Hands-On: Sustainable Approach in Architectural Education

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Abstract. Human activity, including resource depletion, pollution and waste production, has a negative influence on the natural environment. Building industry is one of the major causes of the situation. It is therefore essential to change the approach to building design in order to lessen the impact of human activity on the environment. Architects are still not properly prepared for this change. This is caused by the education they receive in the traditional studio-based teaching process. In contrast to engineering disciplines, the student of architecture is able to look at the issue of designing in a holistic way. However, he is overwhelmed by a large number of topics and subjects that must be addressed. The issue of “sustainability” thus often gets on the edge of his interest. As part of the studio teaching at the Faculty of Architecture of CTU, we are looking for methods to naturally integrate sustainable thinking into the architectural concept already in the early stages of the design. The paper focuses on the so-called design-build projects, as one of the paths that lead to an integral design and an effective way of implementing sustainable design into the architectural concept.

1. The Role of Design Studio in Architectural Education
Method of educating the architect through the design studio has been developing over 200 years and is the foundation of forming a future architect. The student has to deal with solving problems which are growing in complexity and in the course of time he acquires the knowledge and skills necessary for the profession of an architect. The teacher does not come up with ready-made solutions, but by constructive criticism responds to the design that the students create on their own. This way of teaching greatly differentiates teaching of architecture from other disciplines, such as medicine, where students first observe standardized procedures to eventually learn to carry them out, based on this observation.

The design studio led by the authors – teaching practitioners – on the CTU, Faculty of Architecture is searching for such teaching methods that connect theory and practice and imitate the real-life design process as much as possible. Our aim is, that the students design in the spirit of the definition of sustainable development “that meets the needs of the present without compromising the ability of future generations to meet their own needs” [1].

2. Architectural Education in the Context of Sustainable Architecture
Sustainable architecture should represent a complex approach that is ecological and economic but also socially and culturally sustainable and is also fully capable of meeting aesthetic expectations of the society [2]. We believe a holistic approach with the involvement of a wide range of expertise ideally from the initial design phases (the so-called integrated design) is necessary to reach this goal.
The question is, how to accomplish an integrated design approach on a school of architecture. In contrast to engineering disciplines, that are from principle “specialists”, the student of architecture is a “generalist” and is able to approach design issues in a holistic manner. However, he/she is overwhelmed by a large number of topics and subjects that must be addressed. The issue of "sustainability" thus often gets on the edge of his interest. As stated by Tim Sharpe, head of Mackintosh Environmental Architecture Research Unit, "sustainability is mostly created by students as a complement to completed architectural design with technical measures, with little link to architecture of the building."

To our experience two conditions need to be met to integrate sustainable thinking into student studio projects:

- **Assignment of the studio project** – the topic of sustainability needs to become an integral part of the studio brief. Otherwise “a clear understanding of the holistic benefits a sustainable approach can make are often lost or at least underappreciated.” [3]

- **Interdisciplinary approach** – wide range of disciplines – civil engineers, structural engineers, construction experts, budget experts, clients and others – need to be involved from initial stages of the design. Architect, as a studio leader, cannot alone substitute this interdisciplinarity.

"There seems to be a complacency within many schools of architecture that I know that is based on the assumption that the „transdisciplinary“ is just another option. It’s not. It’s not even a “term”, it’s a permanent fact of contemporary life within which conventional practice and context resides.” John Warwicker

The so-called design-build projects seem to be one of the paths to fulfil the above mentioned criteria. These are projects where students not only design the building but also build it with their own hands. This approach reflects the complexity of the architect's profession and has been examined by numerous architecture schools – ETH Zürich, École polytechnique fédérale de Lausanne or Auburn University to name a few. Design-build projects resonate with the theories of American philosopher and reformer John Dewey, who considered physical experience as the basis of learning. He did not understand teaching as the transfer of already organized knowledge, but as the development of the student's experience gained by his own activity.

As part of the design process, students are faced with the necessity to meet other architects, specialists, and construction professionals and thus bring the design process close to real architectural practice. By physical realization of the construction, the students obtain immediate feedback, whether the decisions made during the design were correct and the proposed construction fulfilled the initial assignment.

### 3. Brief History of Design-Build Projects

In Canada and the United States, approximately thirty architecture schools offer different versions of design-build courses [4]. The best-known academic program is probably Rural Studio at Auburn University in Alabama. It was founded in 1993 by professors of architecture Samuel Mockbee and Dennis K. Ruth. They introduced students to one of the poorest regions – Hale County, Alabama – to gain practical experience in designing and building for local low-income people. Mockbee was convinced that for architecture to make sense, it must have a strong ethical imperative and that architects should place great emphasis on the ecological and social qualities of the design. He wanted to replace the theoretical teaching of architecture with the so-called hands-on method, which included the completion of the architectural design into a real building. Over 25 years of its existence, Rural Studio has built over 150 projects. Emphasis is placed on the environmental aspects of design – recycling, re-use and transformation of existing elements and the use of local materials.
Rural Studio had its predecessors. The oldest continuous design-build course is the First Year Building Project at Yale School of Architecture. It was founded in 1966–67 by Charles W. Moore and Kent Bloomer as an alternative to traditional studio-based teaching. In the introductory years of the program, students travelled to the rural region of Appalachia, where they built community centres and other socially beneficial projects. By the end of the eighties, the program focused on affordable housing – since then, students have built a single-family house every year in a selected community that faced economic problems.

Practical approach to teaching was also advocated by Walter Gropius. In his statement from 1939 "Training the Architect" he emphasized that "the young architect of today needs to be trained practically in the use of tools and materials", rather than being chained to the "blood-less drawing board and the phantom of tradition" [4].

Significant and essential for these projects is that sustainability is one of their major topics, whether it concerns energy efficiency, the use of local or recycled materials, low-tech technologies or support for local communities. Thanks to these projects the frequently overused words of ecological and socially sustainable architecture are suddenly gaining their lost meaning.

On the following case studies, we would like to show student projects of various scales that have been realized under our leadership and whose methods follow the ideas as described in the previous text. Our goal is that the students connect theoretical knowledge with their own tangible experience and bring their design into real construction or large-scale models using real materials. We teach students a comprehensive view of architecture, including aesthetic, psychological, social and ecological aspects. It is essential that they are able to see the real consequences of their decisions and learn from these consequences.

4. Case Study 1 – AIR House

4.1. Background
Until the very end of the twentieth century, education in the field of designing ecological buildings in the USA was a "distant and poor cousin" [5] within the framework of established architecture education. It was only at the turn of the millennium that this topic was brought to the fore by the rising oil prices and key publications (eg Sim van der Ryn – Ecological Design, McDonough + Braungart – Cradle to Cradle or Al Gore – An Inconvenient Truth).

In 2002, the U. S. Department of Energy established a university competition to motivate students to engage in the design and building of sustainable houses. Within two years 20 selected university teams from all over the world have to design, build and operate a solar-powered house.

4.2. Assignment
The aim is to design an innovative solar house for a target group that the students choose. Student teams have a plot of 24 x 18 m in size, gross floor area must be in the range of 58-93 m², the height of the building must not exceed 5.5 m.

Student buildings are rated in 10 disciplines, as in athletic decathlon: Architecture, Affordability, Communication, Energy Balance, Household Appliances, Home Entertainment, Indoor Comfort, Market Appeal, Technology and Transport. The range of disciplines aims to evaluate the quality of the architectural and technical design, to verify the functioning of the house in everyday life, its energy consumption and potential success on the real estate market. Thus, the students receive an immediate feedback, if their project fulfilled the pre-determined design criteria.

4.3. Student design
The students of the Czech Technical University in Prague proposed a concept called “AIR House”, designed for a 50+ two-person household. The main goal was to fulfil multiple sustainability criteria – utilizing exclusively renewable solar energy, minimising energy consumption or using recyclable low embodied energy materials. Basic principle of the house was the concept of two skins. The first skin
formed a thermally insulated envelope of living space. The second skin consisted of a wooden pergola with shading lamellae, which prevented the house from overheating during the summer months and carried active-energy elements of the house – photovoltaic panels and solar collectors. For California, AIR House was designed as a zero-energy house. The heat recovery ventilation system ensured optimal air exchange and minimized heat losses during ventilation. The hot-air ventilation unit was connected to a smart house control unit with data collection.

The source of heat and cold was an air-to-water heat pump taking low-potential energy from the ambient air. A solar system consisting of two flat collectors was used to prepare hot water, photovoltaic panels generated electrical power. An important aspect of the solution was the low energy demand in the production and transport of the used materials and the possibility of their recycling after the construction. That is why the entire house – loadbearing structure, thermal insulation, facades, interior surfaces and built-in furniture – was made of wood.

![Figure 1. AIR House. Finished house in Orange County Great Park, California, USA – Northwest view. Photo by author.](image)

4.4. Conclusion

From the point of view of architectural education, the most important aspect of the competition is the fact that it develops an interdisciplinary approach in a team of students from different academic disciplines who otherwise do not come in contact until they finish their studies and become professionals. To achieve the strict competition criteria, architectural students have to communicate with many different disciplines – not only in the field of architecture, but also technology, structure, energy, site-safety, promotion, fundraising or project management. Likewise, Solar Decathlon is an opportunity for students to try to build a real building while they are studying. They can then understand the impacts of their decisions made in the design process from a variety of standpoints.

Solar Decathlon is also a unique opportunity for universities to test an integrated approach to design in practice and to re-evaluate the teaching method where the architect is perceived as responsible for building a "vision" of the building, and engineers are involved too late in the design process. However, it is not just a "question of an architect descending from the top of the mountain, so to speak, it is also a matter of the engineer climbing the mountain and meeting the architect halfway" [6].
5. Case Study 2 – Bridges for Krkonoše National Park

5.1. Background
The pedagogical concept of „Bridges for KRNAP” was based on an experience gained in previous workshops carried out in our studio. The goal was to create an intense working environment, support the collaboration between architectural students and related professions and find such an assignment that would be beneficial to the community.

5.2. Assignment
We managed to establish cooperation with the administration of the Krkonoše National Park (KRNAP), the oldest national park in the Czech Republic. The KRNAP administration identified footbridges and bridges in poor technical condition, requiring repair and offered students creative space for their realization. The duration of the project was one semester.

All 5 studios of the Department of Architectural Design II at the Faculty of Architecture CTU cooperated on the project. The head of the studio selected one site where the studio students subsequently worked on the footbridge project. Our studio chose a place where a stream is crossing a hiking trail leading from Špindlerův Mýlín to Klínové boudy. The site is located in the forest, at an altitude of approximately 1,000 m and is exposed to extreme climatic conditions. The stream modelled an approximately 1.2 m deep channel, which is surpassed by the footbridge. The access to the footbridge is possible only on foot, by bike or, in exceptional cases, on quadbikes.

The task was to design a pedestrian footbridge to replace the current footbridge, which was in a state of disrepair. Regarding sustainability, the footbridge had to respond to extreme climatic conditions of the site, efficiently use necessary material, enable easy disassembly while at the end of its life-cycle, require minimum maintenance and harmoniously fit in the context of the unique natural environment of the national park.

5.3. Student design
The shape of the footbridge was based on the terrain configuration of the trough created by the stream and the movement of the visitors. Its curve created a continuation of the current path and supported the fluency of the smoothness of the walk. Along the trail there is a minimum of resting places. The footbridge therefore offered a place to sit on a bench that faces the valley.

The design responds to extreme climatic conditions. The deck of the bridge is made of steel bars that are used for reinforcement of concrete. Thanks to the gaps between the bars there is no accumulation of snow, water or leaves on the footbridge. Relief on the steel bars ensures safe walk. Due to the gap between the bars the footbridge is optically light and the pedestrians can perceive the stream below. Frequent avalanches occur in the place. The footbridge is therefore designed without railing to minimize resistance to the falling avalanche.

The main material used is weather resistant Corten steel, which is durable and requires no maintenance during the life-cycle of the footbridge. Steel with its red-brown color perfectly fits into the natural context of the national park.

The shape of the footbridge is curved with a load-bearing structure from welded I profiles. The total length is 7.25 m, width 1.8 m. The deck of the bridge is carried by seven modules, which are welded from I and T profiles. The height of the main profiles is optimised due to the different torque acting on the structure. The individual modules are fastened together by screwed joints. The footbridge is designed as modular, individual parts are detachable and easily transportable and can be mounted without the use of heavy machinery [7].
5.4. Conclusion
The design-build format of projects that take place within one semester seems to be one of the optimal ways to lead the students through the process from architectural study to completed construction. With the right preparation and selection of assignments, a large part of tasks can be delegated directly to students so that they are motivated to make informed decisions and take the responsibility for these decisions. Simultaneously, it is impossible to carry through such a project without integrating related professions or a client. By participating in the project from start to finish (which is difficult for larger projects like Solar Decathlon), the students see the implications of their decisions and learn from their mistakes. From the teacher's point of view, it is essential to create a working environment where all students identify with the selected proposal and continue to implement it as one team. Ideally, that in the end no one knows who the author was and the resulting work is perceived as common result. Teamwork is a necessity for today's profession of an architect.

6. Case Study 3 – Diogenes

6.1. Background
The assignment was inspired by the small Finnish wooden chalets called Mökki, Fuller’s Dymaxion or a Renzo Piano project of the same name. Renzo proposed a living unit measuring 2.5 x 3.0 m for the Vitra furniture company. It was to become "the smallest Vitra building, but its largest product". The design had its origins in the fascination of Renzo Piano with the minimum space in which one can live. He named the prototype of the minimal living space after the ancient philosopher who is said to have lived in a barrel.

6.2. Assignment
The aim of the project was to design a minimalist living unit for two people and a maximum area of 10 m², the height was not limited. The purpose was not to design an emergency housing, but a self-imposed shelter. Diogenes should be environmentally friendly and operate independently of the surrounding environment. It had to be able to adapt to any plot, the key was easy transportation and assembly.
6.3. Student design

The Diogenes project, on which our students worked, was the prototype of a minimalist housing unit in nature for two people. It was essential that students focus not only on the aesthetic and operational aspects of architectural design and that they would not use partial environmental aspects purely additively, as is often the case. Testing concepts on large-scale models to a certain extent replaced the construction of a real object. One of the successful projects was the concept of a student who placed his object in the extreme landscape of the Jizera Mountains.

The project conceives a minimal living unit for two people as a spatial experiment that functions independently of the surrounding environment. It is not intended for emergency housing but as permanent and voluntary asylum. The space requirements of day-to-day activities are maximally limited to the edge of comfort, thus minimising the energy needed. It can adapt to any place, landscape or city and is simply constructed using existing technologies. Transport as well as site construction is fast and easy. The concept is based on the thesis that the best energy is the energy unused and therefore proposes a minimal object that consumes a minimum of energy and materials for both construction and operation. Floor area = 5.5 m², volume = 15 m³, height = 5 m.

The author has verified his design on two models – in a scale of 1:4 he proved the functionality of the wood-based loadbearing structure, on a model 1:8 the concept of the cladding by using real material.

6.4. Conclusion

The assignment reflected experience from foreign universities, such as the Mackintosh School of Architecture. The purpose was to assign such a task where the environmental aspect is an integral part of the assignment. Otherwise, the topic of sustainability usually disappears or is at least strongly underestimated during the design process. At the same time, however, the project must be relatively small to cope with the complex task, following through up to the maximum detail, including architectural, structural, material and technical solutions, interior design, transport concepts and construction methods.
7. Conclusion
If architecture is not to be sustainable by simply adding different technical measures, the architect plays an irreplaceable role in the entire process of sustainable building. Compared to the engineering technical-rational approach, an architect should be able to look at the building issues in a complex way, including energetical, social, psychological and aesthetic aspects. He is responsible for applying a sustainable concept from the very beginning of the project.

Our aim is to engender a sense of sustainable thinking within our students by creating an interdisciplinary environment and bringing them into a direct contact with the building process. By offering a precisely chosen assignment the students receive a sense for sustainable architecture, gain the ability to challenge the established architectural and structural stereotypes and learn to integrate the sustainability aspect into their projects. They have the opportunity, and above all, the need, to apply sustainability aspects in the initial phase of the project and not just optimize the already completed design. By building the projects in the scale 1:1 they are able to see the real consequences of their decisions, which they make during the design process, and learn from them.

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