The Climate HubLAB at NTNU

Luca Finocchiaro, Mariya Stoyanova Bond, Leif Martin Hokstad

NTNU - Norwegian University of Science and Technology, Trondheim, Norway

ABSTRACT: The identification of sustainable design with the use of standards and commercially available components for energy efficiency has led architecture students to suddenly become more concerned and thirstier for existing know-how, rather than developing the ability to observe and generate their own solutions. Sustainability in architectural education cannot be limited to making students aware of environmental challenges and ready-made solutions, neither into limiting environmental impact on a purely numerical basis. We need instead to shape architectural practitioners able to use their creativity and imagination to shape new architectural paradigms re-harmonizing natural and built environment. Throughout the MSc program in Sustainable Architecture at NTNU, students rely on different kinds of software to optimize environmental performance and minimize environmental impact of their projects. Teaching experience show that an extensive use of simulation software risk anyway of simplistically reducing complexity behind sustainability to a discreet number of parameters. Question is therefore how results provided by advanced simulation tools can be combined with a holistic understanding of the process. The Climate Hub-LAB, developed thanks to the support of the AVIT program at NTNU, aims at providing students an integrated studio where flow of information coming from different machines and tools, can be collected, and more effectively translated in efficient architectural design concepts on the basis of hands-on experiences. In this paper we will reflect on the the use of digital tools and their role for supporting the development of hands-on activities fostering creativity and imagination.

KEYWORDS: experimental, bioclimatic, design, laboratory, studio

INTRODUCTION

In the last century, the anthropization of the natural environment, together with the human interference with the natural climatic system, have determined a significant rise in global temperatures. Scientists seem to agree that global warming is mostly caused by an increasing concentration of greenhouse gas emissions in the atmosphere. Buildings, throughout their life cycle, are responsible for over a third of greenhouse gas emissions due to anthropogenic activities (Buildings and Climate Change Summary for Decision-Makers 2009). According to the United Nations, to limit global warming within the threshold of danger of 2°C, greenhouse gas emissions due to buildings should be cut by 90% within 2050 (UN framework on climate change. 1992). Such an ambitious target has fostered, in the last decades, the technological development and diffusion of innovative materials and components for energy efficiency. The identification of sustainable design with the use of standards and commercially available components for energy efficiency has led architecture students to suddenly become more concerned and thirstier for existing know-how, rather than developing the ability to observe and generate their own solutions. Sustainability in architectural education, however, cannot be limited to making students aware of environmental challenges and ready-made solutions, neither to making them able to limit environmental impact of the built environment on a pure numerical basis (Finocchiaro 2018). Instead, we need to shape architectural practitioners able to go beyond energy and emissions accounting, to create new architectural paradigms with the purpose of “re-harmonizing natural and built environment” (Dan Chodorkoff 2014).

1.0 SUSTAINABILITY IN ARCHITECTURE EDUCATION

The MSc program in Sustainable Architecture at NTNU is based on the assumption that the ability of handling multidisciplinary processes cannot be taught simply by assigning multidisciplinary tasks to students but needs to be experienced, taking part in multidisciplinary projects and teams. For this reason, the program is open to both architects and engineers, called to collaborate in the design of buildings characterized by minimum environmental impact. In the first semester students are trained in environmental performance analyses and the design of bioclimatic shelters; in the second semester, students are introduced to concepts such as durability, life cycle, and recyclability. In the third semester, environmental performance is related to the use of energy systems and renewable energy. Simulation tools are used to model indoor climate and buildings´ energy demand, while BIM models facilitate accounting of materials’ and related emissions. Besides undeniable advantages when dealing with complex computational analysis, an extensive use of simulation software seem to simplistically reduce sustainability to a discreet number of numerical parameters. Moreover, the most courageous and innovative proposals, generally based on intuition and students´ tacit knowledge, are the most difficult to simulate. Therefore, students tend to prefer to either follow a purely qualitative approach, allowing them to further explore their innovative ideas and visions, or abandoning courageous ideas in favour of more numerically convincing analyses. For this reason in 2013 we sketched the concept of an integrated laboratory for environmental performance analyses that could facilitate the relation between analog and digital tools, between the creative and rational side of the brain. Such a concept is represented in Figure 2.

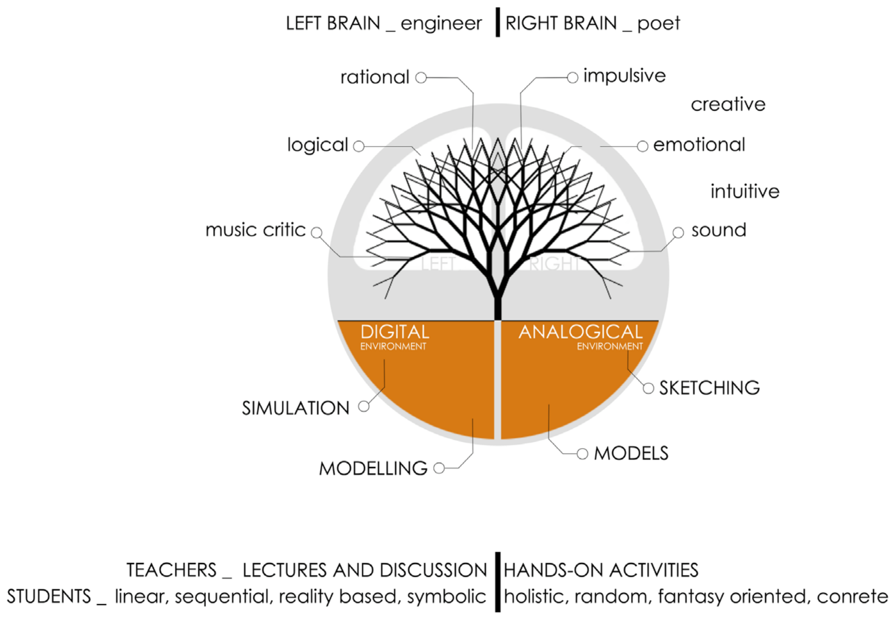


Figure 1: A reasoned use of analogue and digital tools in the program aims to let students train in understanding and relating quantitative and qualitative parameters in creative form-finding processes. Source: (Assembled by the authors 2018)

1.1 The "Climate HubLAB"

By the time an advanced simulation is run, architecture students are commonly able to produce a discrete number of physical models or sketches where an indefinite number of logical connections are summarized. Research suggests that hands-on activities, such as sketching and model making, still represent a powerful tool for processing knowledge and grasp theory (Fernandes et al., Heineman et al., Sunalini et al.). Question is therefore how to combine digital and analog tools in a way to take advantage of the computational capabilities of the first, while exploiting values of hands-on approaches for handling holistic design processes and enhancing students´ learning environment. With this purpose, in 2016, thanks to the support of NTNU, we could initiate the development of the Climate HubLab (figure 3 and 4), as a pedagogical laboratory collecting analog machines for environmental performance analyses of different kinds (such as heliodons and streamlines visualization tools) and equipment for facilitating the transfer of information between the digital and the analog environment.

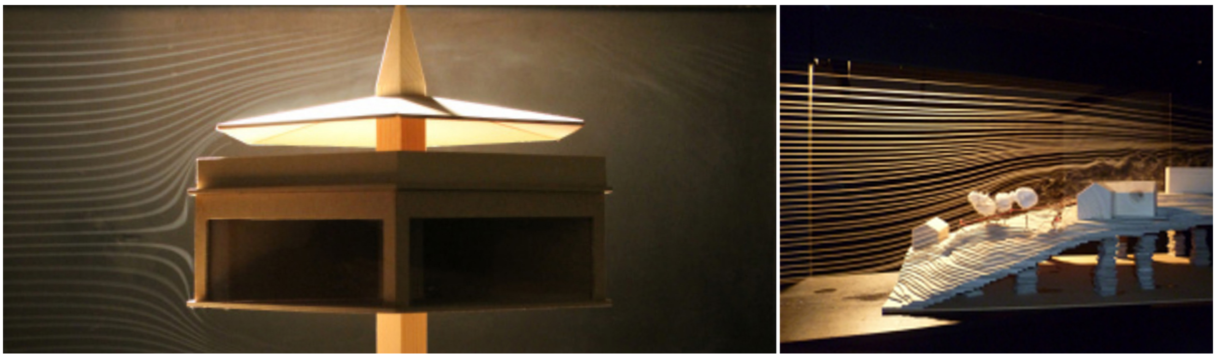


Figure 2: Student testing an architectural model of the Dymaxion house of Buckminster Fuller and a section of a house in the landscape during their project development. Source: (Assembled by the authors 2018)

The ultimate intention of the climate HubLab is that of transforming courses in climate and built form into an experimental pedagogical arena where theory is grasped by involving students in a series of hands-on activities or experiments were analog and digital tools are balanced in a reasoned way. This transition required first of all the transformation of the design studio into a laboratory where students could freely experiment with knowledge and customize experiments to validate their visions and concepts. Besides this, it was necessary to:

- understand how digital tools could be used not only for their computational capabilities but also to enhance the learning potential of hands-on activities.
- facilitate the transfer of information from the analog to the digital environment.
- moving from cumulative to formative assessment practices, giving space to "learning from failure".

This paper reflects over the role of the lab for the transformation of the course into an experimental arena for testing innovative design processes and their potential for pedagogical activities. Reflections hereby described have been built over experiences gained during the last ten years of teaching bioclimatic design at NTNU and are supported by results of an experimental workshop conducted with the help of a PhD student, focusing on pedagogics of environmental design and involving students, teachers and a pedagogist. The workshop, developed inside the courses on climate and built form, focused on the use of analogue and digital tools for bioclimatic design, with an insight on their beneficial or adverse role for creatively handling holistic architectural design processes.

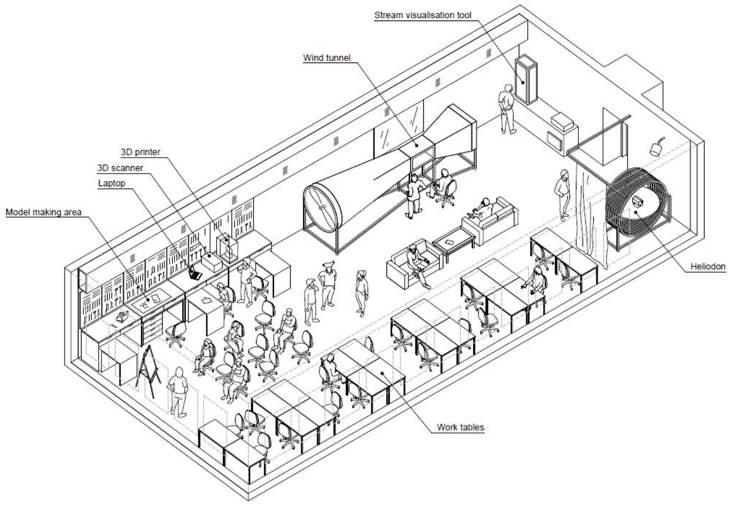


Figure 3: The climate HubLAB at NTNU was conceived and developed with the purpose of exploring the pedagogical potential of equipping conventional design studios with equipment for testing physical models. Source: (Ilya Pugachenko 2018)

2.0 THE EXPERIMENTAL WORKSHOP

Since 2013, courses in "Climate and built form" have been structured in a sequence of pedagogic modules where theory, generally transferred through a lecture, was used as the basis for the use of digital simulation tools. A comparison between grading in the theory and in the design course, conducted from 2010 to 2014, showed however that students could master knowledge in climate adaptive design without necessarily developing the ability to apply it in practice. For this reason, from year to year, focus on the development of the pedagogic modules moved from content to the process of learning: from refining knowledge transferred through lectures, to the development of activities that, following experiential learning theories (Kolb 1984) could enhance student learning.

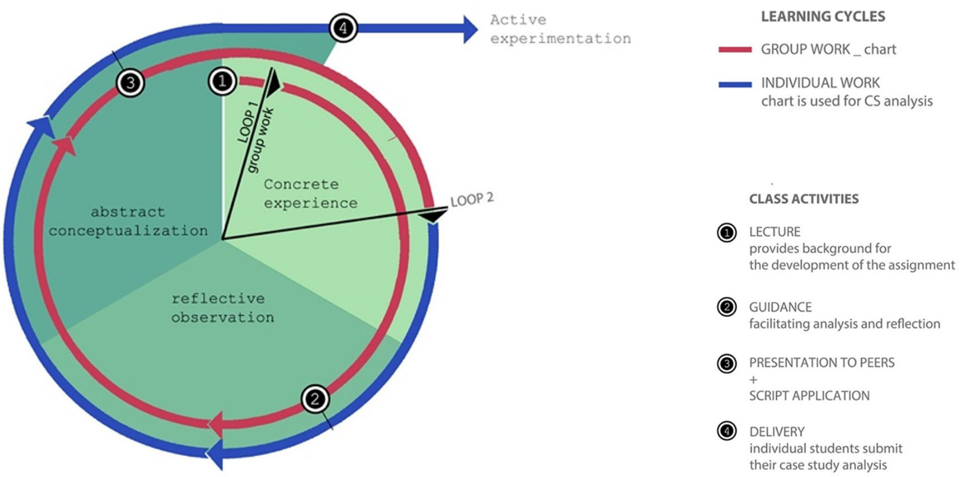


Figure 4: A graphic representation of teaching and learning activities in the revised pedagogic model run in the form of experimental workshop in 2023. Source: (Assembled by the authors 2024)

In 2023, with the purpose of analyzing the pedagogical potential of combining analog and digital tools for environmental design, we designed an experimental workshop where digital tools were used to support the learning potential of hands-on activities, rather than as mere computational tools. The workshop focused on the revision of the pedagogic module about "sun and form" and students were asked to question and reflect over specific aspects of their project through a series of experiments. The workshop was developed as an intensive experimental activity of the regular design course where students, distributed in five different climatic conditions, were asked to design a prefabricated climate adaptive shelter for post disaster recovery. Concepts were developed on a purely intuitive basis in the time of one week before the workshop started. In defining the concept students had to compromise specific functional and dimensional requirements while embedding solutions for improving the project environmental performance, involving form, construction, and systems to employ throughout the year. In this stage students were asked to only look at climatic data without building any model for digital simulations. Once concept was developed, students were asked to expose their concepts to three experiments, where the first and third were based on hands-on activities, and the second one on the use of a digital parametric modeling tool. In the first step, students were asked to formulate three climate-specific questions to investigate using a manual heliodon (i.e. optimize form to minimize self-shading; identify orientation ensuring maximum exposure in winter, etc.). In the second step, students were asked to use a digital script for relating the morphological characteristics of their project to the assigned climatic context on quantitative basis. Finally, students were invited to run a more detailed analysis in an automated heliodon equipped with micro-cameras to analyze solar access and adjust detailed components within the project (i.e. distribution of thermal mass, effectiveness of a solar shading system, etc.).

Each step in the workshop was structured following the four steps internal to the experiential learning cycle. Looking at the second step, for instance, (1) by using the script students would get a concrete experience about the use of simulation tools for morphological optimization; (2) the results would give them the possibility to reflect over their proposals, being able to quantify implications of choices taken in the concept stage; (3) comparing numerical result and their concept morphology, students can now more easily abstract principles for climate adaptive design and (4) enter an active experimentation stage where they can more consciously adjust form of their project on the basis of knowledge gained through the processed experience.

The second stage of the workshop represented the only “digital step” in a sequence of hands-on activities, involving sketching, model making and testing in two different kinds of heliodons. The original pedagogic module about sun and form in the course aimed to equip students with the ability to calculate and analyze heat quantities in a building. Through digital simulation tools, students could analyze heating and cooling demand as the result of the building thermal budget and adjust morphological characteristics in a way to increase solar intake or construction and schedules to improve airtightness or facilitate natural ventilation. The limit of such an approach was that of working on refining a form without being aware of how much that form is close or not to the ideal, or optimal, one, in terms of thermal balance. For this reason, in the digital step of the experimental workshop, we decided to develop a code that could make it possible to identify the optimal form on a numerical basis. The script was developed following the sol-air approach, as defined by Victor Olgyay (Design with climate 1963) according to which the optimal form of a building is the one able to take maximum advantage of solar radiation whenever temperatures are below the comfort zone, while ensuring minimum intake while outdoor temperatures are above it. In this second stage, thanks to a premade script in grasshopper, students could calculate the optimal proportions and orientation of a hypothetical box in the specific climatic context where they were working. This exercise was voluntarily included as an intermediate step such that students would rather use this piece of information to reflect over their proposal, developed on a purely intuitive basis in a more holistic setting. Students would be exposed to learn from failure and adjust the form, rather than get a specific answer from the computer at the beginning of the process and risk to not use their own critical abilities.

2.1. Results

To evaluate the impact of the revised digital module on students’ learning we looked at experiential learning theories while taking advantage of action research methods. Before the workshop, students learning style was mapped following Kolb’s theories (Kolb 1976) asking students to fill a questionnaire about their attitudes when approaching learning tasks. During the workshop, action research methods were used as “a form of systematic inquiry, prioritizing reflection and bridging the gap between theory and practice” (Selener 1997). Following action research methods, we did not only observe but interacted with students and intervened whenever a good opportunity for learning arose. Finally, after the workshop, we collected relevant feedback from students through a questionnaire and an interview in design groups.

Results of the workshop’s analyses are collected in Table 1. The upper part of the table was developed over the analysis of the material delivered by students and complemented with information collected during the interview. In this part it is described how students approached the use of the digital script, if the experiment provided unexpected results or supported a more holistic understanding of “sun and form”, a reflection or a design choice influencing the design process. Finally, it is also added a mark whenever the digital module opened to more active experimentation. In the second part of the Table, it is collected other relevant comments given at the interviews about timing, concept, and administration of the workshop.

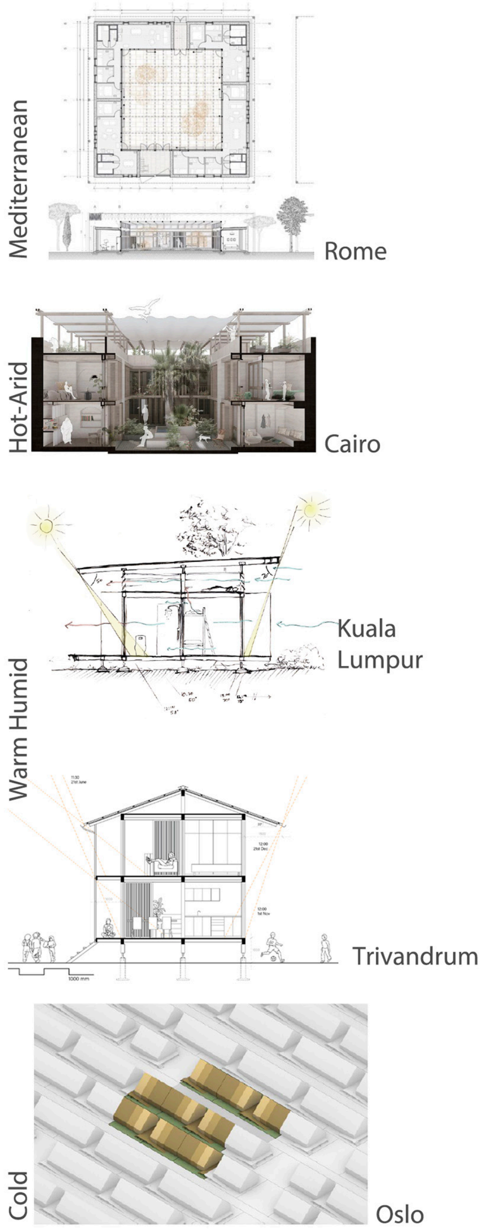
Besides it is not easy to identify a pattern in the analysis of the results, a few reflection points can be drawn. Four of five groups made use of the digital script developed based on the sol-air approach to relate their proposals to the optimal as calculated following the sol-air approach. Only the group working in the cold climate of Oslo recurred to a different software. Students working in the hot-arid and Mediterranean climate, where shading in the overheated season is a relevant concern, claimed to have used the script to test alternative solutions and came into unexpected results that affected their design choices and process ahead. People working in warm-humid climatic contexts such as Kuala Lumpur and Trivandrum, where houses needed mostly to be shaded from the zenith and where natural ventilation and wind patterns played a stronger role for the concept development, got a broader understanding of climate adaptive design issues related to sun and form; none of them claims that the experiment influenced their design process anyway. The group working in the cold climatic context of Oslo, focusing on maximizing passive solar heat gains, used the script to identify the proportion of the ideal box in their climatic context but preferred to leave the project as originally planned (anyway close to the optimal) because of other concerns related to aesthetics and prefabrication of the project.

The groups working in Rome, Kuala Lumpur and Oslo wished that the digital tool module could be implemented earlier and, among them, students from the group working in Rome felt that the digital tool limited their creativity and possibility for exploring alternative design solutions. Together with them, the group working in Trivandrum reported that the digital tool was more difficult to grasp than the use of heliodons and four out of five groups preferred hands-on activities to the digital module.

It is important to notice that only groups working in Rome and Cairo claimed to have used the script to test alternative design solutions, developing choices that affected the design process forward. This might be due to the fact that the climatic context, in comparison to others, resulted more inspiring and brought them to unexpected results that were then translated into concepts. Evaluation criteria of the design course prized anyway those projects that gave evidence of a systematic effort for the adaptation of their projects to climate and context and those two projects seemed to have gained the most from the experimental arena tested in the workshop.

Table 1: A resume of the analysis of the workshop showing a reflection over activities and feedback provided by students, together with students projects on the right side. Source:(Assembled by the authors 2024)

		Rome	Cairo	Kuala Lumpur	Trivandrum	Oslo
Experiment	initial design	●	●		●	●
	bondary conditions	●		●	●	●
	alternative solutions	●	●			
Discovery	as expected	●		●		●
	unexpected	●	●		●	
	broader understanding			●	●	
Reflection	initial design	●		●		●
	on discovery	●	●		●	
	on possible solutions	●				
Design choice	due to experiment	●	●			●
	due to discovery					
	due to reflection	●		●		
experiment influenced the project development		●	●			
Followed more active experimentation on Sun and form		●	●	●		●
Feedback	wished the digital script earlier	●		●		●
	the digital tool limited my creativity	●				
	digital tool was more difficult to grasp than heliodons				●	
	rather pointed at hands-on activities as more valuable	●	●			●
	the workshop facilitated critical reflection	●	●	●	●	



CONCLUSION

According to feedback provided by students after the experimental workshop run in Autumn 2023, equipping the studio with machines for testing physical models facilitated the development of integrated design processes. All groups of students recurred to the manual heliodon for refining their concepts. The planning of the activities did not success in exploiting the connection between analog and digital tools and the three steps seemed to be perceived as independent attempts rather than part of a one flow. Finally, the way activities have been planned and monitored, did not make it easy to understand the connection between the use of the digital script and the desire to follow active experimentation through the automated heliodon or other tools. Only two groups actually used the automated heliodon as third and last stage of the experimental workshop. This was apparently due to the fact that students perceived it as an unnecessary addition or too demanding considering the time pressure of the workshop. Interviews seemed to suggest that hands-on activities became so attractive that the digital tool ended up into a marginal activity. This clearly limited the intention of exploiting the potential of using digital tools as a computational tool for more qualitative analyses run through the use of hands-on activities.

This work represented the first attempt to more systematically analyze the potential of transforming the design studio in a laboratory for the development of integrated concepts. Analysis recurred to action research methods and relied on the learning style inventory for mapping and understanding the learning process. During the workshop students could freely use machines for testing their physical models in relation to the sun but the way in which they took advantage of the lab seemed to be more determined by the climatic regions where they were asked to work. As it is natural, those concepts that had sun as main concern, took the largest benefit of the lab and methods proposed. In this case we could see clear benefits and students succussed in systematically improve their projects on the base of experimental analyses. Those groups that in their concept put the premises for a more detailed analysis about wind and form naturally perceived the workshop as a distraction and ended up not exploiting the activity and potential contribution for the development of the project. The tested experimental framework will be extended next year to define a new module about wind and form where the use of CFD tools will be combined with a water based streamline visualization tool for testing alternative morphological solutions and wind patterns.

ACKNOWLEDGEMENTS

This work has been developed within the DigiHands project supported by NTNU through the toppundervisning program. We would like to thank moreover all students that supported the workshop organization and development.

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