Teaching architecture through an energy and climate lens

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Abstract

Despite the increasing societal awareness of the climate crisis, considerations of outdoor and indoor climate, energy consumption and generation, and the environmental impact of material choices still represent a niche in architectural practice. Given the urgency of the issue, addressing these topics needs to be integrated in architectural design. In this work, we first describe a build-up of teaching formats and position them in view of learners' competence development in architectural design through an energy and climate lens. We identify opportunities to refine our teaching instruments further and improve the learners' ability to independently integrate topics related to energy, emissions, climate, and comfort in the practice of design projects. We end with an outlook of an idealized build-up of these competencies across an architecture curriculum.

Introduction

In light of climate crisis and energy transition, sustainable building design, materialization, and energy use must be radically rethought. This necessary fundamental shift in how we retrofit existing and design new buildings requires a broad overview of the relevant factors and a deep understanding of their interrelationships and impact on architectural design. An integrated design process allows learners to understand the diverse interactions better and utilize them productively for design (Pelsmakers et al., 2022; Mumovic & Santamouris, 2013).

The Professorship of Architecture and Building Systems at ETH Zurich investigates how energy and climate-related building systems interact with architectural design. Figure 1 illustrates the multitude and complexity of energy and climate aspects with their corresponding building systems, which shape the conditions in architectural spaces to which building occupants are exposed. Integrated design involves studying the essential parameters and metrics related to the outdoor and indoor climate, local energy generation and consumption patterns, material choices, and their impact on the environment, e.g., visualized through Greenhouse Gas (GHG) emission timelines (Hischier et al., 2023), and the impact of design decisions on the building users, e.g., expressed by human comfort. An iterative process recognizes the interdependencies of design choices on different scales, therefore allowing architects to consider how new materials and approaches, energy demands, and infrastructure affect how we build.

Design studios are a prominent feature of architecture curricula. Despite a long tradition of blending the functional, structural, social, and technical, the integration of energy and climate perspectives in architectural design remains challenging. We have identified two gaps that hinder the application of energy and climate-related considerations in teaching architectural design:

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1. Theory classes on energy and climate are rarely directly related to the practical design work in design studios. As a result,
2. students find it difficult to effectively integrate energy and climate-related considerations when facing constraints and conflicting targets inherent to architectural design.

To help students develop expertise in integrated architectural design processes, we have gradually enriched all our energy and climate theory classes with project-based elements, such as group work on case studies and regular feedback sessions. With this contribution, we summarize achievements and challenges and give an outlook on how we intend to increase further the students' skills of integrating energy and climate into architectural design.

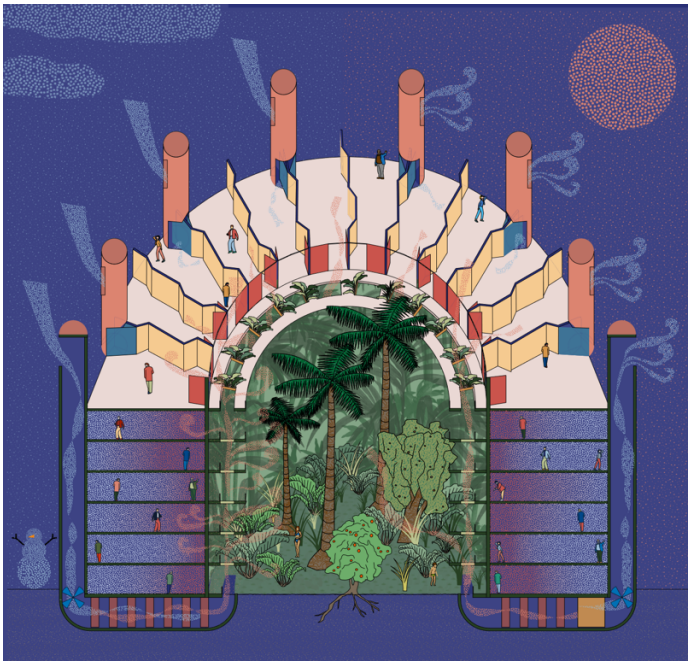

Figure 1: Integrated Design. An example from a collaborative design studio, where learners successfully integrated and visualized energy and climate topics in their projects (Schlueter & Bharathi, 2021).

Building competencies in energy and climate design across the architecture curriculum at ETH Zurich

Within the architecture curriculum at ETH Zurich, we have been building up a set of different project-based learning (PBL; Kuhn, 2001) formats over the last couple of years to support integrated design: *Energy and Climate Design* lectures, *Focus Work projects*, a *Building Integrated Photovoltaics Workshop*, *Computational Methods in Energy and Climate Design*, *Design Studio* projects, and the digital *Integrated Design Platform* for collaborative teaching and learning. Initially loosely connected, we gradually revised the different formats towards a stepladder approach where teaching and learning are aligned and build on each other. An overview of the learning goals, target level of learner independence for each course, and temporal embeddings of the courses in the curriculum are illustrated in Figure 2. The following sections summarize the individual formats and how we further developed and augmented the courses with PBL elements over the last few years. They lead to a proposal for a future revision, which is described in the latter part of this paper.

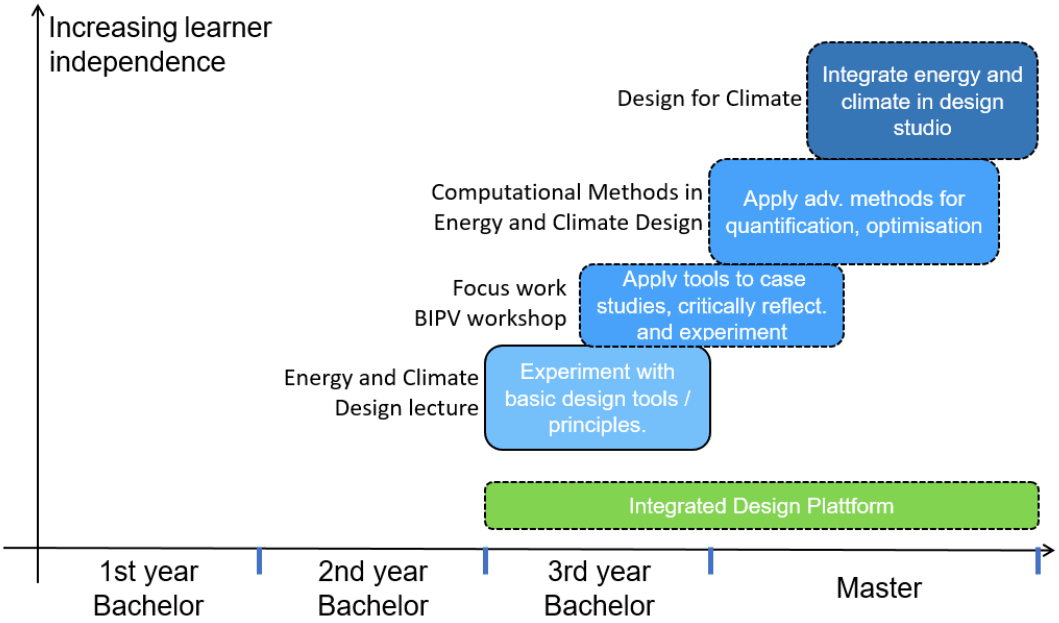

Figure 2: Overview of overarching learning goals and lecture formats in relation to the architecture curriculum (1st-3rd year Bachelor and Master classes) and level of learner independence.

Lecture: Energy and Climate Design 1 & 2

This course uses blended teaching to provide authentic practice opportunities and enable peer-to-peer learning. The two semesters were split into blocks of three weeks each. In each block, the 200-300 learners are given a set of tasks from a sub-topic, e.g., local climate and energy potentials, along with tool recommendations, case study examples, and minimal background information so that they can solve the tasks on their self-selected case study independently within a predetermined learner group. At the end of each block, each group received face-to-face feedback from a tutor (Figure 3, left).

Independent project: Focus Work

The project assists learners in transitioning from relying on teacher support to completing tasks independently. We use feedback and rubrics as ongoing, formative assessment methods to gather learner progress information (Yin et al., 2022). Learners receive feedback during mid-term and final presentations from peers and teachers. This ensures that learners receive regular, timely, and tailored support, helping them understand and integrate feedback effectively and enhancing their learning and performance.

Workshop: Building Integrated Photovoltaics (BIPV) Workshop

Learners designed and fabricated a physical Photovoltaics sample and explored its integration into architectural façades (Figure 3, right). The core concern addressed by this workshop was to accelerate design studio processes while retaining a project-based, hands-on learning experience in a 5-day block course. This was achieved through three measures:

1. Detailed step-by-step instructions guided learners through structured exercises.
2. Templates for submissions gave learners a rigid framework to minimize time spent on formatting and graphical representation.
3. A curated selection of buildings was provided for learners to choose from.

Lecture: Computational Methods in Energy and Climate Design

The course introduces computational design and analysis methods and tools for climate-responsive architectural design. Using a blended learning approach, learners receive targeted information through short input lectures and videos, allowing them to experiment with computational simulation tools. Class time is dedicated to active learning and discussions to

synthesize the learned content of the course in exemplary architectural design tasks. A semester-long design assignment performed in groups encourages a project-based synthesis of content.

Design Studio: Design for Climate

This research-driven studio is offered in collaboration with two architectural design professorships from the Department of Architecture at ETH Zurich and their assistants. In addition, local practitioners from architecture and engineering joined the studio. Through inputs, exercises, and joint interdisciplinary supervision, the design studio assistants also acquire knowledge and methods from research, which they can apply to the supervision of other learners in their design studios. Learners were supervised in regular interdisciplinary desk reviews of researchers, experts, and designers.

Self-access toolbox: Integrated Design Platform

The platform supports autonomous learners in integrating energy and climate in architectural design. It intends to facilitate the exchange of knowledge and experience among learners, teachers, and researchers. It also serves as an interface for design studios led by other professorships that want to integrate climate and energy-related into their design assignments. The platform provides and recommends digital tools supporting integrated architectural design, a collection of case studies and stories reporting integrated architectural design, and opportunities to exchange knowledge.

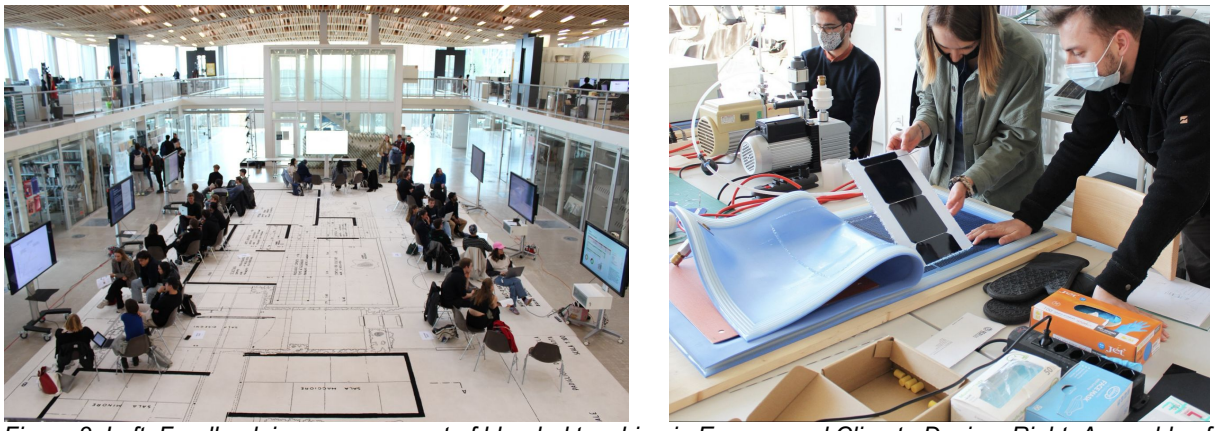

Figure 3: Left: Feedback in groups as part of blended teaching in Energy- and Climate Design. Right: Assembly of custom modules during the BIPV workshop.

Table 1 provides a concise overview of the learning opportunities offered to help students develop an integrated approach to energy and climate-inspired architectural design.

Course title	Type	Year	ECTS	Learning objectives / content
Energy- and Climate Design 1 & 2	mandatory	3rd year BSc	2 x 2	• experiment with basic tools and principles in energy and climate design. • develop a basic understanding of the interaction of passive and active building supply systems with architectural design.
Focus work project	mandatory	3rd year BSc and MA	6	• develop sustainable retrofit solutions. • make interconnections among various elements of sustainable building design. • work independently and make informed decisions. • encouraging reliance on judgment and feedback from peers and teachers.

Building Integrated Photovoltaics Workshop	elective	3rd year BSc and MA	2	• demystify the physics of solar energy production. • identify causal relationships between design decisions and technical outcomes.
Computational Methods of Energy- and Climate Design	elective	Master	3	• perform environmental site analysis for climate and (solar) energy potentials. • apply computational simulation tools to support performance-driven designs. • translate design ideas into parametric models and optimization problems.
Design for Climate	elective	3rd year BSc and Master	14	• utilize digital modeling, simulation, and toolsets to obtain quantitative data about design solutions. • merge quantitative data with design intent, spatial configuration, and spatial quality. • visualize integrated quantitative and qualitative results.
Integrated Design Platform	elective	Any	none	• provide support on requests for questions arising from architectural design.

Table 1: Overview of the stepladder approach to promoting energy and climate design perspectives in the Bachelor's curriculum in Architecture at ETH Zurich.

Discussion

Our interdisciplinary team has made the following observations about learners' competence development: we observed that learners who completed 'Energy and Climate Design 1 & 2' often encountered difficulties in selecting and applying appropriate skills and tools in subsequent architectural design studios. Many struggled with formulating basic questions concerning their design projects. However, learners who had taken additional courses, such as the 'Focus Project' or 'Computational Methods in Energy and Climate Design', were more effective in integrating energy- and climate-related considerations in their architectural designs.

Based on these observations, we identified three pathways to successfully translate energy and climate knowledge resulting from calculations and analyses into architectural design decisions:

1. Learners who take the full range of classes (mandatory and elective) *sufficiently train* the necessary skills to integrate energy and climate design in design classes.
2. Highly skilled and motivated learners reach a *high degree of autonomy*, i.e., they are able to successfully integrate energy and climate-related considerations in their architectural designs through self-study, when reaching out for targeted expert support through the 'Integrated Design Platform' (e.g., by booking consultations when needed).
3. A short intensive training on a focus topic (e.g., the BIPV workshop) establishes an *energy and climate lens* and positively influences learners' design decisions with quantitative analyses.

Summarising our experiences and observations, we propose integrating energy and climate design in the first year of the curriculum. This establishes the energy and climate lens early on as an integral perspective on architecture. In the ongoing revision of the bachelor curriculum, we are planning to select a single theme to illustrate collecting and framing relevant questions, selecting appropriate tools and experiments, performing analyses and interpreting results, integrating outcomes into design sketches and visualizations, and finally formulating new

questions to inform project decisions further and refine the design with a view to energy and climate concerns.

Building on such an initial experience of integrating energy and climate as part of a design and using quantitative analyses to guide design decisions, we provide further opportunities environments in a lecture in the 2nd year of the Bachelor's Programme, a 'Focus Work' project in the 3rd year and the 'Integrated Design Platform' (see Figure 4) as ongoing support toolbox to help students independently integrate energy and climate design principles in architectural designs.

By shifting our focus from subjects to methodologies and positions and introducing an energy and climate lens and vocabulary early on, we hope that energy and climate become one of the foundational pillars for architectural education at ETH.

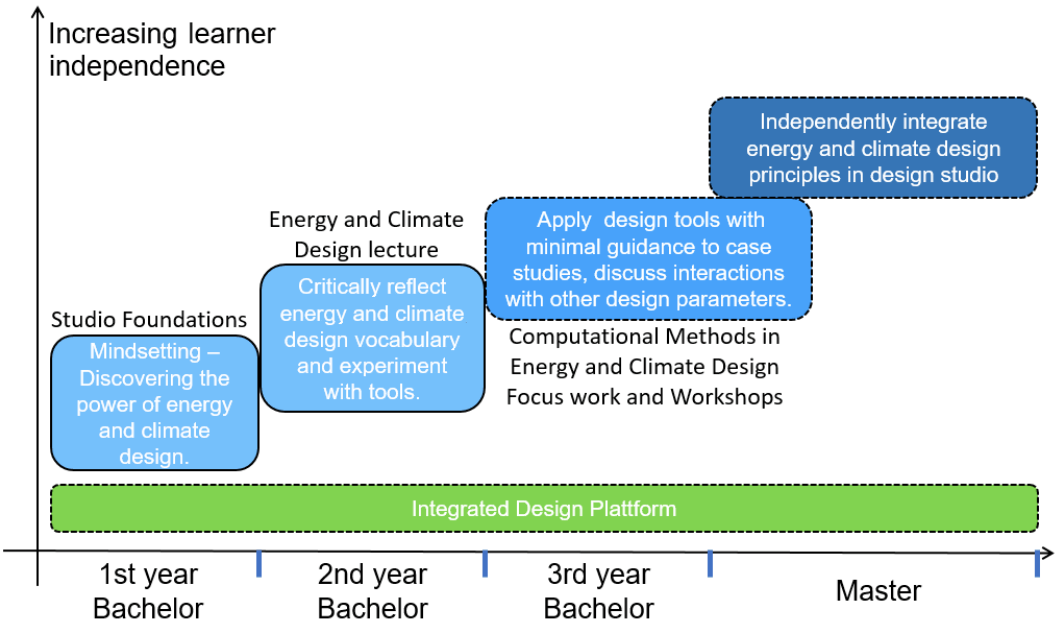

Figure 4: Proposal for a revised stepladder approach where an energy and climate lens and necessary vocabulary are established early, i.e., in the first Bachelor years, to inspire practice during the following design studio classes.

Conclusion

Translating energy and climate courses into PBL formats demonstrated that knowledge often considered 'too technical' and 'too theoretical' can be integrated into the architectural curriculum. However, the sporadic exposure to this topic within one course is insufficient to generally ensure informed decisions in design studios. Instead, continuous training throughout the curriculum needs to reinforce the learned competencies so that learners can translate them independently into solutions for new design problems. This motivated the planned revision of the curriculum, which shall equip all learners with a fundamental energy and climate lens that can be further developed and trained in later elective courses. Furthermore, enabling learners to seek targeted support fosters an autonomy crucial in developing design solutions and can be effectively addressed by platforms connecting peers and experts. When learned as integral aspects of architecture, we hope that energy and climate skills will translate the challenges imposed by climate change and energy transitions from complications into inspirations for future architectural design.

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