PEDAGOGICAL INTEGRATION OF ACOUSTICS FOR THE MASTER’S DEGREE IN ARCHITECTURE AT LAVAL UNIVERSITY AND THE PHYSICAL AMBIANCE WORKSHOP

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Physical ambiance in building science describes perception of the environment as various parameters related to human senses such as climate, lighting and sound. At the School of architecture of Laval University, learning to recognize, to plan, and to control the acoustical soundscape is part of the professional or research master’s degrees specialized in ambiance. The courses include a theoretical aspect and a practical aspect which integrate the knowledge of an architectural design project, often related to a national or international contest. The students learn to consider and to manipulate the acoustical anticipated ambiance, simultaneously with the other physical environment they can influence through their conceptual process. They have to adjust their design to reach targets in thermal, lighting and acoustic quality within a collaborative mode with mechanical and civil engineering students. From the first steps of the building design, they analyze the implication of urban noise. Then they design the spaces of the building accordingly to the acoustical needs of each program, especially when rooms are acoustically sensitive. Finally, they use acoustic insulation parameters and data to think about the right assemblies. This presentation describes in detail how this design project works and points out its benefit to the practical formation of future architects.

Keywords: teaching, acoustics, architecture, physical, ambiance.

1. Introduction

The architectural physical ambiance represents all the human perception inside a built environment. Designers therefore need to understand parameters like climate, lighting and sound. A good control of the environment can upgrade the whole experience of users in or around a building and improve comfort or performance in various ways. At Laval University, students can select physical ambiance as one of their specializations during their master’s degree, which is required to become certified architects.

This paper explains the context of teaching and learning acoustics at the school of architecture, the description of classes and the resources involved in the workshop itself. The exhaustive description of this part of the curriculum helps to understand how future architects can learn to integrate all physical criteria, including acoustics, through an integrated design inside a special workshop involving multi-parameter analysis and team work with other scientists.
2. Architectural acoustics at Laval University

At Laval University, architectural acoustics was integrated for the future architects for decades now, especially after the early 70's with Prof. Jean-Gabriel Migneron. The development of this specialized field of architecture gave the school a long experience in the teaching of acoustics. It was not only dedicated to architectural acoustics, but also to urban and environmental acoustics with the collaboration of the urban planning department. Research was accomplished inside the research center in urban planning and landscape development (CRAD).

A 45 hours introductory course is offered as an optional class to undergraduate students during their third year of the bachelor’s degree. The course covers three parts, theoretical basis about sounds, room acoustics and sound insulation. It shows the importance of acoustics in architectural practice with the understanding of scientific concepts and the integration in the building, according to room functions. The same class is also offered to students in the certificate program dedicated to digital audio design at the music faculty.

The school of architecture is also a leader in climate and lightning with members of the Groupe de recherche en ambiances physiques (GRAP). Together with acoustics, those topics compose the physical perception of architecture, not only in teaching but also in research efforts. An undergraduate course in environment is mandatory to get basic concepts and to learn the control of independent parameters. Then, interested students can choose physical ambiance as a part of their specialization. It is in this field that they can fully explore and understand the power of this ambiance for the architectural creation. Each year, there are between 20 and 32 master's candidates in this field of studies. They have a theoretical class about physical ambiance and they spend at least 9 hours weekly in the workshop given concurrently.

3. Theoretical physical ambiance course

Simultaneously with the workshop, the group of students has to take the theoretical lecture dedicated to the physical ambiance. Covering climate, lightning and acoustic, a third of the 45-hour class is dedicated to sound. These three phenomena define the links between nature and architecture. This fact is a reason for the durable architecture orientation of the course. Each aspect is approached with the same methods, using evaluation and prediction tools. It illustrates and explains how unique ambiance are created using the physical properties, the volumes and the materials. The impacts on human comfort and health as the environment use of energy and resources are pondered. As students must earn a certain level of autonomy when they will need to find information about acoustics, some basic literature is presented during the courses. The suggested books have a visual approach convenient for architects [1-2].

3.1 Objectives

The main goal of the combined class and workshop is to achieve a better understanding of the fundamentals in each aspect, thus giving students a detailed control over the perception of the built environment. This is an important part to consider in sustainable design as physical characteristics of an existing site or to improve the project's conception of the wealth of its occupants. The prediction of physical ambiance qualitatively and quantitatively is a substantial way to optimize the value of architecture. Quantitatively, it is all about resources, material and performances, and qualitatively it is about perception and well-being of the built environment around humans. Both of these approaches are equally important for the physical ambiance.
3.2 Philosophy

The diminution of the energy consumption of buildings and the optimization of the comfort of users are the means to reach more responsible and ecological construction. To follow this goal, the emphasis should be oriented on each part of a building, and especially its envelope as it is the transition between the building and its surroundings. The envelope has an important role as it must provide the appropriate filtering of the air, the light and the sound. The architect can modulate this interface by changing and solving systems based on many variables where the equation between energy and comfort is often the first requirement, with mechanical equipment or not. The bioclimatic strategies are all interrelated, so the approach optimize all performances during the design process, trying to minimize the negative counterparts. For example, green buildings often involve natural ventilation where acoustics become a critical issue they are located in a noisy environment. The success of this kind of building depends on a well-controlled design, and the right adjustment of most interrelations between all parameters.

3.3 Work related to the class

Through the learning process, a dedicated work is asked for each of the physical aspect. This is used to verify the comprehension of each phenomenon and to allow a more practical approach. In acoustics, students have to use their knowledge to plan the acoustic ambiance one of the big rooms of the design for their workshop’s project. They need to describe it as precisely as they can by using suitable calculations. The outcome of the course is the preparation of a presentation of a poster showing the assimilation of results in the optimization of the design. They must address problems on different levels, with the systemic approach of integrated design process. On a macro scale, it shall account for the impact of the studied location, then having the building development on a mezzo scale for one or many selected rooms. This is finally completed by the selection of materials and assemblies, with the micro scale for the most important details. In acoustics, these parameters correspond to the aspects presented by the table 1. Those assignments are very useful to link the theoretical lecture to the practical workshop, then getting closer to the real practice.

Table 1: Three scales for acoustic ambiance analysis

<table>
<thead>
<tr>
<th>Levels</th>
<th>Scale</th>
<th>Examples of few analysis required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro</td>
<td>Urban (Site, environment, building)</td>
<td>Sound climate of the site, urban or transportation noise, outdoor spaces or agora, openings, sound penetration in the building, etc.</td>
</tr>
<tr>
<td>Mezzo</td>
<td>Architectural (Room(s), space organization)</td>
<td>Acoustic of large rooms, public halls, organization between rooms and their relations, etc.</td>
</tr>
<tr>
<td>Micro</td>
<td>Materials (type, acoustical properties)</td>
<td>Details of the construction, wall cuts to illustrate sound insulation, special acoustic devices, etc.</td>
</tr>
</tbody>
</table>

4. Physical ambiance workshop

The physical ambiance workshop is a course focused on durable environmental themes. It is mandatory for the master’s degree students (M.Arch.) specialized in physical ambiance. The challenge is to develop a sustainable architecture using natural ventilation and lightning while keeping control of the human comfort. The workshop length 9 hours a week of supervised class during a whole semester, 225 hours at the end. A day-long period of 6 hours allows teachers to discuss with each design teams. Approximately 9h of work are required outside the normal attendance. It is worth 6 credits of scholarship.
The work required tend to combine the art and the science of physical ambiance control through the design process. The main project implies to understand, to synthesize, to evaluate and to express environmental knowledge of the architectural design.

4.1 Objectives

Several objectives are simultaneously pursued by the physical ambiance workshop. The emphasis is not put specifically towards one of them. They are all equally important for the success of the workshop. At the beginning of the design process, students have to meet the natural and the built characteristics of the site. Then they quickly need to understand the impacts of climates, thermal, light and sound on the physical and the human environment. They must use the physical ambiance to generate new and efficient design hypothesis.

The students have to understand the key concepts related to the accountability and to the duties of the architects regarding the environment and resources conservation, inside architecture and urban design. They must develop their capacity to incorporate environmental variable inside the project. Through the process, they must satisfy many aspects: biological (comfort), ecological (natural resources), social, operational (building program) and perceptual.

Finally, they must show they are able to design a complete and complex project, which begins with an architectural idea, a conception program and a site. The project has to include structural and environmental systems, a studied building envelope, a defined construction assembly and security systems. It must answer all the principle of a responsible environmental impact, the complete C-4 design criteria from the Canadian Council of architectural certification.

4.2 Choice of project

The choice of the projects is made by finding an interesting project with a detailed program. It is often hypothetically dedicated to a site where the students can go at least once to fully understand the impact of the environment to their project. Sometimes the project is part of a larger contest for architects. Throughout the years, many students participated in actual architectural contest related to the project chosen for the workshop. Many of them got award for their works.

The counter effect of this kind of choice is that some years, the project is a bit further from acoustics as there is not any room really dedicated to sound but the essence of the acoustics remain present. When it occurs, it’s possible to find multiple way to implement acoustics as an added value to the project. It is always possible to think about the sound environmental impact, more if it is a green building because it has to remain quite open on the surroundings. There are also some large rooms used quite often as an entrance hall for the building. If there is any large room, there is a place for acoustic and the sound insulation problems could remain an interesting field of acoustic intervention.

4.3 Workshop process

The students are divided into teams of three or four people to join their mind and works around the design challenge. Each group has to propose a solution to the same building. They get along with their partners after they know the subjects by doing some research about similar projects and designs. They are encouraged to use the design strategies of Sun, wind and light: Architectural design strategies [3]. Then the iterative design process starts. The first goal is to fix the essence of the conceptual frame, to make a draft of the building and to locate it on a site. The project is always associated with a real site to use actual climate, light and acoustic data. At this step, the project is mainly described by his relation to his environment. The main architectural concept must emerge with building form.

The second part of the process implies a more detailed answer to the architectural program. The conceptual ideas are confirmed or modified. It’s time to implement and verify the structural system and the main material. At this stage, the concept evolves through the room repartition in relation to their
functions. The physical ambiance has an important impact on the architectural design decision. It’s the phase involving the most radical modification from a week to another because some decisions could impact many aspects of the proposed design.

The last part involves all the integration of the physical ambiance. This step is when the complete integration hopefully took place. The adjustments are made for each of the physical ambiance. It is in this part that all the material is decided so the room acoustics and acoustic insulation are evaluated.

For each design stage, in addition to the teacher's weekly intervention, the teams have to present their conception in front of the class. The presentation includes two posters and a model of the building. On these occasions, the jury of few architects and specialists are invited to criticize each of the projects.

4.4 Interdisciplinary collaboration

To replicate the professional architectural process, for a few years, a collaboration started between the school of architecture and the engineering faculty. Each team is paired with a class in civil engineering and another one in mechanical engineering during the design process, with their teacher's supervision. The structure of the planned building is verified and enhanced by the civil engineers and all the ventilation systems, the choice of its components and the calculation of its energetic costs and performance, fall on the responsibility of the mechanical engineers. This approach allows the students of the three different programs to get an experience close to the real-life work.

5. Available resources

There is a number of resources available for the students. They can use them as soon as their undergraduate workshop because many projects explore topics who can profit some acoustic knowledge. For example, when the students conceive a small public building in their second year of study, they quite often have some conceptual challenges in acoustics to address. Another way to get an introduction to acoustics challenges is given by Jacques Plante, an associate teacher of the school who often choose a theater for an undergraduate workshop because he is a known specialist of these buildings [4].

5.1 Teachers and consultants

Typically, a teacher from each topic covered is associated with the workshop and the theoretical course. From time to time, according to the project, some consultants could join the teaching staff for a specific intervention. It is especially the case in building science with professionals from the industry or researchers in sustainable building design and wooden construction.

5.2 Software

In addition to architectural design software, some prediction tools can be used to add acoustical calculations as design components of building projects. Even if extensive simulation tools can be available to students, as DIVA for Rhino, Energy Plus, Grasshopper, Athena, and Pachyderm.

They are mostly made for climate and light ambiance, but some calculation tools offer valuable evaluation for acoustics, like ray-tracing sound reflexions or reverberation time calculation. For more complex designs of halls, CATT-Acoustics could be used, but it's not typically the goal of the workshop to get to this level of precision. The main problem or limitation with simulation software is that there is not enough time for students to study the theoretical notions, to pass through the learning curve letting them evaluate their particular design, and to hand in an efficient architectural proposition during only 4 months.
5.3 Infrastructure

The Acoustic Laboratory of Laval University (LAUL) is the largest infrastructure belonging to the School of architecture. The laboratory includes two reverberant rooms of 200 and 60 square meters and a semi-anechoic chamber of 60 sq. meters, as it is shown in figure 1. It's not commonly used during the ambiance workshop because chosen projects focus on design and do not give enough time for practical experimentations. The laboratory is mainly used to demonstrate some acoustic phenomenon and for external research projects or acoustics measurements.

The students who want to pursue their learning with a science master’s degree or a Ph.D. can take advantage facilities managed by the research group in ambiance, which also include an artificial skylight lab, and a hydraulic canal. The team of the GRAP could achieve research projects about any field of the physical ambiance. Systematically, the students of the workshop join the research group to elaborate their final essay for their master’s degree.

![Figure 1: Plan of the Acoustic Laboratory.](image)

6. Further possible developments

The joint participation of young engineers and architects during their studies at graduate levels improves the results and is pedagogically recommended knowing that integrated design becomes common in professional practice. However, organization of these kinds of activities stays a challenge for faculty members as the school of architecture is not located on the main campus. The distance and transportation time limit the number of interactions, but good project management is suggested to help teamwork. That semester requesting a lot of involvement for students, maybe the schedule could be reviewed to synchronize engineering and architecture knowledge development from theoretical class through the joint workshop.

REFERENCES