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Integrating Environmental Phenomena in the Initial Architecture Studio: Reflections on Modeling of Convective Currents in Living Spaces

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Abstract: In the seminal vision of Donald Schön about the design process, this is defined as a conversation between the designer and the materials of a situation. Later, Nigel Cross would add that modeling is the language of that conversation par excellence. In the light of these ideas, this descriptive article discusses the role of analog models in enabling and enhancing reflective design and the inclusion of environmental topics, usually absent from the initial architectural design studios. To illustrate the potential that modeling has in these cases, a first-year studio exercise in which modeling of heat, specifically of convective currents, is shown. Finally, the authors reflect on the relationship between concepts, the cases presented and the learning opportunities that arise together with the responsibilities of educators.

Key words: reflective design; analog models; environmental phenomena; architecture; learning

1. Introduction

Design is the journey of discovery.
- Schön

Currently, an increasing number of architectural schools have expressed new concerns about incorporating environmental variables into their student developed projects or some cases involving environmental variables in their curriculum, but there is still a possibility of discovering resistance to incorporating these variables early in the design process (González, 2013).

To alleviate this problem, those who play the role of educators tend to apply these variables to students' time in advance, and the knowledge of these variables was previously taught to them in theoretical subjects. At first glance, this seems advisable, but since difficulties still exist, it is appropriate to ask whether the logic of knowledge application, which assumes two separate moments in the educational process - the first when the student receives the knowledge, and the second when he applies it - is always beneficial for this integration to occur in a natural way.

According to American philosopher Donald Schön (1983), this logic intensifies the division between knowledge and action, and wastes the inherent quality of design to produce profound learning, which is its internal reflection. Understanding this nature of design is the core activity of our discipline and seems to be a key prerequisite for the integration of environmental variables to encounter less resistance.[i]

2. The Thoughtful Schön Designer

In the classical view of how an architect-designer operates, which, although idealized, has been the accepted view from the early Renaissance to the height of the Modern Movement in the last century, he was capable of creating something ex-nihilo. According to Alberti (1404 -1472), designers and architects can project on paper, that is, draw a geometric image that is completely conceptualized in their minds, "without resorting to any matter" (Lang, 1965). Therefore, the origin of any design lies in his mind, where he is projected unidirectionally onto a painting (design) or a model. This behavior - which we can refer to as internal psychological processing in more modern language - surprisingly, at least in theory[ii], it occurs in the absence of feedback from the design, and in the situation faced by the designer through design.

Five centuries after Alberti, Donald Schön is the one who has described the activity of designing probably in the most opposite way to this classical description. If in the latter, the designer carries out what could metaphorically be a monologue, then in Schön's description (1983), the designer establishes a dialogue with his/her design situation, selecting some of its components, to which he/she speaks and, above all, listens to them. The mutual conversation and listening between designers and the problems and constantly changing situations they face are essentially reflective activities of design. Schön did not refer to reflection as a synonym for thought, although he did not exclude it, but as a literal dynamic of reflection between the designer and the context. The designer described by Schön is reflective, not only because he thinks, which is the basic condition for reflection, but also because his thinking develops simultaneously with the development of the situation he/she is facing. Coincidentally, other authors believe that designers, in the process of co-evolution of two elements, sequentially reflect solutions to problems, and vice versa (Dorst & Cross, 2001). In short, designers are not projecting or imposing a completely premeditated solution to this situation, but engaging in metaphorical dialogue with the situation to reach a solution.

Although Schön's method was influenced by his teacher John Dewey's thought, there is a fundamental difference between Schön and him, which is related to the background of this article. If for Dewey, any disciplinary reflection occurs in a temporary pause outside of practice and uses the language of science, then for Schön, reflection is inseparable from disciplinary practice and its language. Even when dealing with scientific issues, Schön pointed out that designers do not use language unrelated to him, but are loyal to the unique research forms of their discipline (Waks, 2001).

3. The Language of Conversation

If the design process is metaphorically a conversation between the designer and the situation he or she faces, it is worth asking how the designer speaks to the situation? And how can the situation respond? In this regard, several authors have reached a consensus that this dialogue is carried out by the model of the situation or its parts, and its elaboration during the design process plays a fundamental and irreplaceable role (Schön, 1983; Lawson, 2004; Cross, 2010; Dunn, 2007).

Nigel Cross (2010) emphasized that modeling is the language of excellent design and therefore is at the "center of the discipline". He said that a person can develop skills in this language, which is equivalent to skills in scientific language (numbers) and humanistic language (letters).

4. Exploratory Models

The practice of making models is a long-standing tradition in architecture, and in the field of subject teaching, it is one of the most common activities we can find in the workshop. However, not all of the models we refer to contribute to the reflective design process.

At the opposite extreme in this regard, on the one hand, it is a project end demonstration model, and on the other hand, it is an exploratory or process model. If we use Schön's metaphor, the former is a static record of a conversation that has already ended, while the latter is a materialization of an ongoing conversation.

A famous historical example of the exploratory model is the hanging model of ropes and sandbags. Antoni Gaudí designed the model to study the complex static and geometric problems within the limits of stone masonry of churches not built on the basement of the Colonia Güell (Figure 1). This model was classified by Collins (1971) as a "projection machine", allowing Gaudí to distinguish the combination of phenomena - mass, gravity, and geometry - with which he could engage in dialogue to find solutions. The model in its final state was not expected by the architect, but appeared during that conversation. This situation is also in line with Schön's view, that even when exploring unknown territories, designers will not abandon their own investigation methods.

Figure 1. Rope pendant model, small sandbag, and silk paper. Antoni Gaudí. Source: Puig Boada, 1976.

The exploratory model proposes a scientific analogy, hence it can be called analogous in some cases, whose fundamental purpose is to allow the aforementioned reflection of the designer.

Regarding the role of exploratory models in architect education, Dunn (2007) believes that one of the core ecosystems[iii] of the disciplinary learning environment arises between architects and students who design them. This ecology is largely based on the physical and cognitive physical relationships between students and the models they construct and manipulate.

It must be considered that a lot of information in the model can only exist in this way if students can perceive it through sensory exploration. In this sense, it is important that, for example, students can hold the model with their hands and rotate it so that they can observe it from all necessary angles, or show it to others when rotating, approaching, or leaving the model with their arms. You can also obtain different perspectives by tilting or lifting, rather than moving the model. The information that students actively acquire through their bodies may include exploring potential resistance or weaknesses in the material used in model making, and by touching its surface or applying pressure on it.

From the perspective of reflection or dialogue proposed by Schön, it is even more important that students can modify the model and make modifications easily. This is a characteristic of exploratory models that can be intervened in multiple ways, especially in the early stages of the design process; They may eventually be cut, folded, stretched, twisted, etc. Dunn (2006) used the term "affordances" coined by Gibson (1979) to refer to the ability of the model to provide students with opportunities for action, while the possibility of establishing dialogue and reflective dynamics between students and the perfectly executed final representative model is minimal.

As we mentioned at the beginning of this section, these physical exploration models are typically used by students to explore geometry, proportions, joints, positions, or other aspects. However, physical modeling rarely explores relevant environmental phenomena in spatial experiences. In order to incorporate these phenomena into the design process from the beginning, the author of this article developed a series of workshop orders that require such modeling. To illustrate this article, a case study of convection generated by a heat source was chosen as the modeling object. The background of this teaching experience is a first-year architectural design workshop at the School of Architecture at the University of Santiago, Chile.

5. Modeling of Convective Currents in TAA1

The most relevant aspect of the exercise described here is conducted within the framework of a delegation sequence with similar features in its method. In each case, students have the opportunity to solve architectural design problems by exploring and understanding specific environmental phenomena. The first two tasks respectively involve the role of natural light and airflow in spatial experience. The third task is to design a coffee shop/bakery located in the city center, between the middle walls. As a solution, the following three areas should be considered: (1). In the bread preparation area, according to regulations, two electric furnaces should be placed; (2). Sales area; and (3). Cafeteria area. The bathroom is only considered a damp area and there is no in-depth study of its functional solutions.

In order to focus students' attention on the phenomenon of high temperatures, they must all consider organizing habitable space within a simple volume of 12 × 12 × 6 m, which must be guided by one of the four possible options proposed by the teacher (Figure 2).

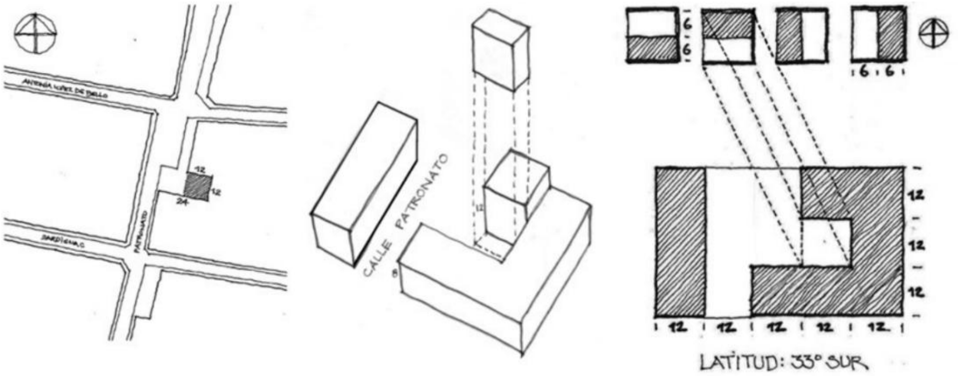

Figure 2. Location of the site in the neighborhood (left), the volume on the site (center), and the four possible volume orientation options (right).

While addressing the basic functions and ergonomics of the project, each student must propose a space configuration to utilize the excess heat generated by the oven during winter and distribute it along with the aroma of bread to different areas of the project. In addition, it must propose an opposite strategy for summer, allowing heat in the air to be dissipated and keeping residential spaces cool. While meeting these requirements, students must also address the relationship with their background, which was addressed in the first few exercises this year, but always considering that the emphasis on this opportunity is related to thermodynamics.

5.1 Preliminary stage

Based on the modeling methods that accompany the subsequent design process, the four-week preliminary stage was intentionally proposed in a prescribed manner, aiming to familiarize students with the behavior of convection through the use of low-cost equipment (Figure 3). The basis of this method is that air and water - these two liquids - have similar mechanical properties[v], but have different densities and viscosities. In order to make the modeling method scientific and effective, it was compared with the CFD software of the Mechanical Department of our school, proving that the modeling method is reasonable and reliable for the goal of first-year architectural design practice.

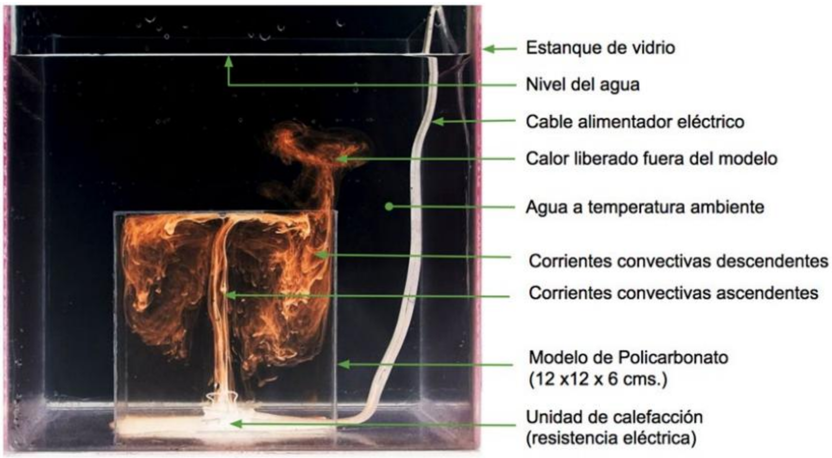

Figure 3. Initial modeling of convective currents. Student: María Ignacia Rastra.

The components of the device are as follows: an 18 × 24 × 24 cm colorless glass pool (Figure 4); Clean water at room temperature, in which scale model made of transparent polycarbonate is immersed (Figure 5); Heating unit (resistance)[vi]; Marking pigment (to make convective currents visible). In addition, a camera installed on a tripod can record each experiment.

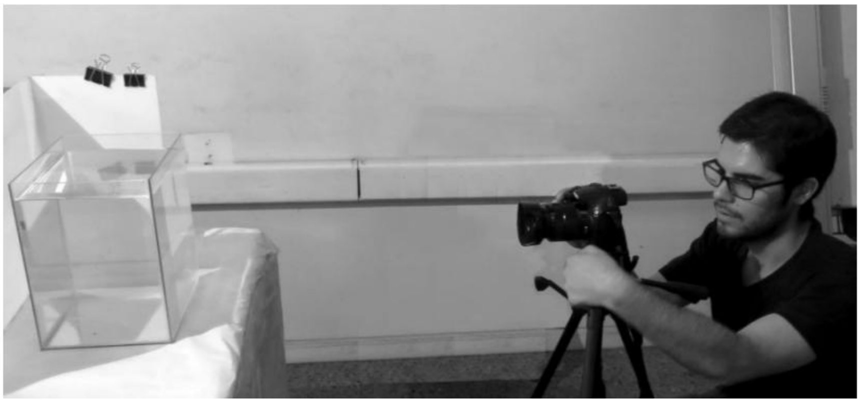

Figure 4. A student prepares the video record of one of the experiments. On the left is the glass pool.

Figure 5. Transparent polycarbonate diving model.

In this first approach, students in teams of four investigated the behavior of convective currents in a similar model for all, testing three positions of the heating unit. In this way, it was possible to record the thermal patterns determined in each position, which in turn determined different zones of higher or lower temperature. The objective of this first part of the exercise was to discover the relevance of the position of the heat source, since, although the geometric configuration of spaces and openings was the same, the trajectories described by the flows were clearly different (Figure 6). The fact that all students use similar models enables programs to compare and helps understand that thermal modes are not harmful, but rather follow certain thermodynamic laws. The first step can also be observed that convective flow can be driven or domesticated within a certain range, which is a fundamental issue in using heat as a design material.

Figure 6. Three distinct thermal patterns in the same geometric configuration of spaces.
Students: María Ignacia Lastra, Valentina Roco, Chiara Massaccesi, Catalina Leiva.

5.2 Development

After the initial stage, each student is free to propose their own design assumptions, where possible heat flow geometric patterns will run through the three areas required for the commission. This initial assumption was expressed through pictures and must be tested experimentally. In the first example shown here (Figures 7, 8, 9, and 13), students proposed a configuration of a three-story space with a heat source located in the center of the lower level. His thermal assumption for winter (Figure 7) is that there will be three relatively different regions - A, B, and C. The subsequent experimental test section[vii] confirmed this hypothesis (Figure 8).

Generally speaking, except for some exceptions that require thorough modification, for most students, this is a continuous adjustment. During this six-week phase, work was carried out simultaneously with the design of wire, cardboard, and other materials of the same scale, submersible polycarbonate models, and traditional models (Figure 9).

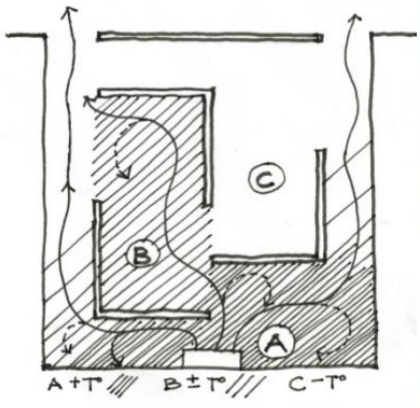

Figure 7. Hypothesis drawn of convective currents.
Student: María Ignacia Lastra.

Figure 8. Convective flow modeling framework.
Student: María Ignacia Lastra.

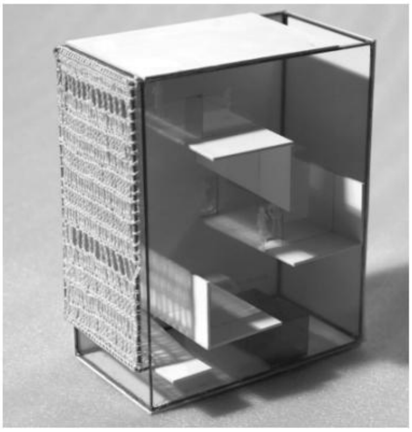

Figure 9. Models of wires, cardboard, polycarbonate, and braided wire.
Student: María Ignacia Lastra.

This stage has special requirements for students and teachers, as it is not only to make thermal dynamics work from a purely mechanical perspective, but also based on the experience of the people living in the project during winter and summer. At this point, the functional aspects of spatial and route distribution have also been determined, which must be coordinated with thermodynamics. In addition, based on the location and direction of each project on site, a satisfactory response must be made to the sun protection and light quality requirements of various indoor spaces.

At the same time as the seminar, the laboratory subjects collaborated with this exercise to familiarize students with the basic concepts of heat transfer and some principles of convective flow. The second example shown here (Figures 10, 11, 12 and 14) develops his hypothesis based on the stack effect, which enables him to effectively meet demand in winter (Figure 10) and summer (Figure 11). In this case, as in the previous example, the student simultaneously used traditional wire, cardboard, and polycarbonate models (Figures 12 and 14).

Figure 10. Thermal pattern in winter.
Student: Juan Pablo Díaz.

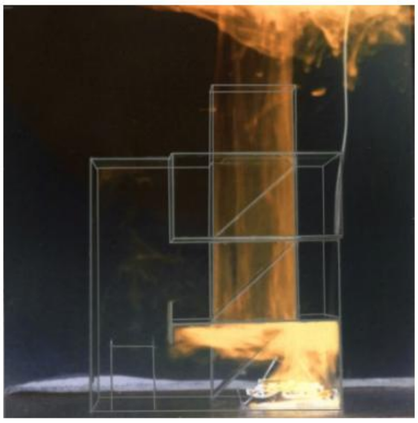

Figure 11. Thermal pattern in summer.
Student: Juan Pablo Diaz.

Figure 12. Traditional wire, cardboard, and polycarbonate models.
Student: Juan Pablo Díaz.

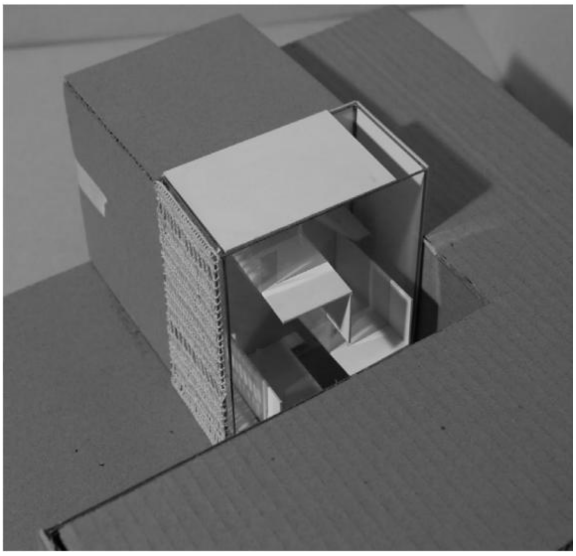

Figure 13. Final model under simplified urban background.
Student: María Ignacia Lastra.

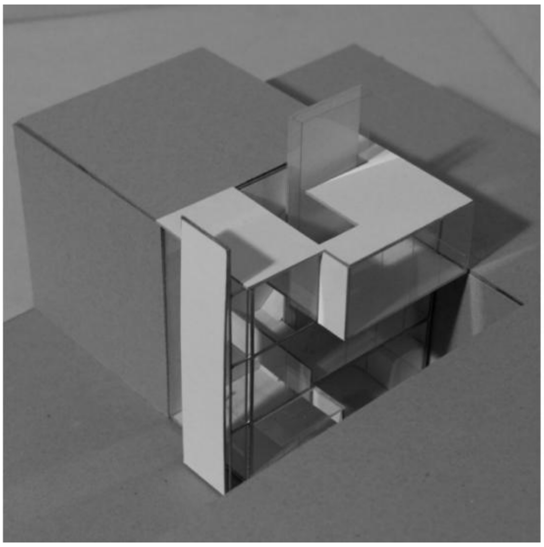

Figure 14. Final model under simplified urban background.
Student: Juan Pablo Díaz.

6. Relationship and Reflection

6.1 Listening - speaking

As we have seen in the previous sections, several authors unanimously agree that one of the fundamental characteristics of the design process is its conversationality, which is related to the modeling process. Those who converse through modeling are the designers - student and some components of the problem he/she faces. In this task, some models are more suitable for certain conversations than others. For example, if students need to have a conversation with the geometry of the project, a wire model may be more advantageous than a cardboard model. Perhaps, even, just drawing it is enough. If it is proposed to engage in a dialogue with the light and shadow of the project, a cardboard model exposed to the light source may be sufficient and appropriate. But what does this suitability depend on? Based on the experience described in this article and other similar experiences in which the author participated, we believe that as predicted by Schön (1992), this actually depends on the model's listening and speaking abilities.

Their listening ability directly depends on the action opportunities that students can discover in the model. In the context of the dialogue in the design process, these actions are the way for students to propose methods. Therefore, this characteristic indicates that the model must have conditions of gentleness or plasticity in the design process to cope with manipulation and modification, because like real conversations, conversations must proceed smoothly and the speed is typically determined by delivery time in formal education. For example, gypsum models may be very difficult to accept - metaphorically speaking, deaf people - exploring geometric changes within a limited amount of time. However, in order to explore the constructive limitations of materials with similar mechanical properties, such as concrete, it may be very suitable to listen and speak eloquently. Therefore, the materials used to create the model are crucial for defining its ability to listen and speak; Just as it can promote reflection on the terminology proposed in this article, if your choice is wrong, you can push the design process towards monologue.

In the case of convection modeling described, although its listening and speaking abilities are partially limited by the complexity of the modeling object, it can accept key modifications in understanding convection, such as changing the position of heat sources while maintaining the same spatial configuration, which is essential in the initial stage of the project.

Similarly, the ability to talk about a model depends on its ability to reveal things. From an educational perspective, this is a very important feature. In this sense, the model has become a tool to show "a part of the environment" for students to directly understand, rather than necessarily being taught by teachers as suggested by Ingold (2000). Similarly, in the described case, the specified materials for modeling and the elements of experimental equipment are also decisive. Diving models made of polycarbonate, transparent ponds, and marking pigments help reveal the most complex convection. It is possible to see them rise and move in the shell according to specific geometric shapes, and drop when the temperature is low. Their visibility also enables them to record through video, thereby changing the timing of thermal dynamics during playback, and improving the metaphorical eloquence of the model.

Just like in real conversations, the terminology of modeling must be reliable. In terms of TAA1, the experimental modeling method designed by the professors aims to approach the dynamic reality of the phenomenon being explored as closely as possible. Although liquid medium is used instead of air medium, the aim is to ensure that the behavior of convective flow in water is similar to its behavior in air, which has been confirmed by professors from the university's Department of Mechanics.

Of course, we did not seek scientific accuracy which in this context is meaningless, but a plausible approximation to the behavior of the phenomenon in living spaces. The model was intended to provide reasonably reliable information for first-year students that would allow them to make design decisions.

6.2 Explore - discover

The goal of Schön's reflective design process is to explore and discover solutions, rather than projecting solutions. However, in order to activate this process in the educational context we describe, it is necessary for teachers to design a method to deploy the intangible dynamics of heat in spaces designed and constructed by students themselves.

As this phenomenon becomes visible to them, it becomes manageable. Only from that moment on, the student was able to ask questions to the model, modifying the configurations of spaces, positions and sizes of the openings, to which the model was able to answer effectively. From an experimental perspective, each method constitutes a hypothesis that can be confirmed or excluded at this level, making it possible to gradually make progress on the basis of continuous discovery.

In addition, due to video recording, our understanding of this phenomenon has also deepened. This appeal enables people to observe this more carefully and make necessary observations without the need to prepare for the experiment rig each time. Due to changes in video playback time, it is also possible to detect unobservable behavior in real-time.

Finally, the most important discovery in incorporating environmental phenomena into the design process is the interdependence between thermal phenomena and accommodation forms. Therefore, what constitutes is not a series of watertight processes: on the one hand, it can be understood as an exploration of shape, and on the other hand, it is an exploration of its environmental quantitative performance, but a single process of progressive uncovering that generates more information about the same research object each time.

7. Final Considerations

The experience of thermal modeling explained in this article enables us to confirm the power and teaching usefulness of design metaphors as a dialogue proposed by Schön more than 30 years ago and recently strengthened by Cross (2010). Our contribution is to test his suggestions, which we can metaphorically refer to as an emerging environmental dialogue theme in architecture teaching. We note that this is a promising path for incorporating environmental variables into the student design process, although it requires considerable effort and dedication from educators.

In some cases, this also involves a change in mindset. This is about stopping seeing the design process as a moment for students to apply previously acquired knowledge, and seeing it as a source of knowledge itself.

Attempting to make students understand the role of environmental variables by incorporating them into the reflective dynamics of design may seem obvious, but how to achieve this is not so obvious. This task requires understanding the reflective nature of design activities and understanding the foundation of such reflection. In this sense, the author's contributions cited in the first part are enlightening and also imply the responsibility of the teacher.

This article focuses on how to create conditions for students to integrate environmental variables in a reflective manner for design, rather than transferring the main responsibility for this integration from students to the teachers in the design studio when they have to apply previously learned environmental concepts at another time and place, and assigning the task of coordinating learning opportunities to the latter. Even so, or perhaps because of this, the student is still the main actor in his or her learning, because as an apprentice designer, he or she is invited to participate as a discoverer rather than a mere application.

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All figures are from the authors' collection of photographs or drawings except where the source is indicated.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Note

[i] Muy tempranamente, en su revelador informe "Energy Conscious Design in Schools of Architecture", Marguerite Villecco (1977) sostuvo que la incorporación de cualquier nuevo paradigma en la enseñanza de la arquitectura debería hacerse respetando las prácticas y filosofía de la disciplina - dentro de las cuales el diseño es una práctica y filosofía central - y no desde fuera, de lo contrario encontraría una resistencia permanente.

[ii] Los registros de varios arquitectos contemporáneos de Alberti muestran que estos frecuentemente necesitaron la retroalimentación de sus dibujos 'de proceso', sin embargo Alberti es taxativo en afirmar lo contrario.

[iii] La idea de ecología está usada acá en consonancia con la aproximación ecológica al aprendizaje, corriente educativa que define al par estudiante - ambiente de aprendizaje, no como dos cosas dentro de las cuales el estudiante aprende lo que el ambiente le enseña, sino como una entidad unitaria que conoce y aprende. Para más información ver Barab, S. A., & Roth, W. (2006)

[iv] James Gibson acuñó la palabra affordances para denominar las oportunidades de acción que un organismo puede detectar en porciones del ambiente, de ahí el apelativo "ecológico" en el trabajo de Dunn (2007).

[v] A este respecto existen varios experimentos hechos por ingenieros y físicos estadounidenses en la década de 1950, de los cuales se han publicado videos de difusión para estudiantes de ingeniería y física de pregrado, realizados por The National Committee for Fluid Mechanics de los Estados Unidos. Ver, por ejemplo: https://youtu.be/nuQyKGuXJOs

[vi] El video tutorial para la fabricación del calefactor se puso a disposición de los estudiantes en YouTube. https://www.youtube.com/watch?v=c5CMACcJQCQ&feature=youtu.be]

[vii] Enlace a video time-lapse de prueba experimental https://youtu.be/uWFjlOiqOqA