successes, challenges and learnings from the integration. Based on responses received until now (most professors are still busy with semester end activities and we expect to receive all self-assessments in the coming weeks), it was observed that the professors were satisfied with their efforts towards the integration, however felt that different strategies needed to be employed for widespread intervention. Although the preparation of lesson plans were easier its implementation was a comparatively difficult task. It was observed that more work needs to be done on learning methods and sustainability infusedcontentdevelopment,whichisnotreadilyavailableincurriculummandatedtextbooks.

The evidence of efficiency of sustainable design and services is only possible by running simulations on software's, but it is time consuming to provide software training to students as there is no room for such activity in university mandated syllabus. While professors themselves strongly agree that with respect to skill development and to find future jobs, it is highly relevant and important to update the existing syllabus with Sustainable Cooling Technologies; however, they had a hard time in helping students realize the importance of sustainability beyond ethics and climate change. The students wanted to know how they are actually going to benefit monetarily from whole building design knowledge.

As support from ACIP, professors highlight that the MOOC to be opened up for students on an easily accessible platform. Professors have also requested training and assistance beyond modules and requirement of teaching aids such as lecture videos, animations, podcasts. As support from college management professors have requested dedicated lab or a few instruments like the dry bulb thermometer, CO2/humidity measuring devices, data loggers and computers equipped with sustainability software to allow them to conduct physical experiments which have been observed to aid best in students understanding of thesubject.

It was also requested that institutes like COA, AICTE should give sustainability or sustainable design subject a standalone presence across all years along with integration in other subjects.

*Refer to **Appendix 5.9.** for the integration evaluation feedback form. Refer to **Appendix 5.10** and **5.11.** for individual assessment reports submitted by the professors.*

5.4 Key outcomes from pastphases

- Developed training content for 'Sustainable Cooling for Architecture/EngineeringEducation'
- A Massive Open Online Course (MOOC) was created and extensively used as preparatory tool for trainingworkshops.
- Certification from ISHRAE and AEEE for technical content wasprocured.
- India-specific Building-Energy- Modelling tool for optimum and efficient HVAC design (SmartEnergy), developed by ISHRAE, has been upgraded to include 5 Sustainable Cooling Technologies,
- Above mentioned 'public goods' used to train 96 professors from 26 architecture colleges through 6 workshops in Train-the-Trainer formatworkshops.
- Similarly, 317 students from 10 colleges were trained through 6 workshops with engineering colleges in the First Phase of theProject
- Sustainable-Cooling Enhanced Syllabi for 30+ architecture courses co-created through collective-intelligence workshops withprofessors.
- Memorandum of Understanding (MoUs) with 8 of the most resonant and enthusiastic colleges (from the 1stPhase network) were signed and subsequently, 4 Architecture and 4 Engineering Colleges supported through 1 to 2 curricula integration cycles of 6 months each in the Second Phase of theProject.
- Knowledge support portal (Freemarket Platform) developed, sustainable cooling technology animations, and teaching aids,kits' developed and disseminated to all colleges in network to support pedagogyupgrade.
- MoU with COA and Center for Science and Environment (in progress) signed to conduct Teacher Training programs amongst colleges engaged in their respectivenetworks.
- BEE has informally recognized this program as a vital resource for improving their effort to mainstream ECBC knowledge assimilation into bachelor's level curricula in Architecture Colleges.

In addition to the above objective outcomes, the following subjective transformations have been witnessed through the efforts of the program:

- Professors have begun underscoring distinction between thermal-comfort and air conditioning in design studiobriefs.
- Narrative shift of 'green' buildings from being a value-adding, hobby, USP etc. to be a non-negotiable global security and safety issue through sensitization sessions that foster discourse related to the climate-change and built-spacenexus.
- Concept of "Whole building" design studios (with partner Engineering Colleges participating in a 'buddy program') welcomed in all instances and integrated into MoU's signed with all institutions.
- Engineering students now see the Sustainable Cooling Technology realm of the economy as a meaningful professional field with opportunities for fulfilling, creative, and challenging work where they can elevate their purpose to that of beingchangemakers.

5.5 Recommendations

5.5.1 *Expanding the Evidence Set*

- Currently, the number of stakeholders (academic institutions) that are engaged in the Pilot Program is modest – 8 colleges. The deep-dive workshops and the subsequent curricula integration handholding support with these finite set of institutions has led to the distillation of specific 'integration' methodologies for 5thsemester subjects, 6thsemester subjects, and Environmental Studies (EVS) elective courses; these are encapsulated in the Curricula Integration Manual produced in previous phases of the Project). *The proposed Phase 3 of the project seeks to utilize the pedagogy materials, physical teaching aids, classroom application techniques, upgraded software's, and other collaterals (experiments, field measurement exercises, games, evocative questions for debates and other generative themes for a dialogical educational process) that have emerged in Phase 2 across a larger set of colleges to ascertain their general validity when applied in a relatively standardized manner across a larger set of colleges.* This phase will focus on stimulating uptake of these prepared aids and tools by professors trained in their use through specific workshops pivoting around specific courses which are naturally allied, within the rubrics of the current curricula, to integration of principles of passive design, building physics, and sustainable cooling technologies.

- This phase will seek to expand the evidence-set to cover more university curricula (proposed universe size of 8 architecture and 8 engineering colleges associated with a total 8 deemed or state universities) to provide a robust evidence set of insights, best-practices, and mechanisms for deep energy efficiency and sustainable cooling integration to BEE+COA effort currently underway. The immediate benefit, complementary to the final outcome of the evidence-based policy making advocacy efforts with accrediting (AICTE) and regulatory (COA) bodies that govern architecture and mechanical engineering education, would be the transformation of curricula that directly shapes the academic practices of approximately 120 architecture colleges (approximately 1/4thof India's totally architectural academic universe) and X engineering colleges (RAC course) inIndia.

- Three eminent partner architecture and mechanical engineering colleges (affiliated with the same regional university) will be identified in each selected city. These institutions will be engaged with through signing a Memorandum of Understanding (MoU) to affirm their intent to support curricula upgrading through efforts by trained professors' post-conclusion of workshops.

- In order to curb the inordinate investment of time and energy required to recruit colleges to formally sign up for the exhaustive pilots, the proposed project seeks to work with widely recognized and preeminent institutions in India who have been engaged with capacity building amongst architecture and other building sciences related educators. In this context, the Program team has receivedin-principle buy-in from the COA and Center for Science and Environment to jointly host and conduct Teacher Training programs amongst colleges engaged in their respective networks. These programs will be publicized as joint offerings with the partner organizations and it is anticipated that the unimpeachable credibility and high regard for these institutions will lead to swift recruitment of the required colleges for the project's interventions.

- Finally, to curb the possible adverse effects of administrative and legislative apathy towards the objectives of the Project, the process of selecting the 'target' universities will take cognizance of states which have adopted the ECBC and where state governments have been engaging with Regional Universities an anointed them as hubs for ECBC capacity building.

5.5.2 *Deepening Evidence Base*

In addition to expanding the envelope of institutions, this phase seeks to 'deepen' the evidence base. The overarching logic of this element of the theory-of-change is that 'university curricula establishes a minimum requirement, not a limiting boundary on program content of education'. The reassertion of this unequivocally accepted ontological truth about educational curricula provides the fulcrum for this theory-of-change lever. This will be accomplished as follows:

- The current intervention's emphasis on working with syllabi of one specific semester at any given time in a college is necessarily a controlled simulation of the real-world condition which would involve simultaneous execution of curricula integration across multiple ongoing semesters. For instance, odd-numbered semesters conducted during one half of the academic year, and even-numbered semesters executed through the second half of the year. The deepening of the evidence-base would involve deployment of upgraded lesson-plans across 2 semester-long cycles spanning odd-and-even semesters. In this manner, all key courses across the 5-year bachelors course, which are suitable for integration of the project's objectives, will become the subject of the interventions to beapplied.

- The ACIP team will execute combined Training Programs, one each for Professors of the 3 Architecture and 3 Engineering Colleges per city. The technical training content of the workshops will be specifically designed to address the curricula integration possibilities for the specific courses that will be available for intervention in the subsequent intervention cycle. Since the proposed project seeks to eventually harness curricula integration opportunities across all semesters of a Undergraduate Architecture Program, the Architecture Professors Workshop will be conducted 2 times a year (to encompass odd-numberedandeven-numbered semesters according to the University Curricula nomenclature system, respectively) and the RAC professors workshop will be conducted once each year prior to the relevant semester cycle wherein the RAC subject is taught in adherence to the Regional University's academic calendar. Thus, each year will involve conducting of 12 workshops (8 architecture and 4 engineering workshops)

- This deep-dive workshop will include extensive training sessions that empower, guide, and provide technical actionable-knowledge to professors to seamlessly deliver and subsequently be empowered to embed syllabus-content related to sustainable cooling strategies across courses covering seven core themes: humanities (history and theory), climatology, building materials,buildingtechnologies,structuraldesign,buildingservices,andarchitecturaldesign.

- The workshops will encompass extensive training on fundamentals of building physics such as: heat transfer, psychrometry, adaptive thermal comfort, passive cooling design strategies, climate analysis, and solar geometry, followed by training modules related to science and engineering principles of sustainable cooling technologies such as Structure Cooling, Radiant Cooling, Evaporative Cooling, Solar Vapor Absorption Systems, and Natural Refrigerants. All modules will provide comprehensive pedagogy technique training related to teaching aids (physical models, software tools, activities, experiments etc.) and relevant pedagogy techniques suitable for specific courses being addressed. The workshop will also leadtoco-creation (through group work sessions amongst all participating city colleges) of enhanced lesson plans for the relevant humanities, design, and technical subjects that will be piloted in the subsequent semester in all the city colleges simultaneously.

- Prior phases of the project's engineering (RAC) academic interventions relied on a 'additive' climatechangeandbuildingenergyefficiencysensitizationmodule(toengenderempathyfor the inequitable social and environmental conditions perpetuated by business-as-usual building cooling practices), deep technical training on sustainable cooling technology science principles and engineering design, and a concomitant sustainable cooling design software training module in a selective set of thought-leader colleges. This year long exercise has established 4 'hub colleges' in India which have been nurtured by the project to a palpably enhanced state of preparedness for formally integrating Sustainable Cooling Technologies into their RAC course lesson plans while staying within the rubrics of their respective university curricula. This phase will involve transitioning away from the direct student-training approach amalgamated with a pedagogy-technique awareness module for RAC course Professors (which can be thought of as a sculpting exercise for chiseling the approach to the use in the proposed phase) and graduate from student-level capacity building to capacity building and pedagogy technique training exclusively for Professors, in consonance with the approach used for Architecture Colleges. This will reduce the resource burden on the project and enhance the replicability of the SCT-enhanced RAC curricula template. It is noteworthy that this specific element of cultivating a complementary set of sensitized and intellectually equipped HVAC engineering Pedagogues, who can train students on design sustainable cooling systems, is completely absent in the teacher ECBC-related training programs currently being implemented by BEE in collaboration with the CoA as the implementation partner.

5.5.3 *Improving Pedagogy Support*

- The prototype physical teaching aid kits, for amplifying and reinforcing building physics and passive design technique pedagogy, and scaled working models of Sustainable Cooling Technologies, that have been deployed in 2 host colleges, have commenced the process of enhancing the pedagogy support available to teachers of the specific college. While the DIY-kitsandassociatedassemblydrawingsforthescaledworkingmodelshavebeenmadeavailable to all network colleges in the previous phase of the project, their uptake and use in the colleges which do not have their own physical model prototypes is impaired by the general dearth of resources to create their own set of aids through devising projects for students of advanced semesters or other indigenous and autonomous processes. The proposed phase of the project envisions fabrication of complete 'energy efficient & sustainable cooling' kits for all network colleges. This activity will also be part of the co-financing strategy of the project which will employ the fabrication and sales of user-friendly physical teaching aids, designed and manufactured in collaboration with professional product design firms and sustainable cooling technology manufacturers. The proposed activity also encompasses engagement with other accomplished partner organizations working in the realm of Sustainable Buildings (e.g. TERI, who have expressed their in-principle consent for supporting this activity) to write joint-funding proposals with colleges to seek funding from other National Designated Authorities (such as Department of Science and Technology) or Global Environmental Facility (GEF) to actualize the mission of this activity: to establish sophisticated sustainable cooling labs (equipped with physical teaching aids and sustainable cooling modelling software's). The manner in which this activity advances the theory-of-change is that once physical aids, offering direct tangible academic pedagogy and enhanced student engagement benefits, are procured by academic institutions, they are far more likely to voluntarily engage in the curricula integration pilot as committed partners; their financial investment in teaching aids entrenches their commitment to effectively using these aids for differentiating themselves from their peers as an institution offering a higher quality education for the same tuition fee. This catalytic activity is anticipated to expedite the process, of establishing 16 pilot integration efforts across architecture and engineering colleges to eventually 'tip' this pivotal part of the built-space supply chain. Concomitantly, this strategy allows for maintenance of a smaller outreach and management team since the time-cycle from initial contact to signing MoU's with network colleges is expected to significantly contract in this scenario.

- A comprehensive curricula integration catalog (comprising course-specific pedagogy techniques, syllabus topics, activities, experiments, games etc.) has been distilled through the simulated lesson-plan development sessions in 16 workshops conducted with 25 architecture colleges. This material has been compiled into a Sustainable Cooling Pedagogy Handbook that has become part of the academic 'commons' through previous phases of the program. The proposed phase of the project seeks to significantly enhance this manual, developed from field research, by integrating inputs from collaborative sessions with behavioral and pedagogy science experts to create a learning-centric pedagogy technique 'library'. This enhanced manual will ensure that the limitations of the hegemonic abstract models of learning behavior which regard students as a pliable entity that respond effectively to the banking concept of education[8] are transcended. The manual so devised will address the current discomfiting pedagogy wherein students are passive recipients of a sterile teaching-centric pedagogy deployed without provoking critical thinking, empathy, and predicated onthesimplistic notion that merely augmenting the quantity of information deposited in the student mind stimulates absorption by the student mind. More pragmatically, it will also serve as a ready-to-use 'how-to' manual for all relevant architecture courses to integrate ECBC in accordance with the MoU between COA and BEE.

- Empathy-building and sensitization sessions during the nascent stages of any semester-long course is a central curricula integration element that has been advocated by the previous phases of the project. While Professors have unequivocally extolled the virtues of this emphasis on 'getting students to care' in the first few weeks of a semester and included these elements in their lesson plans devised during workshops, their execution has involved formidable administrative and logistics challenges that have required addressing; in many instances the execution was greatly disparate from the planned activity and often inadequate as devices to engender empathy, curiosity and motivation to learn amongst students. The central hurdles have been identified and the proposed project endeavors to address them by vetting and selecting civil society organizations that will work as 'sensitization partners' for the project. These organizations, located in regions of resource-extraction and conflicts related to building materials and fossil fuels, or regions detrimentally affected by inequitable energy access, or engaged with victims of urban heat-island effects or hazardous levels thermal discomfort (e.g. informal housing in marginalized communities who experience routine power cuts that are endured within poorly ventilated or weatherized homes), will be recommended to partner colleges who can then engage independently with these organizations to conduct sensitization site visits and studytrips.

- Further, the proposed project will ensure vigorous uptake of the following set of resources (disseminated through the *'Freemarket'*Platform:

    - Sustainable Cooling Pedagogy Handbook (referred to earlier) - A repository of sustainability cooling & energy efficiency pedagogy techniques that are designed to be delivered through a combination of recommended methods, tools and systems of learning (associative, experiential,etc.).
    - Presentation material and associated video-recorded lectures to enable post-workshop access to the modules delivered duringworkshops.
    - Other resources (videos, software's, articles, journals, Case studies,etc.)
    - Physical teaching aids kit (referred to earlier) along with Do-It-Yourself (DIY) kit that professors can use to fabricate the aids in-house orexternally.
    - Video recordings supporting the usage of these tools inclassrooms

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[8] Banking models of education is a term used by Paulo Freire to describe and critique the traditional education system. The name refers to the metaphor of students as containers into which educators must put

knowledge

5.5.4 *Change-Management Support*

- The scope of previous phases of the program was largely restricted to providing deep technical training and resource support through teaching technique recommendations and teaching aid kits/manuals. A pivotal theoretical underpinning of the previous phase was that teachers, adequately trained and supported by the Program and incentivized as well as fortified by the progressive management at the institution (demonstrated by signing a ambitious and farsighted MoU with the Program) would seamlessly transition into an empowered state of reflective and responsible praxis to deliver the highly refined and reformed lesson plans. The formidable management tenacity for status-quo practices, propensity for conformity amongst established teachers who do not feel adequately motivated to change tried-and-tested lesson plans, thereby self-inhibiting their agency and breeding complacency, have proved to be daunting challenges in the previous phases. These experiences make it abundantly clear that the implementation of any futureeducational policies that might be influenced through this work will be undeniably marred, and the efficacy of the reformation effort therefore greatly compromised if the program doesn't not evolve an academic change-management approach to address these crippling lacunae.

- In recognition of these imperative aspects of change-management support that academic institutions are currently deprived of, the proposed project phase willintegrate:
  A. 'Behavioral-Change Training Modules' wherein Professors and College Managements will be primary actors. These modules will explore cognitive and behavioral biases, associated heuristics which impede organizational and operating process transformations required for entrenching curricula integration processes throughout the 5-year program. Furthermore, they will be designed to spur collective intelligence amongst stakeholders in the academic power structures (e.g. amongst teachers of parallel subject streams such as humanities, technology and design, between these groups, and between professors and management) to foster consonance, counter parochialism, and mitigate potential future situations of discord amongst management and professors during the course of the pilotengagement.
  B. Establishment of a curricula integration 'coordinator' within the college who becomes the 'single point of contact' for administering and tracking the entire curricula integration process. The project will involve experimentation with the concept of a College-level 'Sustainable Cooling Master Trainers', a team of two professors (serving as corresponding surrogates in the event of leaves of absence) who would receive exhaustive technical and pedagogy technique training and have access to re-training modules through the 'Freemarket' Platform already developed. The program proposes to incentivize this new academic position by seeking formal recognition for the specific professor amongst senior college management and certification of the position in conjunction with the project's institutional partners (e.g. ISHRAE, COA, AEEEetc.)
  C. Curricula Integration Handholding, Monitoring, and Troubleshooting: A curricula integration tracker will be developed to meticulously monitor actions related to lesson plan integration across all participating colleges. Combined bi-weekly review calls will be organized with all participating colleges in a city to monitor the progress and to addressissues.
  D. Evaluating Curricula Integration: A framework (a formal assessment test and descriptive feedback form) to evaluate baseline 'capacity' amongst the test group and control groups will be developed; the framework will build on prior work already undertaken in other academic institutions across the globe and will avoid re-inventing 'capacity measurement' methodologies for surveying wherever possible. Concurrently, a post-intervention assessment framework will be developed. The assessment will evaluate the test and control group on their knowledge on the concepts being addressed in the lesson plans. While the pre-assessment evaluation is conducted at the start of the session / semester, the post-assessment is conducted prior to the final exams. The pre/post evaluations would be analysed to highlight

the effectiveness of the different methods of teaching, systems of learning, etc. against the sustainability concepts being addressed in the lesson plan for the respective subjects. The feedback provided to the control group would be analysed to understand the impact of the delivery methods and the new sustainability infused lesson plan. The analysis would help distil recommendations for curricula integration methodologies to be advocated for with relevant regulatory and governingbodies.

5.5.5 *‘Keystone’ Projects to aid Culture-Shift*

The previous phase of the project has unveiled the challenge of creating an enduring sustainability culture-shift in complacent academic institutions in India. Currently, the architecture and engineering academic ecosystem related to the built space ‘industry’ functions in a largely insular manner. There are no punitive consequences, incentives, or pressures – financial (taxation or increased revenue incentives), social (peers), market (competitors), or professional (regulatory bodies) in the academic ecosystem ensuring curricula is upgraded to integrate passive design and sustainable cooling across the spectrum of learning/teaching opportunities. In the absence of these external drivers of change, culture-shifting ‘keystone projects’ have emerged as a possible solution for specific types of institutions wherein a inspired leadership is lacking or ones where institutional hierarchical considerations throttle creativity, empathy and inclusive ownership amongst all stakeholders. These ‘keystone’ high-visibility projects are designed to provide internal catalysis through satisfying a visceral need of ‘validation’, present to a varying degree amongst most stakeholder groups, to achieve the objective of a burgeoning ‘demand’ for an upgraded, sustainability integrated pedagogy. The subsequent project phase endeavors to experiment with this idea through the device of the following projects:

A. City-wide Sustainable-Cooling Mapping Project with network colleges. This concept has already received buy-in from current network colleges wherein tasks related to these projects will be embedded permanently into the lesson plans of 7^{th}, 8^{th}or 9^{th}semester students who are equipped to carry out simple thermal comfort audits of sustainably cooled buildings in their city to compliment real-time cooling energy modelling data through installedsensors.

B. COA conducts an annual thesis award program across 5 zones in India wherein 5 colleges with 50-100 entries from each zone participate in the awards. Out of all entries, 2 are selected for the final presentation, amounting to 10 thesis projects showcased at the national level. The proposed project will devise, develop, and support a new award that follows the same model of target audience participation under the ‘Thesis Award Programme’, as an extension to the pre-existing award. The new ‘building energy efficiency award’ will seek to reward 5 final year students, 1 from each zone, with housing project designs as their thesis, and will be evaluated on a set of criteria through building energy modelling software’s. COA has in-principle agreed to sign a MoU to thiseffect.

C. Along with credible preeminent national institutions with an impeccable track record of devising highly credible and popular rating systems (such as TERI), but who will not seek to reduce the essence of the intervention to rekindling a ‘green building certification’ driven approach, rate and publish rankings of colleges that offer holistically integrated architecture programs which graduate students that are future-ready and have the skill, attitude, courage and empathy to change the trajectory of India’s inexorable rise in building energy consumption.

D. Formally co-create and publish a ‘model’ energy efficiency integrated undergraduate curricula with the AICTE. AICTE has in-principle agreed to sign a MoU to this effect. This will incentivize uptake of curricula integration amongst colleges outside the direct beneficiary network of the proposedprogram.

E. The pioneering spirit and actions of the 16 colleges which will hopefully catalyse the ensuing trajectory shifts in pedagogy across their academic ecosystem will be recognized through positive mobilizations. These gathering of students, professors from neighboring architecture and engineering colleges, project team members, and other members of civil society organizations that are part of the Smart and Sustainable Space Cooling Coalition, will participate in orchestrated ‘celebration’ events outside college premises to validate and illuminate the courage displayed by the persons of academic institutions that have executed pilot integrations successfully. Mainstream media coverage (through engagement with Education and Environment Section Editors of exemplary newspapers) and socialmedia coverage of these events will be coordinated as part of the project’s effort to underscore the efforts college professors, heads of department, coordinators etc. as discourse shapers that will eventually lead to the establishment of guidelines for the new normative practices in RAC engineering and architecture curricula in India.

F. The obdurateness and complacent culture pervasive in the hierarchical institutions that the project’s previous phases have engaged with have been an enduring hindrance to projects efficient progress. The proposed project’s activities will include a deep engagement with the Global Strategic Communications Council to orchestrate concerted and synchronized media coverage to influence the ecosystem to achieve medium-term industry-level policy. Illustratively: AICTE’s Architecture Board and COA’s Training and Research Centre (TRC), ISHRAE, IGBC and GRIHA could be persuaded to implement the program’s recommendations through a wave of convergent reportage appearing over a highly concentrated timespan pivoting around a significant calendar event or woven around annual severe weather periods; for instance, peak summer blackouts or grueling heat waves in urban regions. These communication activities, in consonance with other direct evidence-based advocacy efforts, seek to ‘tip’ the ecosystem at the beginning-of-pipe through objective transformations such as inclusion of the Sustainable Cooling Technology Modelling Student Certificate Program with activities of ISHRAE / IGBC Student Chapter training activities and other outcomes indicated in the theory-of-changeconstruct.

G. In conjunction with student clubs (e.g. environment clubs) of partner colleges, the Project will set-up ‘annual awards’ to identify and dissect climate unresponsive or unsustainably cooled buildings in their city. This culture-shifting project will thereby nurture a critical thinking culture in the institution and cultivate irreverence towards status quo thinking about the modern practice of Architecture and irresponsible energy use by air conditioning systems. It is anticipated that a catalyzed student body will be pivotal in the process of ‘tipping’ the ecosystem through evidence-based policy advocacy activities. It is also reasonable to expect that amplification of the expression of student discontent about the current state of irresponsible architecture and air conditioning systems in their cities will significantly increase attractiveness of curricula integration recommendations in the perception of Regional Universities, and therefore have a significant bearing on the cascading influences on COA and AICTE who govern and regulate academic affairs of RegionalUniversities.

6 Fairconditioning Programme 2014 to2018

Fairconditioning is a building-cooling Demand-Side-Management (DSM) related education, capacity building, and pilot implementation program. It is designed as an evidence-based policy support program that seeks to create a critical mass of evidence for programs that could be scaled-up across India and other tropical climates to achieve behavior change amongst occupants of air-conditioned indoor spaces, reduce building heat loads (cooling demands), and reduce energy/greenhouse gas (GHG) intensity of artificial cooling systems. The goal is to determine the types of programs, and their essential features, that can successfully avoid power generation to improve energy access and to lower GHG emissions.

Fairconditioning articulates a three-iii approach for transforming the cooling of interiors in India: (i) Influencing consumer behavior, (ii) Improving efficiency, and (iii) Integrating available technologies.

cBalance, along with Noé21 - a UN-registered Swiss non-profit organization - were the co-creators of the Fairconditioning program. cBalance is the Fairconditioning program implementing partner in India.

Fairconditioning had two projects:

1. The Building Energy Modelling and Advisory Project(BEMAP)
2. The Technology Adoption Project(TAP)

The BEMAP addresses a systemic knowledge and skills gap amongst practicing architects and HVAC consulting companies through conducting rigorous training workshops which integrate energy efficiency within the building design process for practicing architects and engineers.

The TAP seeks to curtail the gap between ‘intention’ and ‘action’ amongst commercial cluster consumers of ACs who have demonstrated inclinations to be good stewards of the environment but whose actions are not commensurate with these virtuous intentions. It addresses Voluntary Technology Adopters (organizations and institutions), that are persuaded with a decision-support and energy-efficiency eco-system in the form of pro-bono technical feasibility studies, network building with vetted green building architects (proficient with building envelope efficiency and passive cooling design), sustainable cooling technology providers in India, and bridge-building services through workshops and roundtables to catalyse uptake of design concepts and technologies to reduce cooling related energy consumption and GHG emissions.

BEMAP and TAP mesh well with ACIP because the architect and HVAC firms trained during the BEMAP workshops may absorb qualified and motivated interns emerging from the ACIP student certification workshops and collectively make low-cost or pro-bono technical feasibility studies available to SMEs through the TAP.

All documents, videos, animations, etc. can also be viewed here.