Digital Understandings in the Construction of Knowledge

Report of experiences in contemporary architectural design teaching

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As part of an ongoing research on the study of digital tools envisioning innovation in the design process, this article intends to demonstrate how analogical and digital design thinking techniques can improve and expand the range of creative methodologies in the context of an undergraduate architectural design studio. The approach presented builds on the improvement of a theoretical-didactic model during three strategies, each aiming at different steps of the design process. The first one explores analog design thinking techniques on the initial concept decisions, the following demonstrates the joint use of parametric and BIM tools as an alternative resource for generating complex forms, and the last one presents BIM technology as a pedagogical instrument for learning a constructive system. Thus, besides presenting the methods, instruments, products, and results generated, this paper will also discuss the gains and difficulties faced, appointing a new approach to undergo in the future.

Keywords: Digital Design process, Architectural design teaching, Design thinking, Parametricism

INTRODUCTION
From the 1960s on, the field of architecture began to face gradual changes as a result of the rising of new digital technologies applied to the design process, changing procedures which were, until then, completely analogical. Initially focused on the graphic capabilities of Computer-Aided Design (CAD) systems, these technologies started to have a more direct role in the design process during the 1990s, which can be observed in the experiments of Peter Eisenman, Marcos Novak, Greg Lynn, among others (Natividade, 2011). More recently, new design approaches have emerged through parametric design software such as the Building Information Modeling (BIM) system, and through visual programming software such as Grasshopper and Dynamo. In addition to these, digital visualization techniques such as virtual reality and augmented reality (VR and AR) and digital manufacturing through 3D printers and CNC milling machines (computer numeric control), have become increasingly accessible to designers. Encouraged by such factors, authors like Rivka Oxman (2006, 2008, 2012,
design within the broader field of architecture.

Although the concept of digital design is already present in the research of European and North American educational institutions, in Latin America, more precisely in Brazil, such technologies are still being implemented. Authors such as Neliza Romcy (2017), Fernanda Machado, et al. (2017), point out the novelty of such content in the architectural curricula in the country and the importance of this approach. Celani (2006, 2008 and 2017) corroborates with those assertions, reinforcing that this is still a field only partially explored and developed in Brazil. The author, together with Maycon Sedrez (Sedrez and Celani, 2014), highlights the importance of adopting new technologies in the design process in contemporary architecture, a factor that has, in turn, “instigated teachers to seek new cognitive processes involved in design learning.” Sedrez and Celani (2014) also reinforce that the analysis and comparison of the different didactic procedures of digital design allow the identification of new ways of thinking architecture. In this sense, they cite the work of Oxman (2008) by pointing out three main elements that must act integrated into digital design: “the conceptual content, the experimental methodologies, and the digital skills” (Sedrez and Celani, 2014).

In this context, and as the object of a research focused on architectural design process innovation [1], a theoretical-didactic model applied within the scope of an undergraduate design studio in a Brazilian Architecture School has been improved. Departing from a strategy initially focused on analog creative design thinking techniques (Design Thinking Strategy), the model demonstrated a potential for improvement both on formal design developments and on the technical-constructive understandings through the exploration of digital knowledge. As a result, so far, two other research strategies have been explored, whether through the adoption of BIM tools (BIM Strategy) and/or parametric design (Parametric Design Thinking Strategy), in different phases of the design process.

This article, therefore, aims to report and discuss how analogical and digital design thinking techniques can be incorporated envisioning innovation in the design process of an undergraduate architectural design studio. This will be demonstrated through a brief description of the design studio program followed by the presentation of the three strategies already applied, their qualitative results and a possible new approach to undergo in the future.

METHODOLOGY

The Architectural Design Studio II (PA-II) belongs to the 2nd year (4th semester) of the undergraduate curriculum at a Brazilian Architecture School. With an average number of 15 students per teacher, since 2012 the studio program regards the development of a landscape design hotel. Encouraging the use of different design tools, the studio aims to engage the students in all aspects of the design process through studies carried out on two different scales. On the macro scale, groups of four to five students define the hotel concept and overall landscape design. Afterward, on the micro-scale, each student in the group designs an individual small hosting unit of 60 m². Besides relating to the overall concept, the unit must respond to four basic core functionalities: to rest, to bathe, to eat, and to amuse. The low programmatic complexity of the units plays in favor of dedicating more time to the formal and constructive exercises. Implemented on three stages of development, the design process gradually increases the complexity and level of detailing. These are the “conceptual-environmental” stage, the “programmatic-formal” stage, and the “material-constructive” stage. Regarding the material-constructive phase, from 2015/2 on, the discipline has been adopting exclusively the woodframe construction system for the hosting units, closely associating the design process with that of the construction technique.
DESIGN THINKING STRATEGY
The design thinking strategy was implemented in 2012 (Ponzio, Machado, 2015) and was characterized by the use of analog design thinking tools employed as instigators of the creative process during the “conceptual-environmental” and “programmatic-formal” stages. Departing from the site visit and embracing an “experience design” approach (Benz, 2015), on the “conceptual-environmental” stage each group focused on elaborating the Hotel concept. That was achieved through the construction of a narrative based on cultural, local, and environmental observations. This stage also comprehended the definition of the target audience, the hotel amenities, and experiences. Among the design thinking techniques employed were: brainstorming, mind mapping, polarity mapping, thinking hats, scenario analysis, and conceptual moodboards. The next stage, the “programmatic-formal”, defined - at the macro scale-, the site plan with itszonings and connections systems and, - at the micro-scale-, the hosting units’ parti. This was the moment of the unit’s formal generation studies, having as a departure the general hotel concept defined previously by the group and the programmatic core functions of each unit. The students were encouraged to exercise with referential moodboards and architectural analogy techniques (Andrea Ponsi, 2013) in order to relate the unit’s parti to the abstract hotel concept. Until 2017/1, a combination of analog and digital techniques such as paper models, hand sketches, Sketchup models and two-dimensional CAD schematic drawings were employed. Finally, at the “material-constructive” stage, a greater definition of the hosting units was expected. In order to do so, the woodframe technique was initially presented to the students through theoretical classes accompanied by explanatory reference materials (Rob Thallon, 2009; Francis Ching, 2010) [2]. During this stage, CAD tools were used almost exclusively: Sketchup for the three-dimensional models - one architectural and another structural, and AutoCAD for the two-dimensional technical documents. Therefore, at the end of the design process, the dissociation of three-dimensional models and two-dimensional representations often complicated the student’s understanding of the construction system, sometimes resulting in a lack of accuracy on the technical documents.

Although this strategy enhanced the creative formulation of the design concept with the design thinking techniques, the material-constructive stage used digital tools mostly as a representational medium and within the boundaries of the Euclidean geometry, limiting the student’s choices on exploring formal solutions of a certain complexity. Figure 1 represents the development stages of the design
process adopted until 2017/1, demonstrating the respective teaching methods employed and their products.

Taking advantage of the implementation of parametric tools on the school’s digital instrumentalization disciplines starting from 2017 on, and aiming to solutions to the appointed problems, two digital strategies were planned and tested at different moments in the following years in a complementary way to the analogic design thinking exercises [3]. First, in order to explore formal solutions further and investigate the joint use of parametric design and BIM technology, a parametric strategy was applied and tested in 2017/2 [4]; secondly, a strategy dedicated to explore the use of the BIM system in order to explain the woodframe construction technology was applied in 2019 [5].

PARAMETRIC DESIGN THINKING STRATEGY

According to Oxman (2017), there are several models of design thinking, among which, “emerging as a unique distinctive model of design”, the parametric design thinking (PDT). For Oxman, that is a new category of design thinking capable of being explored within parameterized digital technologies. The possibility of developing a creative design process is here supported by computer programs describing geometric relationships in a parameterized way, among which visual programming software such as Grasshopper and Dynamo. Oxman continues explaining that the use of such technologies can lead to the development of innovative creative processes involving skills such as computer programming, algorithmic logic development, and scripting.

In order to implement a parametric (algorithmic) approach in architectural education, Romcy (2017), in turn, establishes four steps: 1. The understanding of computational language concepts through the use of practical examples; 2. The understanding of the object x algorithm relationship; 3. The development of the algorithm of an existing object from the deduction of its compositional logic and possible parameters; 4. The development of a design through the algorithmic approach. Among the didactic techniques suggested by the author to implement those steps, stands out the use of a parametric reference model. Besides demonstrating the algorithmic logic and computational language concepts, the model has the potential to display certain content that is intended to be addressed, such as, for example, the compositional design logic and/or a construction process.

Thus, in 2017/2, the parametric design thinking (PDT) strategy focused its efforts especially on some of the student’s difficulties in developing, representing, and detailing complex non-coplanar shapes during the development of the individual hosting unit designs. Taking advantage of the recent introduction to Rhino/Grasshopper algorithmic visual programming lessons in the school’s curriculum, the PDT strategy made use of these teachings, making them available to the PA-II students. These included the development of a parametric model - “the parametric reference unit”, with low geometric complexity following an algorithmic modeling logic within the reasoning of the woodframe system [6]. Divided into four stages (figure 2), the modeling process described two “lofted” profiles forming a volume that was later sectioned according to the construction system module, generating lines to which wood studs were incorporated. Once the proposed parametric description was completed, the integration between the algorithmic modeling and the BIM platform was demonstrated, thereby creating a link between geometric modeling, the attribution of constructive data, and the graphical representation in an A-BIM approach (Feist, 2016) [7]. At the end of the process, students were introduced to some of the potentials of algorithmic logic, such as to obtain formal variations in a given project in a controlled manner without the need to restart the modeling process. Therefore, by means of a “parametric reference unit”, the students were not only presented with the basics of algorithm thinking and the main concepts of computational language but also, for those desiring to develop more
complex geometries, a referential methodology capable of being used in the development of their design studio projects. Nonetheless, the referential model strategy did not enable PAII students to autonomously develop their individual algorithms. This was partly due to an elevated formal complexity presented in the individual designs, extrapolating the simplicity of the reference model. Therefore, extra pedagogical assessments were necessary, such as online video classes and specific tutoring on individual student’s designs.

In the design studio, only four students out of a group of fourteen opted to follow the PDT strategy, especially due to the formal complexity of their parties. For those, the steps of the design process occurred as follows: first, at the “conceptual environmental” stage, the analog design thinking strategy continued being employed in each group in order to develop the hotel’s general concept; at the group “programmatic-formal” stage, the site plan was defined (Autocad/sketchup); and, at the individual “programmatic-formal” stage, an introduction to shape grammar was presented to guide the initial hosting unit’s form explorations, in an attempt to connect with the hotel abstract concepts; here analogic sketches and models were employed and, optionally, it was offered guidance for those interested in exploring parametric tools; at the following “material-constructive” stage, each of the four students, based on the previous formal definitions, transposed the project’s study volume into the Rhinoceros platform as initial lines, proceeding then to the Grasshopper plug-in connection, transforming the lines into surfaces; after that, they started to develop the parametric individual units guided by the “parametric reference unit” methodology, elaborating the projects’ structural guidelines to finally identify the specific construction components through the Grasshopper/ArchiCAD connection (figure 3). Later on, the project documents were elaborated and the two-dimensional details were produced. At the end of the semester, semi-structured interviews were applied to all of the fourteen design studio students who exercised with the “parametric reference unit” (PA-II and/or RG-III). In the replies, the four students that chose to continue with the PDT strategy on the PA-II discipline demonstrated that, despite the difficulties, the experience was considered positive. However, all of the students that worked with the “parametric reference unit” (in RG-III) concluded that the advantages of parametric modeling represented a potential tool in order to expand the design possibilities, such as design variability, automation of repetitive processes, and geometric control of complex shapes. Figure 4 represents the development stages performed by those implementing parametric/BIM tools at the “programmatic-formal” and “material-constructive” stages.
BIM STRATEGY

Assuming that a BIM process involves the constructive technique in the PA II design studio by the means of digital knowledge. In this context, Romcy (2017), Leal (2018), and Medeiros (2015) corroborate with the use of parametric BIM models in order to explain didactic contents. That said, in 2019, the BIM Strategy was developed based on a BIM reference model-the ‘BIM reference unit’ (Figure 5), starting to function as a part of the revised “material-constructive” stage of the PA II discipline design process.

Figure 5
Modeling/construct process of BIM reference unit
Author: Victor M. Schulz (2019)
The design process sequence employed during 2019 followed the originally proposed (Figure 6), where the “conceptual-environmental” stage was responsible for analogical design thinking techniques used in groups to define the general hotel concept and, on the “programmatic-formal” stage, besides the employment of a predefined general hotel site plan (BIM and/or sketchup), individual form generation studies were explored through analogical and digital exercises (CAD - Sketchup) in order to reach the unit’s parti. Afterward, a “technical constructive” stage was created separately from the “material-constructive” one, in order to present an in-class exercise in which the BIM reference unit acted as a pedagogical instrument informing the students of the woodframe system. According to Delattore (2014), the teaching of tools and processes BIM must be implemented gradually, therefore, the BIM reference unit presented low formal complexity, aiming to exemplify regular technical woodframe solutions. The proposed methodology involved the virtual construction step by step of the unit following a logic similar to in loco construction, from the foundations to the roof. The exercise was divided into three stages: structure, wall enclosures, and openings (doors and windows). Between each stage, it was expected that the students could adapt the sequence into the assembly of their individual project in ArchiCAD. This methodology aimed to bring the students closer to the construction site, inducing whatsoever the understanding of the construction of a real woodframe house. Integrating the strategy, a template in ArchiCAD, and a guidance-text was provided. During the transposition of the knowledge apprehended on the BIM reference unit to the individual units, an initial difficulty faced was that the model’s reference grids functioned mainly for the understanding of its internal logic and not that of the individual projects, corroborating, in some cases, towards a literal transposition of some of the technical solutions. These situations, however, were possible to be solved in the individual corrections and on a posterior revision of the reference model for later consultations. After the BIM exercise, the students proceeded with the detailing of the individual units and the production of the construction documents. Important to realize that this strategy was employed on two occasions during 2019, one of which included a bigger sample, on a total of thirty-nine students. At the end of the semesters, semi-structured interviews were applied, asking if the in-class exercise associated with a software/process BIM improved the students’ technical-constructive understanding. The analysis of the answers concluded that the BIM strategy contributed positively to the woodframe system understanding, reaching its main objective. In addition, previous incompatibility problems between three-dimensional models and two-dimensional representations have been solved, since in BIM software these are linked products. The proposed template,
in turn, contributed to the standardization and quality of the graphic aspects of the overall student’s projects. Also of greater concern was that, due to the insertion of the BIM reference unit in-class exercise only after the “programmatic formal” stage, many projects suffered from significant adjustments and redesigns, taking precious time at the end of the process dedicated to construction details.

CONCLUSIONS

In Brazil, as explained earlier, there is still a lack of comprehensive cognitive strategies of architectural design associated with digital knowledge, especially at the undergraduate level. Most experiments take place in short workshops or independent technical and/or instrumental disciplines, focusing only on certain aspects. Therefore, to better understand the potential of design thinking tools - digital and analogic, on all aspects of the design process, this research has been carrying out experiments on a specific theme and program at an intermediate undergraduate design studio over the years. In order to better explore the technologies and techniques employed, although the experiments concentrated on different aspects of the design process, they were conducted cumulatively, adding knowledge progressively. If the Design Thinking strategy has brought to further experiments the use of conceptual analog techniques, the BIM and PDT strategies applied at different moments of the design process, resulted in two reference models that aimed to improve through digital knowledge, the formal and constructive aspects of the design process. However, and in spite of the positive outcomes here demonstrated, there are still improvement aspects to consider.

When comparing a sample of the individual results of the three different strategies (figure 7), it is possible to observe a similarity on the overall formal solutions of the first (DTS) and last models (BIMS); what differs the strategies is an improvement on the construction understanding and accuracy, drawing coordination and visualization on the BIM model. The PDT unit, on the other hand, opens up the possibility of breaking with the formal regularity still within a woodframe system, although requiring more time to solve the details and a better knowledge of the Grasshopper-Archicad connection for this level of study. However, taking into consideration that the project also regards a group development of a Hotel composed of four to five hosting units’ types, it is important to consider the need of creating a certain group identity. Thus, after taking into consideration all the issues raised individually on the Design Thinking, PDT, and BIM strategies, this research is presented with this question: how can a digitally informed design process help create a strategy that attends successfully a group concept within a referential formal identity, material language and constructive constraints?

To better address that question, this research is willing to propose a new strategy within an unified theoretical model to be implemented in 2020 - the Parametric Morphological Matrix Strategy [9] (Figure 8). Structured in four different stages, this strategy foresees addressing the following issues:
In order to characterize the BIM reference unit as essentially informative, therefore increasing the tectonic knowledge into the student’s following formal decisions, it is proposed to advance the the BIM reference model exercise before the “programmatic formal” stage;

In order to help assess the relationship of the concept x form and create a common group language related to the overall hotel concept, at the “programmatic-formal” stage, it will be implemented in groups another analogical design thinking tool - a “morphological matrix” - an analytical-combinatorial technique (Zwicky, 1969). This tool aims to allow a series of combinations of conceptual, geometric and structural principles arranged in a matrix diagram, in which possible associations will inform the next stage of the process (Guilford, 1967);

Finally, the matrix will inform an algorithmic reference model common to each group, defining the possibility of individual parametric variations (parametric units). On the correspondent “material-constructive” stage, the connection Grasshopper/ArchiCAD is envisioned to follow, allowing the students to connect all design aspects to constructive models and documents sharing a limited number of variations.

Therefore, this article was intended to demonstrate former and future design process strategies aiming to create a methodology that, making use of analog and parametric design thinking tools, can contribute to a continuous improvement of the teaching and learning of the architectural design process.

NOTES

[2] In Brazil the woodframe technique, although recent, is gaining force in the AEC industry, having its first woodframe apartment buildings constructed in 2019.

[3] From 2017/1 on, students started to be instrumentalized in BIM/ArchiCAD technology in the discipline of Graphic Representation II (RG-II) in the 3rd semester and, in Rhino/Grasshopper in the discipline of Graphic Representation III (RG-III) in the 4th semester.


[7] To start exploring the integration between the algorithmic platform and the BIM platform, a Grasshopper plugin called “Grasshopper Archicad Live Connection” was used.

[8] This strategy was associated with Victor M. Schulz Master’s Thesis.

[9] This strategy intends to be associated with the developments of Cindy Lasso Estupinan Master’s thesis.

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