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Shaping Sustainability in Architectural Education: The Integrated Design as a Tool

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Abstract: Climate change is bringing new challenges for architectural education and calls for a new paradigm in the way we teach architecture and urban design. Therefore, a shift has become crucial to enhance the implementation of sustainability within university programs.

This paper is, an experimental study taking place, in the first year of master's degree in civil engineering and architecture at the University of Liège, and within the context of an integrated design.

The interconnection between design studio and theoretical course on sustainability allows students to develop in-depth knowledge and understanding of sustainability issues by integrating the environmental quality of the building into their designs.

During this studio, and to respond to their architectural choices, several tools are applied within the design process to help students develop their building designs, such as interdisciplinary contributions. Our study is constituted of data collected via questionnaires and interviews as well as examining learning activities, teaching methods, students' outcomes, and their interactions with their instructors. The analysis reveals that sustainability and environmental quality criteria are developed in a holistic way of design thinking in coherence with all the functional, aesthetic, and technological aspects in the design process while respecting the specific contextual requirements…

The findings provide evidence that integrated design plays an important role in shaping sustainability in architectural education. This can be achieved through an interdisciplinary collaborative approach that calls for more involvement from students, and that puts into practice their theoretical bases within the design studio.

Keywords: Sustainability, Integrated design, Collaborative Learning, Teaching.

Introduction: The challenge of integrating sustainability in architectural education

When debating the challenges facing the environment, integrating sustainability in architectural education has become a crucial and urgent requirement.

According to Altomonte (2012), although it faces several pedagogical and professional barriers, the role of higher education as a means of introducing new generations of building practitioners to the principles and practices of sustainable environmental design is becoming highly significant.

Morin (2004) considers that teaching sustainability issues allows apprehending the contemporary world in its complexity, by considering the interactions that exist between the environment, society, economy, and culture. For him, it is time to think about "educating for the planetary era".

Salama insists on the urgency to think about this paradigmatic shift, a new paradigm of reflection not only in the knowledge taught but also in the way of teaching and learning architecture.
It is, in a way, a transition toward a systemic pedagogy where teaching is treated as a whole and conceived as an integral part of a process (Salama, 2005).
Therefore, a paradigm shift in policies and pedagogical methodologies is needed to facilitate the transfer of knowledge between sustainable sciences and building applications, and to enhance the implementation of environmental sustainability criteria within the creative design process (Altomonte, Cadima, et al., 2012).

Many studies have been conducted to integrate sustainable development into education at undergraduate or graduate levels since sustainability is a concept that should become the focus and the aim of architectural education worldwide.

Different experiences introducing new teaching methods have emerged to bridge the gap between environmental-related building sciences and architectural design.
According to research conducted by the group of reflections on sustainability at the University of Montreal, the association University Leaders for a Sustainable Future states that since 1990, more than 300 universities have signed the Talloires Declaration, which commits them to the pursuit of a sustainable future. In Quebec and Canadian universities, the Sustainable Campus Project at the School of Architecture and the Faculty of Design is part of a movement to integrate the principles of sustainability into university activities, not to mention the "Greening the Diploma of Architecture in Canada" initiative that took place in 2002.

It is a national transdisciplinary academic forum that is the result of an initiative launched and then extended by colloquia in Quebec in 2004 and in Winnipeg in 2007 to identify the disciplinary transformation necessary to engage the academic community in the transdisciplinary process of the sustainable project.

In this context, the European academic project EDUCATE (Environmental Design in University Curricula and Architectural Training) aims to deconstruct the pedagogical barriers to the integration of environmental design and energy efficiency in university curricula and the practice of architecture.
Thus, it proposes the harmonization of educational systems, course structures, accreditation, and qualification prescriptions.

EDUCATE highlights an integrated pedagogical framework " for curriculum development featuring a roadmap for the integration of sustainable environmental design at the different levels and stages of architectural education and post-professional training… Multi/inter/transdisciplinary contributions to program innovation have been explored, together with the appraisal of applied and experiential learning techniques, new analytic visualization and simulation tools, and the analysis of advanced insights from educational research…" (Altomonte, Yannas, et al., 2012)
The integrated design process responds to this multi-disciplinary approach through a collaborative process, starting from the beginning of a project to provide integrated, optimized, innovative, and sustainable solutions to reduce cost, time, and complexity.

This paper proposes to analyze a similar integrated design approach that considers the implementation of sustainability within the whole design decision-making process. It will be based on collaborative work, and the contribution of different interdisciplinary experts, and it will lead to the concept of the integrated design process adapted to the pedagogical context.

1. Method of the Study

1.1. Case study: Integrated design studio of master's program in civil engineering and architecture at the University of Liège.

Our observation is conducted in the four months of the first year of the master's program in civil engineering and architecture within the design studio at the University of Liège and its connection with the course on Sustainable Environmental Design.

In a context similar to an architectural design competition, 21 students are challenged to work together in several teams through a collaborative learning process.
They are called to design a contemporary building while respecting complex programmatic requirements, form, function, structural systems, technical constraints, spatial qualities, etc.…

It is an interdisciplinary collaboration between students in civil engineering architecture from the University of Liege and students in civil engineering construction from the Ecole des Mines d'Alès in France. Some of the projects developed at ULiège in the first semester will be pursued by the Ales students in the second semester.

Through this architectural design process, the design studio is related to the Sustainable Architecture and Urban Design (SAUD) course that combines theoretical teaching and practice. It consists in developing an architectural project following an integrated approach, and that combines architectural aspects and sustainability through the development of several environmental criteria in the design process. This course aims to provide students with the necessary skills to understand the principles of sustainable development, applied to architecture and urban design.

It includes the analysis of some existing methods and tools of sustainability assessment of buildings and neighborhoods and more specifically the High Environmental Quality initiative for building (HEQ).

Moreover, students benefit from the collaboration with several experts from different fields in architecture, building envelope and environmental quality, structure, fire safety, accessibility standards, fluids, and HVAC... to best respond to their architectural intentions and choices.

These contributions will lead us to the concept of the integrated design adapted to the pedagogical context; it is defined as an interdisciplinary conceptual approach based on collaborative work.

Figure 1*: *Students' meeting with their instructors and Architect.

***Figure 2:** Students' online meeting with Engineers.*

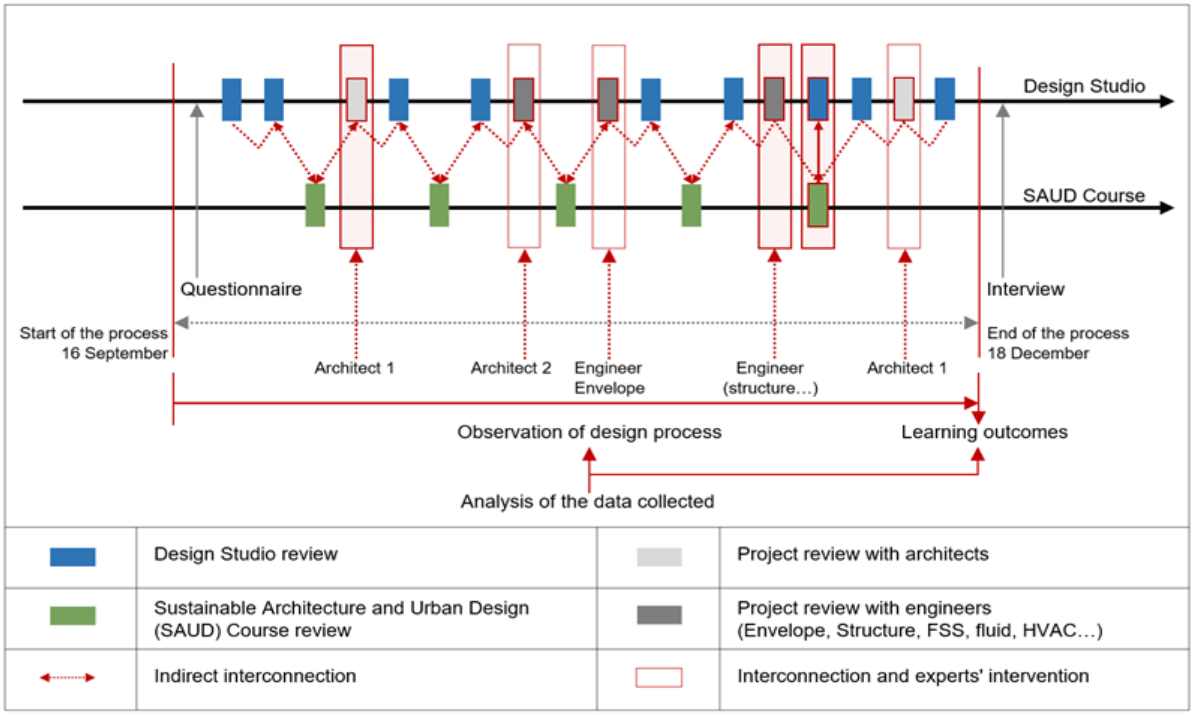


Figure 3: *Observation scheme*

1.2. Observation of the Case study

Our exploratory study, as shown in Figure 3, consists of observing project reviews to identify how the environmental criteria were considered in the design process. Also, it is mostly meant to recognize students' capacity to develop projects that combine architectural aspects and environmental quality related to the context, program, and technical requirements.

Through the whole design process, the methodology involves examining the learning activities, teaching methods, and pedagogical strategies as well as the students' outcomes.

From 16 September (the start of the design process) to 18 December (jury and end of the process), the study lasts 14 weeks. Both the design studio and SAUD course take place simultaneously. The design studio has two instructors who share, during reviews of projects, discussions, and exchange ideas with different groups of students, each on Monday and Thursday mornings (8 hours a day). SAUD lectures are held each Tuesday afternoon before practice (4 hours per week).

Depending on how quickly the process evolves, experts from different fields review the design once or twice a month. For instance, the first expert intervention is with an architect to assist students in the preliminary design phase.

The methodology for understanding students' experiences also includes a data collection technique, a questionnaire, and an interview survey with different groups of students, instructors, and some experts. The questions are mostly focused on the curriculum and its role in promoting sustainability, the connection between the design studio and SAUD course, and the integrated design approach. Instead of a numerical value, the data collection method is considered qualitative.

Students are interested in answering the questionnaire, and the feedback shows a positive attitude towards the integrated design experience. The first question attempts to identify the focus of the current university curriculum on environmental issues. Most students agree that "... these statements are

Table 1: *Integration of the observed Design Studio and Course, depending on SOLO Classification*

Understanding Level	Design Studio	Sustainable Architecture and Urban Design (SAUD) Course	
		Theory	Practice
Pre-structural Level Introduction of basic SD principals	Site analysis and understanding of the urban and architectural context	Introduction to Sustainable design knowledge	
		Case studies on sustainability assessment methods: HEQ approach Targets 1, 2, 4, 5, 6, 8	Understanding and integrating Target 1
Uni-structural Level Setting up connections of principals	Research phase of the architectural choice, Formal concept, structure Functional programming	Introducing theoretical basis:Targets 2, 5, 6	Integrating Targets 2, 5, 6 in design Project
Multi-structural Level Identifying how to apply principals	Mastery phase of the technical structural system and regulations	Introducing theoretical basis: Targets 4 and 8	Integrating Targets 4 and 8 in design Project
Relational Level Integrating and application	Sustainable design considering functional, aesthetic, structural and environmental aspects.	Deepening the integration of different HEQ Targets within the design project	
Extended abstract Generalization, Production	Final Project		

increasingly asking us to go beyond just choosing a material because we like it but to justify its environmental sustainability... In this project, we realized that making a choice that is thoughtful and that it would take us some time to decide will facilitate the steps that follow."

As an answer to a question about the interconnection between the design studio and SAUD course, a respondent comments that: "It was an enriching learning experience in terms of environmental quality. There was a completely different way of thinking about the design project. We had all the HEQ targets to reach, which we integrated entirely all along with the project and not just at the end of the process...".

A group of students also notes that "…It was quite easily integrated... we paid attention to how to establish ourselves about the city.
The interaction with the (SAUD) Course was more encouraging and I think it fed our project a lot (...). The site analysis phase (...) was the leading principle: a major part of our project was based on target 1".

Regarding the HEQ targets, respondents comment that " certainly, they are complex to manage, and they push the thinking further, but it was very exciting because the project is more viable than a classic architectural object... Not only do we get a beautiful architectural design, that functions with the environmental quality targets... and is beyond the bioclimatic design... but it is also an entire consideration of the use and origin of the materials".

1.3. Focus on the interconnection between the design studio and theoretical course

The SOLO classification (taxonomy of the Structure of the Observed Learning Outcomes), proposed by Biggs and Collis (1982), identifies five stages for students to reach a complex level of understanding, moving towards multi-structural, relational, and extended abstract knowledge levels.

Table 1 below presents an operational matrix where instructors' input in each module is mapped to expected levels of students' understanding:

This taxonomy is explicitly used by Ozer and Turan (2015) to analyze the data obtained from the behavioral pattern of students as a result of their integrated system model. It is also mentioned before by Hamza and Horne (2007) in their study conducted at Northumbria University.

Architectural design studio forms a whole with theoretical courses as a holistic system. Kolb (1984) proposed a model of "learning by doing" in a cycle that connects practice and theory on the one hand and reflection and action on the other.
In our case study, we believe that "learning by doing" is exercised in this pedagogical experience.

As shown in figure 4, the articulation of the design studio and the theoretical course integrating sustainability criteria fosters experiential learning focused on student involvement and further encourages their creative critical thinking where knowledge is applied in the architectural design project.

2. Results

The outcomes of the applied method in the design studio are illustrated graphically in figure 5.
It shows the evolution of integration of the environmental quality targets(HEQ) alongside the architectural aspects through the design conceptual process.

The High Environmental Quality initiative for building (HEQ) is based on 14 targets divided into 4 themes: energy, environment, health, and comfort.
Only 6 targets are considered in this project as follows :
- Target 1 entitled "Physical relationship of the buildings with their immediate environment",
- Target 2 incorporates an "Integrated choice of construction processes and products",
- Target 4 "Energy Management",
- Target 5 "Water Management",
- Target 6 "Waste Management",
- Target 8 incorporates " Hydrothermal comfort" with its various parameters.

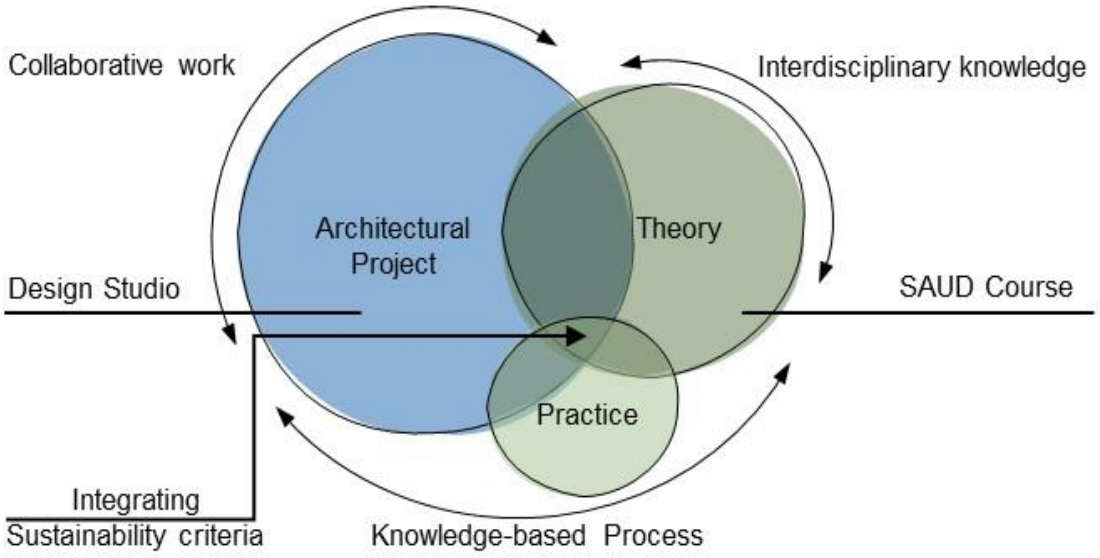


Figure 4: *Modelization of the observed Integrated approach*

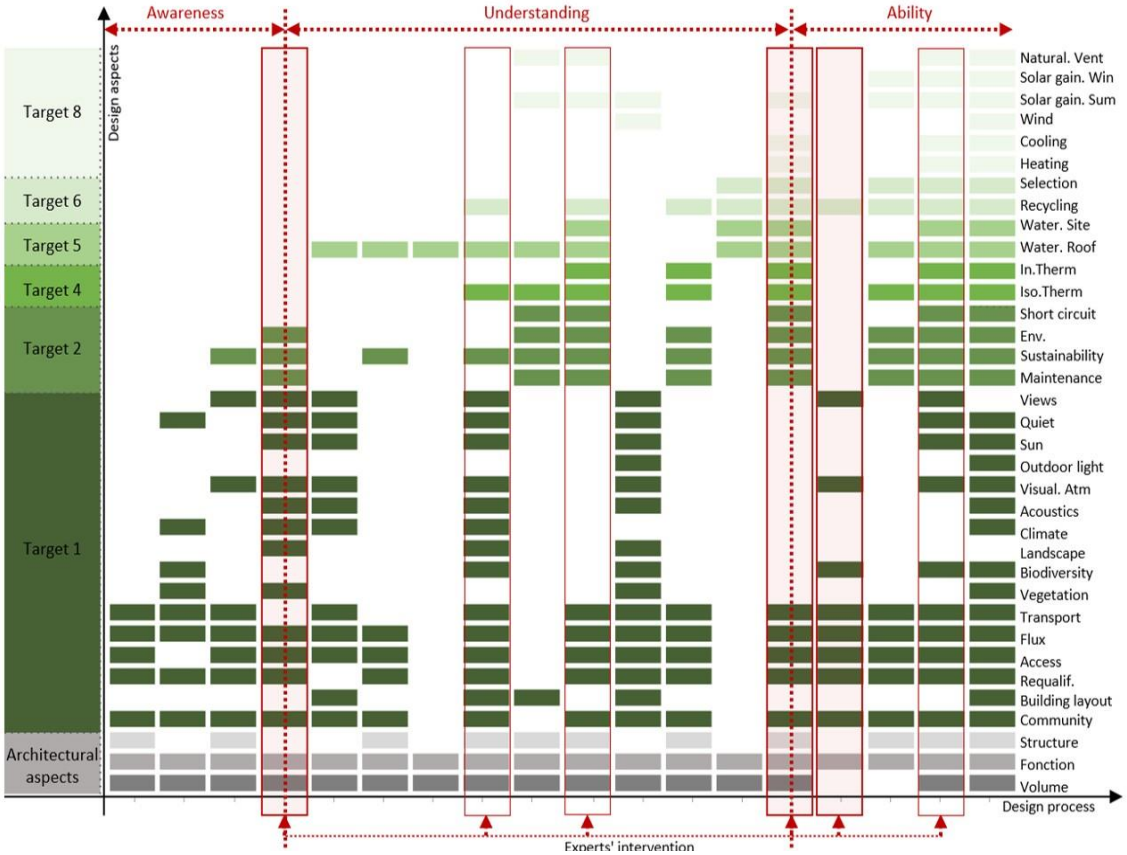


***Figure 5**: Track of environmental quality criteria HEQ targets within the design process*

It can be seen that, from the early phases of the design process and following the analysis of the urban context, target 1, which addresses the relationship of the building with its immediate environment, is coherently present with the various functional, formal, structural, and technical aspects of the design.
This is the phase of initiation to environmental awareness, which deepens as it moves towards the understanding and finally the use of environmental knowledge in the architectural design process. Indeed, throughout the entire design process, the course and design studio create a direct connection between the different targets of environmental quality and their applications.

The intervention of different experts and the contribution of analytically debated knowledge further encourage creative critical thinking among the students.

As shown in Figure 5, with each of their interventions new HEQ targets are validated and the project is increasingly part of complex holistic systems approach, as in the case of target 4 (Energy management) and target 2 (Integrated Choice of Construction Products, Systems, and Processes) following the intervention of the building envelope and environmental quality expert. Also, in target 5 (Water management) and 8 (Hydrothermal comfort) following the intervention of engineers (structural, fire safety, accessibility standards, fluids, and HVAC).

In this pedagogical context, the architectural design is considered as a whole building design that leads us to the concept of "holism".
The Whole Building design requires an integrated process in which the design teams work together throughout the project phases to evaluate the design for cost, quality of life,

future flexibility, efficiency, overall environmental impact, productivity, creativity, and how the occupants will be enlivened (Fathi, 2007). At the end of this integrated approach, students can propose a coherent solution that combines architectural aspects and environmental quality in a creative and critical manner.

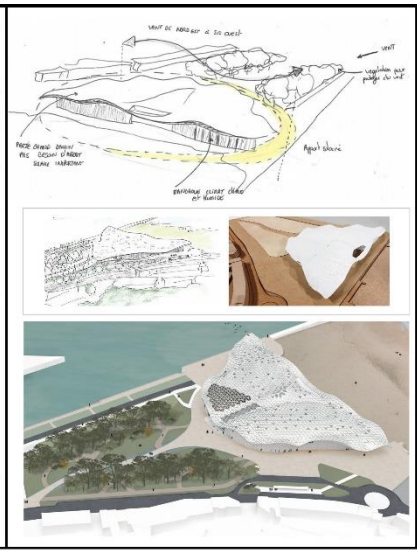
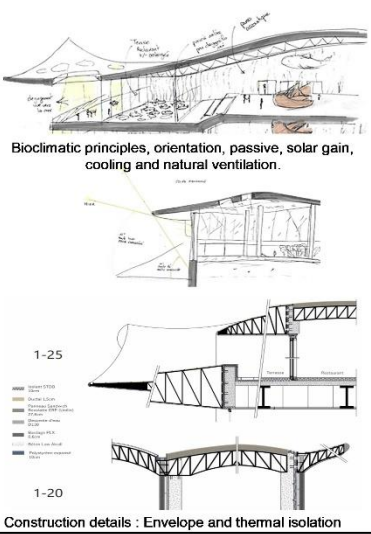
The students' outcomes provide different solutions to the sustainability issues in a holistic approach that aims, at the same time, to acquire awareness, understanding, and ability as shown in Table 2 :

Level 1, Environmental Awareness: since the preliminary design phase, students have used site analysis to define design solutions that can both optimize natural conditions and create spatial design challenges and opportunities.

Level 2, Understanding Environmental aspects: students used compositional aspects and volumetric design to propose an architectural language that can represent a design language for sustainability.

Level 3, Ability to Design Sustainable Building: students developed construction details that became essential for the overall design and architectural language definition and displaying technological solutions that could contribute to the technological sustainability of the project.

Table 2: *Sample of students' outcomes that show the design evolution and knowledge-based process.*

1 Design Process			
	Observation of Students Outcomes (learning activities and teaching methods)		
	Preliminary design and sketches	Design development	Construction drawings
	Level 1 : Environmental awareness	**Level 2 :** Understanding environmental aspects	**Level 3 :** Ability to design sustainable building
	Site analysis defining environmental solutions.	Architectural concept, function and volume choices depending on environmental aspects.	Technological solutions deepening environmental aspects as different details show.

3. Discussion and Conclusion

Based on the analysis of the data collected during the observation, and on learning outcomes within the integrated design approach, our study demonstrates the ability of students to propose design alternatives that respect architectural aspects as well as the ability to develop sustainable projects.

Following a complex, holistic, and systemic process, this approach makes it possible to articulate the parameters of sustainability in coherence with the various aspects of the architectural project while ensuring its integration in its context, limiting its impact on the environment, and promoting the comfort of the occupants.

Through the connection between the theoretical course and the design studio, as well as the intervention of different experts, the students acquire and put into practice an interdisciplinary conceptual approach that favors collaboration and a more involving experiential learning, and which opts to encourage their critical vision.

SOLO taxonomy indicates that the design process and learning outcomes differ from one group of students to another due to the chosen strategy and the complexity of the project.
This complexity results basically from the interdisciplinarity in the pedagogical framework put in place, and the dual training of engineers-architects.

Indeed, the sustainable issue should neither be considered as a specialist field nor taught in a module of the academic program.
Rather, it should be an integral part of the curriculum and be considered as a source of inspiration for conceptual design.

In this context, learning is acquired in phases that integrate the necessary knowledge, understanding, and the necessary ability to promote in-depth learning for an integrated architectural pedagogy.

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