IMPLEMENTING DIGITAL PERFORMATIVE DESIGN IN DESIGN STUDIO: A TEACHING EXPERIENCE

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ABSTRACT

This paper presents an experimental design studio of digital performative design conducted in an architecture course, in Brazil. This teaching and learning experience included a period of three week exercise as part of an integrated design class. The overall objective of the experiment was to introduce the concept of performative design through a design exercise based on actual digital practice. The term performative is understood as the synthesis of two main features of the digital design: transformation or generation of geometry and analytical evaluation of performance based on simulations of physical conditions. Performative design is therefore based on methods that integrate, in digital design process, evaluative simulations to techniques of shape definition (geometry and property), in an automated or semi-automated manner. The design exercise was performed on conceptual study level. The given design conditions were the terrain and program requirements as functions, areas and constraints. The chosen performance which should drive the shape was structural efficiency and the computational tool used to support simulation was BESO3D (for Rhinoceros), developed by Innovative Structures Group from RMIT University. Experiment results show that using the BESO Performative method, supported by the use of the BESO 3D tool in design studio classes in architecture was worthwhile. Experiments with the method: allowed to create a considerable number of design solutions within a solution space; easily used digital tools; enabled the realization of a large number of cognitive actions in a short time; valued formal exploration; enhanced structural performance as engine for generating the shape of the building. The experiences of design reported in this study showed that, despite the limitations and restrictions contained in the practices of design studios of architecture course, design processes based on digital performative methods can be applied effectively in this universe. Its use can stimulate shape generation in a creative way and enable experimentation with multiple formal possibilities.

Keywords: Performative Design, Design Studio, BESO, Digital morphogenesis

1. INTRODUCTION

The term performative is understood as the synthesis of two main features of the digital design: transformation or generation of geometry and analytical evaluation of performance based on simulations of physical conditions (Oxman, 2008). Performative design is therefore based on methods that integrate, in digital design process, evaluative simulations to techniques of shape definition (geometry and property), in an automated or semi-automated manner. Within this concept, the performance itself becomes the decisive element in the creation or modification of architectural form.

As morphogenesis, Performative design is based on the ability of form finding instead of form making, aiming to achieve unexpected solutions and even unique design (Oxman, 2008). The way designs can incorporate structural and materials to geometry, even in the early stages of design, is a question that, according to Oxman (2008), attaches itself to the way the Performative design systems are defined.

One of the essential characteristics of Performative design is the development of practice based on multidisciplinary teams, with extreme collaboration between architects and structural engineers (or specific specialist, for example environmental), still in the early stages of the form generation. Together with the architectural and structural knowledge, collaborative teams of the Performative design have the participation of professionals with high capacity in computer programming (Andrade, 2012). Unlike this universe, the conventional designs processes, is characterized by low collaborative practices in which designers talk among themselves only in advanced stages of the design process, when the initial shape has been designed (Eastman, 2009).

In the design studios of the architecture courses in Brazil, design processes are essentially based on conventional practices (Kos et al., 2006). With the exception of some specific experiences of collaborative design, in most cases, the conception of the form is made by the architectural student without prior discussion with professionals from other building performance fields and its consequences in the form generation. Discussions, when they occur, are generally ulterior, routinely evaluative.

In an attempt to modify this approach, this paper presents an experimental design studio of digital performative design conducted in an architecture course, in Brazil. This teaching and learning experience included a period of three week exercise as part of an integrated design class. The overall objective of the experiment was to introduce the concept of performative design through a design exercise based on actual digital practice described in several publications (ANDRADE,2012; .OXMAN, OXMAN, 2010; BOLLINGER, GROHMANN, TESSMANN, 2008; TESSMANN, 2008; ANDRADE, RUSCHEL, 2011).

It is important to consider that within the limitations and constraints of teaching practice in architecture design studio classes, in Brazil, it can be mentioned: no use of a systematic practice of collaborative design between architectural students and other professionals that could give support to the design practice; limited knowledge and background, if any, in scripting and the use of specific computational tools used in performative design practice; design problems are usually abstract and solutions have little relationship with the architectural tectonics; limited student solution repertory; the time used to carry out the design solution is limited to a few weeks (usually part of a semester).

Considering all these limitations and restrictions that make the design processes practices of the Brazilian architecture courses different from the default profile of the design offices that are developing designing methods based on performative design (ANDRADE, 2012), we sought to identify the existence of methods that could simulate some elements of performative design reality, which therefore could be used for a performative design practice in architecture courses. Analyses of methods, techniques and computational tools, used in performative design practices, were carried out in order to identify those that could be operationally feasible in design studios for architecture courses in Brazil. Computational tools were identified that didn’t need to be computationally programmed in order to adapt to the scenario of design studios, which could reproduce the role of other designers, serving as a "virtual partner" during a "pseudo collaborative practice". It was possible to identify a simple and easy computational tool to be used. The computational tool concerned is called BESO 3D (for Rhinoceros) and it is an implementation of the Bi-directional Evolutionary Structural Optimization (BESO) method. Therefore, it was postulated that this tool, for its simplicity of use and no requirement of deep knowledge in software manipulation or in scripting, could be used in a performative design process implemented in design studio of architecture course.

2. DESIGN EXPERIENCE

The design exercise consisted of a design studio held at the Architecture Course of the Faculty of Engineering and Architecture at the State University of Campinas (FEC / UNICAMP). This exercise was part design studio discipline callled Integrated and Collaborative Project (AU 120). The overall objective of the experiment was to introduce the concept of Performative design through an experience that encompassed a practice based on this concept.

To prepare students for the design studio, seminars were held, and lectures were given about digital design and the BESO method. In possession of theoretical knowledge and practical examples of performative design, students developed (during three classes) design studio experience itself.

The design exercise was performed on conceptual study level, to propose a laboratorial complex for Unicamp. The given design conditions were the terrain and program requirements as functions, areas and constraints. The chosen performance which should drive the shape was structural efficiency and the computational tool used to support simulation was BESO3D (for Rhinoceros).

After the theoretical preparation, in the first day of studio, called Studio 1 (Figure 1), students were asked to bring scale terrain model and prototype of buildings; site plan with indication of main determinants of their surroundings and supporting material. With this in hands students were asked initiate first volumetric solution proposition.

Figure 1 Pictures of the Studio 1 held on September 9, 2011.

The second and third day of classes, Studio 2 and 3 (Figure 2), occurred in the computer lab and consisted of formal exploration exercises of volumetric defined in Studio 1. However, now the main criterion of form generation based on the structural performance was introduced. In these two classes the students were introduced, trained and began using the BESO3D (for Rhinoceros) software.

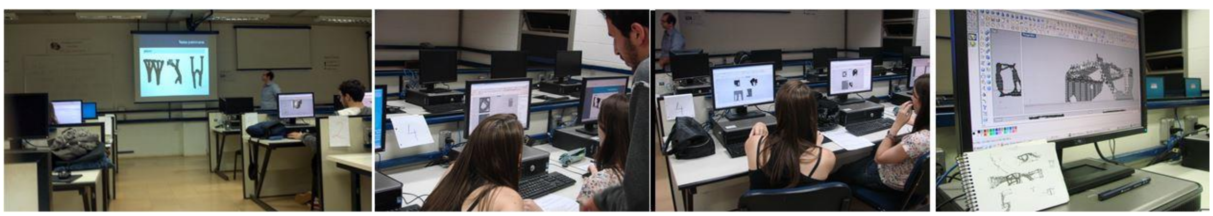

Figure 2 Pictures of the second and third Studio Classes held on September 16 and 23, 2011

2.1 The software

The software BESO3D (for Rhinoceros) was developed by Innovative Structures Group (ISG) of RMIT University, which consists of a group of experts in structural engineering and architecture, which seeks to enhance collaboration and innovation in design experience. This group is an initiative of Professor Mike Xie of RMIT University and the Peter Felicetti from Pty Ltd Consulting Engineers (INNOVATIVE STRUCTURES GROUP, 2009).

The BESO3D (for Rhinoceros) is a software developed for the topology optimization of two and three dimensional structures using the latest algorithms for BESO (HUANG; XIE, 2010). This software is in a package that contains two main parts: a plug-in for Rhinoceros software (BESO.rhp) and a program for the BESO method (BESO.exe). The Rhinoceros plug-in modifies the objects constructed in this program at a recognized model in software BESO.exe and reads the results of optimization, transforming the generated solutions in three-dimensional objects visible in Rhinoceros. The independent motor BESO.exe performs Finite Element Analysis (FEA) and optimization, using for that the BESO method (INNOVATIVE STRUCTURES GROUP, 2009).

2.2 The method

By the limitation of the application of BESO3D software (for Rhinoceros), the method is suitable for use in the generation of three systems: walls, building enclosures, and columns. Theoretical classes on the BESO method, exemplified its application for architectural practice. It was also shown the design process schema of the form generation of an envelope, using the BESO method (Figure 3). It should be noted that the sharp light green represents the cycle stages which are automated decision by the use of BESO3D (for Rhinoceros) tool.

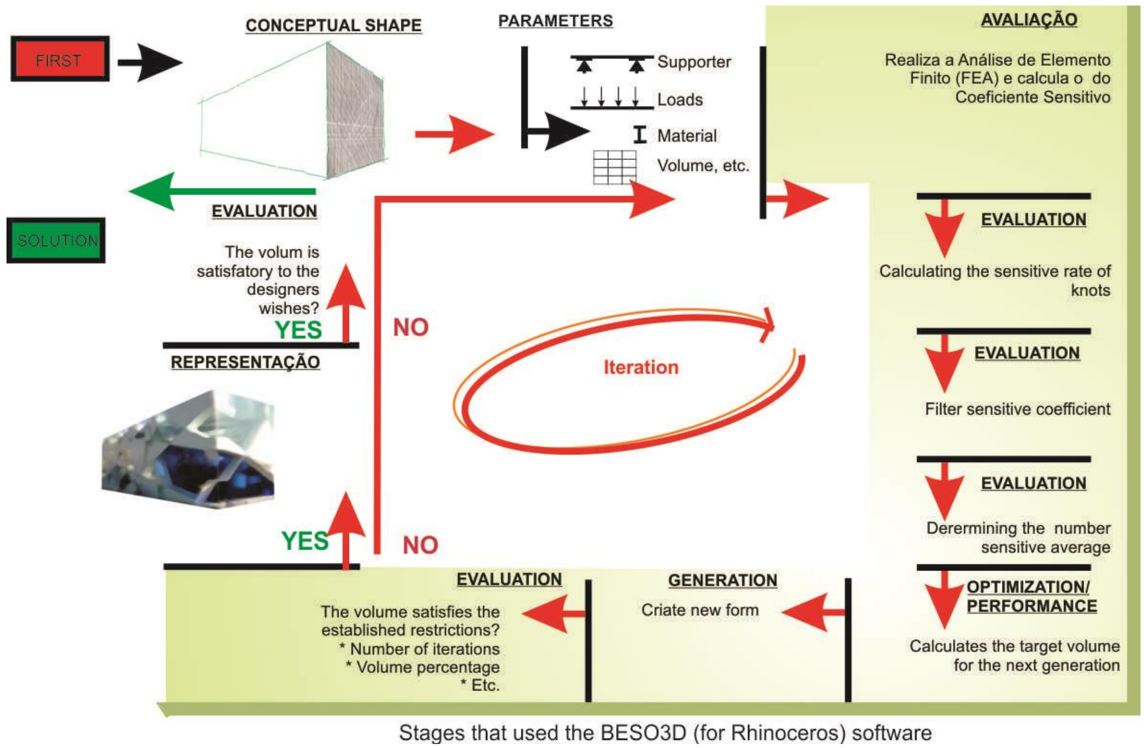

Figure 3 Form Generation Process by using of the BESO method

2.3 Procedures for analysis and interpretation of data

To better understand products, processes and their relationships, the experiment was analyzed using protocol analysis, with emphasis on the use of techniques of content analysis.

To evaluate the actions of designers, we used a technique of protocol analysis based on retrospective record. This technique consists, according to Suwa, Purcell and Gero (1998), to ask the subject to remember and report their thoughts after the completion of their tasks. The downside is that, due to the deterioration of memory, the information retrieved from memory are selective. To reduce this problem, we used the strategy suggested by Suwa and Tversky (1997), which consists in reproducing images and recordings of the activities performed by designers, and, based on them, ask them to report your past thoughts while performing those tasks. The images of the design process were obtained by means of photos, which recorded different times of the project activities in the classroom, and, for classes conducted in the laboratory, print screens of computer screens at scheduled time intervals fixed for all teams (every 15 minutes). These procedures, according to Suwa, Purcell and Gero (1998), allow you to provide visual cues about the sequence of activities that were conducted, doubts, rework, thoughts, types of interaction, etc. These visual information were used to help understand the motivation for their actions.

To analyze the results, the movement of subject during the process of problem solving was mapped (SUWA; PURCELL; GERO, 1998). Therefore, it was necessary to make a segmentation process of visual and some verbal protocols, based on common goals and intentions of the designers, so that the protocols "gross" could be divided into segments. Also, set up categories of cognitive actions. These were used to quantify, and aimed to systematize and analyze the cognitive actions of the subject. In this work, we used the categories of cognitive actions proposed by Suwa, Purcell and Gero (1998), which are: physical, perceptual, functional and conceptual.

The physical category refers to actions that result in physical representation on paper (drawing), on space (physical model) and digital media (digital representation). The perceptual category refers to actions attendance at visual and spatial characteristics of the elements represented in the models and sketches. The functional category refers to the actions of conceiving nonvisual information expressed in visuals. The fourth category, conceptual, refers, according to Suwa, Purcell and Gero (1998), the cognitive actions that are not directly related to physical representations or visual and spatial characteristics of the elements. Each of these categories was divided into subcategories.

The collected data were grouped into two categories: information about the process and the product. The data come from the process were: the filming designs processes, photos registration of design activities, PrintScreen of computer screens (in classes conducted in laboratories), footage of the presentations, with the narration of the students on the design experiences , questionnaire and interview (with footage from the testimony of students). The data relating to products were extracted from: model, memorial justification and graphic material (plans, sections, facades, perspectives, sketches, diagrams, etc.).

The next step was the definition of segments of primitive cognitive actions, indicating the category, content and sequence. The design process of Studios 1 and 3 were then categorized by segmentation. The procedure consisted of segmenting each Studio in four times (segments of time). In each of them, identified the most important categories of projective actions used during the form generation. Through these actions, we identified the main guidelines that should guide decisions projetuais.

With these categories, it was sought to identify in the design key cognitive processes actions employed during the form generation of the buildings, trying to check the flexibility of the method to deal with changes, with the unexpected, the immeasurable, with the possibility of thinking dubious solutions and the quality of reached solutions.

In addition to analyzing the actions, the products presented by the teams were evaluated, comparing the structural and functional performance with aesthetic quality and spatial solutions. Among the requirements for evaluating solutions, we can highlight: the quality of the architectural solution; design adequacy to programmatic constraints; quality of the architectural solution, in terms of visual identity of the proposal, functional quality, dimension spaces quality; contextualization to environmental program; and, compliance with design requirements. For the evaluation of the product, were followed by the following procedure: were asked five designers, professors of design, who judged the students' work based on the evaluation criteria listed above.

3. INTERPRETATIONS, ANALYSES AND FINDINGS

3.1 Comparative analyses of the protocols

When we comparing the protocols for the categories of visual physical actions of the teams (see table 1), it was observed that in Studio 3 there was an increase in the number of design actions and in the number of categories of cognitive actions. This leads us to conjecture that the Studio 3 projetuais actions were more intense for indicating a greater amount of design solutions within the same time interval.

Table 1 Number and categories of physical tasks performed in each segment in Studio 1 and 3.

	Studio 1				Average	Studio 3				Average
Segment	**S1**	**S2**	**S3**	**S4**		**S1**	**S2**	**S3**	**S4**	
Drawing	2	2	3	3	**2,5**	5	5	2	1,5	**3,37**
Moving	1,5	3	1	0	**1,12**	2	1,5	1	1	**1,12**
Building	,5	1	3	1,5	**1,5**	3	3	2	2	**2,5**
Modifying	0	0	1	1	**,5**	0	,5	1	1	**1,75**
Copying	-	-	-	-		1	,5	1	0	**1,75**
Setting	-	-	-	-		2	2	2	2	**2**
Viewing	-	-	-	-		3	3	1,5	2	**2,37**

3.2 Analysis of the results of cognitive actions and segmentations

When comparing the number of tasks performed by segment in Studio 1 with Studio 3, it was observed that in all experiment the amount of tasks of the category of physical action segment was higher in Studio 3 (Table 2). The Studio 1 had an average of 40% of the number of tasks less then Studio 3. This means that in the Studio 3 physical design actions were much more intense than in the Studio 1.

Table 2 Average of the number of tasks performed within each segment (S) of the Studio 1 and 3

	Studio 1				Total	Studio 3				Total
Segment	**S1**	**S2**	**S3**	**S4**		**S1**	**S2**	**S3**	**S4**	
Average	**9**	**15**	**19**	**13**	**56**	**44**	**41**	**25**	**27**	**137**

The nature of the problem was different in the Studio 1 from Studio 3. In the Studio 1, the key concepts that guided the proposal were defined. In this class many discussions took place. Studio 3 consisted of the development and testing of design solution conceptualized in Studio 1. Studio 3, by their nature, was intended for the creation of the basic architectural form solution, led most intense form generation action, with the creation of formal options that until then were not imagined by the students.

Because the forms generated by the students were designed based on structural performance, it was possible to reach efficient forms, from a structural perspective. Programmatic issues were also considered during the digital morphogenesis. The use of the BESO method, while maintaining an intense amount of physical tasks, demonstrated an active process of decision making, allowed to explore efficiently the form, used the performance as a driver of morphogenesis.

3.3 Dominant cognitive actions

Time for Tasks

On first student attempts to use the BESO, the time taken for tasks completion was large, which was justified because the amount of tasks that resulted in the form generation was lower in the beginning of design process. In many cases, tasks were not completed in the first segment, due to errors generated in the computer. To the extent that design teams improved their expertise in using the software BESO, there was a reduction in time for defining parameters and form generating. Thus, it was possible to shorten the time interval and generate several formal options in the Studio 3. The segments of the visual physical categories protocols showed that, over time, the forms are being generated correctly. The number of forms generation was also enlarged.

Domain in the Tools use

Despite the limited knowledge, at least one student from each group had basic skill in the use of Rhinoceros software. During Studio 2, the main commands in BESO 3D (for Rhinoceros) were presented and it was shown how to generate forms using the BESO 3D. Therefore the students had a basic understanding, but adequate to carry out the experiments.

The main problem in using the tooling was related to their limited potential to start the optimization aiming the structural performance of a form generated from a complex geometry. There were little notions of how to consistently assign loads, forces, structural support points, material coefficients related to structural components. Issues related to skill in handling Rhinoceros were also expressed by some teams. In situations where only one student knew how to manipulate the Rhinoceros, the solution used was to build the 3D model in another software and export to the Rhinoceros. Interoperability problems were detected in some situations requiring reconstruction model in Rhinoceros.

Number of Appeared Solutions

Through basic geometry, it was seen that the use of 3D BESO (for Rhinoceros) generated a great variety of solutions in a short period of time, enabling to expand the solutions space. These solutions, in some cases, have been used as conceptual design.

Reaction to Use of the Method

While the generated forms were complex, the initial morphology should be simple, limiting the creative potential. Nevertheless, students ´reactions to the use of the method were quite positive. Regarding the question about the reaction to the use of the method, the responses were as follows: contributed to the creative process, the method changes the design process, valuing formal decisions, despite the need for expertise in Rhinoceros, allowed the exploration of new formal possibilities of the building.

3.4 Products Analysis

What could be observed in all cases is that the grades of the formal requirements were higher than other topics (Figures 4, 5 and 6). Issues related to the design and functionality of the spaces of the building was considered secondary in this phase. That did not mean, however, a mere formalist concerns of solutions generated, but showed that the method by enhancing the material, structure and form, generates solutions that exploit more intensively these design aspects.

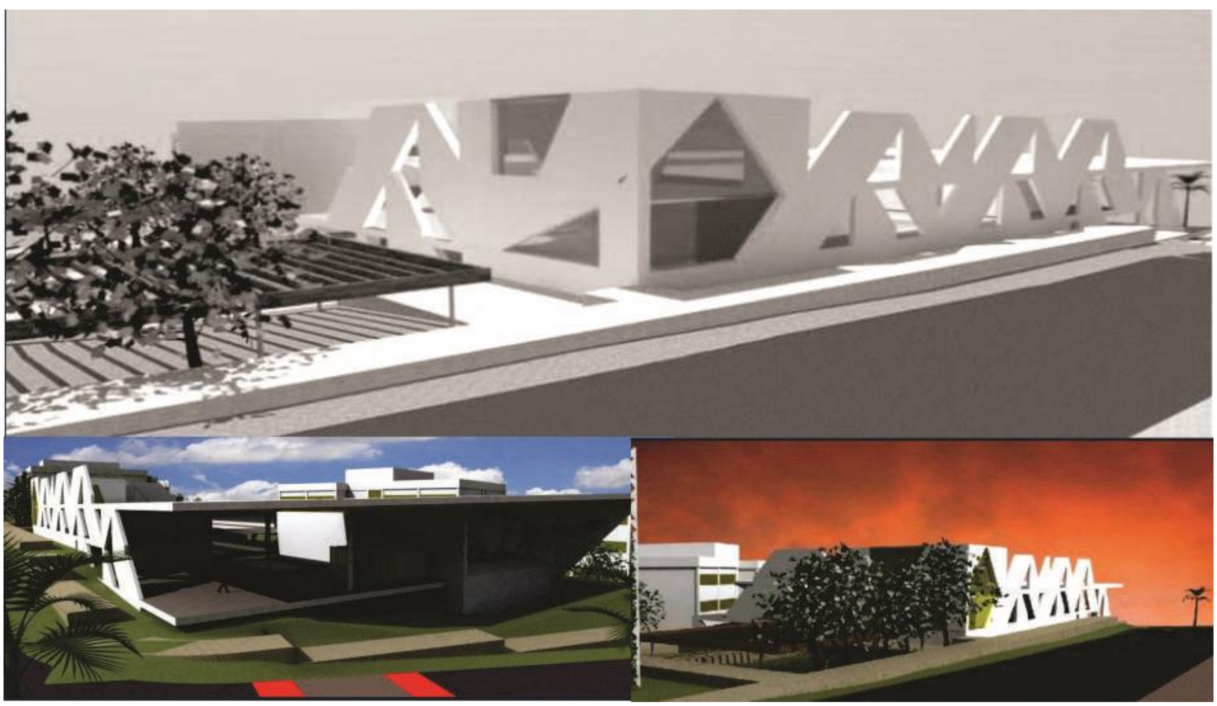

Figure 4 Solution design present for Team 2

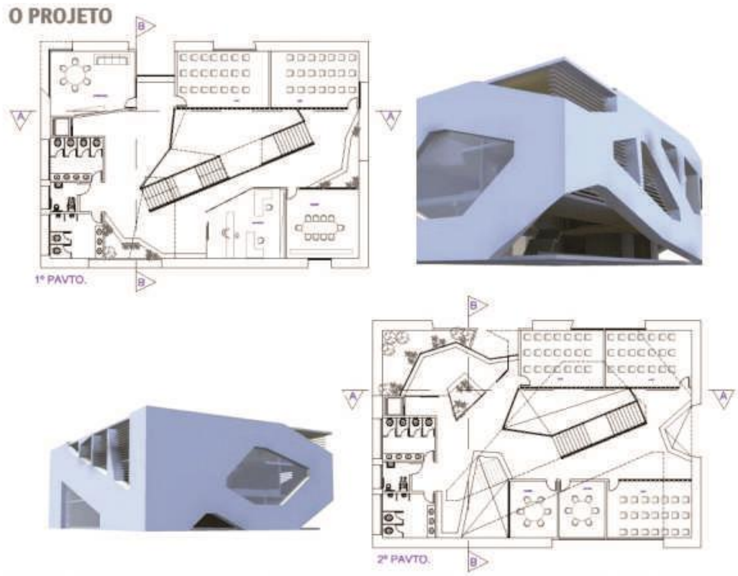

Figure 5 Solution design present for Team 4

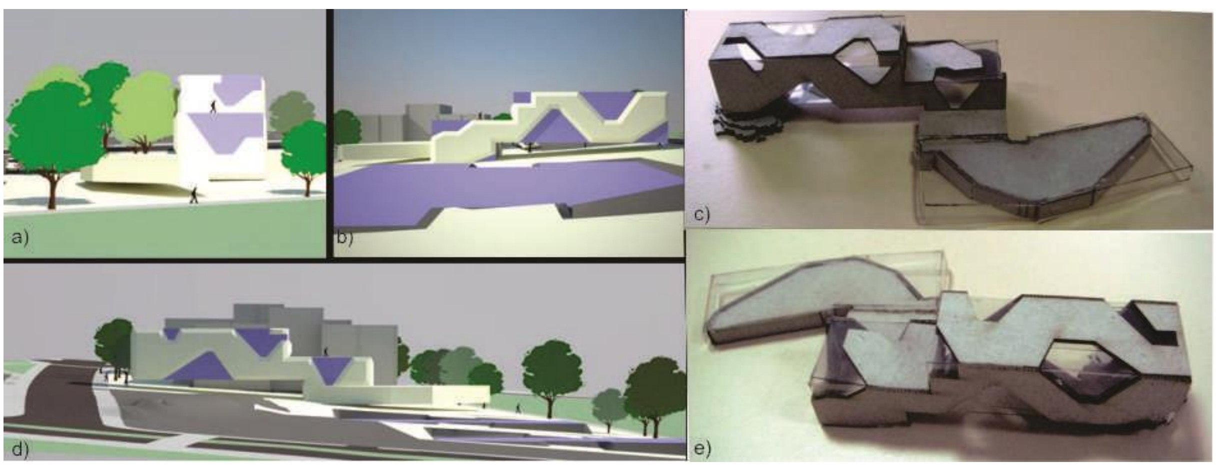

Figure 6 Solution design present for Team 5

During the design development, other performances were considered, transforming some aspects of the architectural solution. These results show that the use of BESO, by emphasizing the structural performance instead of the quality of the hierarchy of space, for example, indicates that has a best result if used in architectural programs without much functional complexity.

Even if we consider the structure as a driver of the form generation, by the positive results of the formal evaluation, it could be conjectured that the use of BESO stimulated the form generation, in a creative way. This statement can be proven with the response from the students about the interest in using the BESO for other design experiences.

Another interesting aspect observed in the design processes is that each of the teams used different procedures for form generation, whether through abstract formal exercises to define the geometry of a part of the building (in these solutions the shape resulting of the BESO experiences influenced the another part of the building); is through the transformation of a pure volumes, the BESO, to define the distribution of the program of the new building; or used in a manner that reflects the program distribution of the space, to reach the desired architectural solution.

4. RESULTS

Experiment results show that using the BESO Performative method, supported by the use of the BESO 3D tool in design studio classes in architecture was worthwhile, enabling test different design formal solutions. The experiments were able to result in varied and rich, designs solutions from the volume and the space point of view. Moreover, they were efficient as structural perspective.

The design process began with the definition of global spatial relationships (Figure 7), which resulted in the choice of basic geometry (basic form). The next stage consisted of use the BESO3D tool generate the architectural form based on structural performance. The third stage consisted of reviewing the structural solution, which was resolved in an efficient manner, considering the restrictions of the program expressed in zoning. After this stage, in which the designer has interacted with operative parts of a mechanism that generates the digital form, occurred the development of the design process. At this point, the designer acted directly in the form that was generated; dialoguing with it. The architectural solution, then, was matured and led to the stage of design development or the process was returned to the redefinition of global spatial relationships, and the process was restarted (see Figure 3). It is also interesting to note that during the design process was an increase in the number of restrictions.

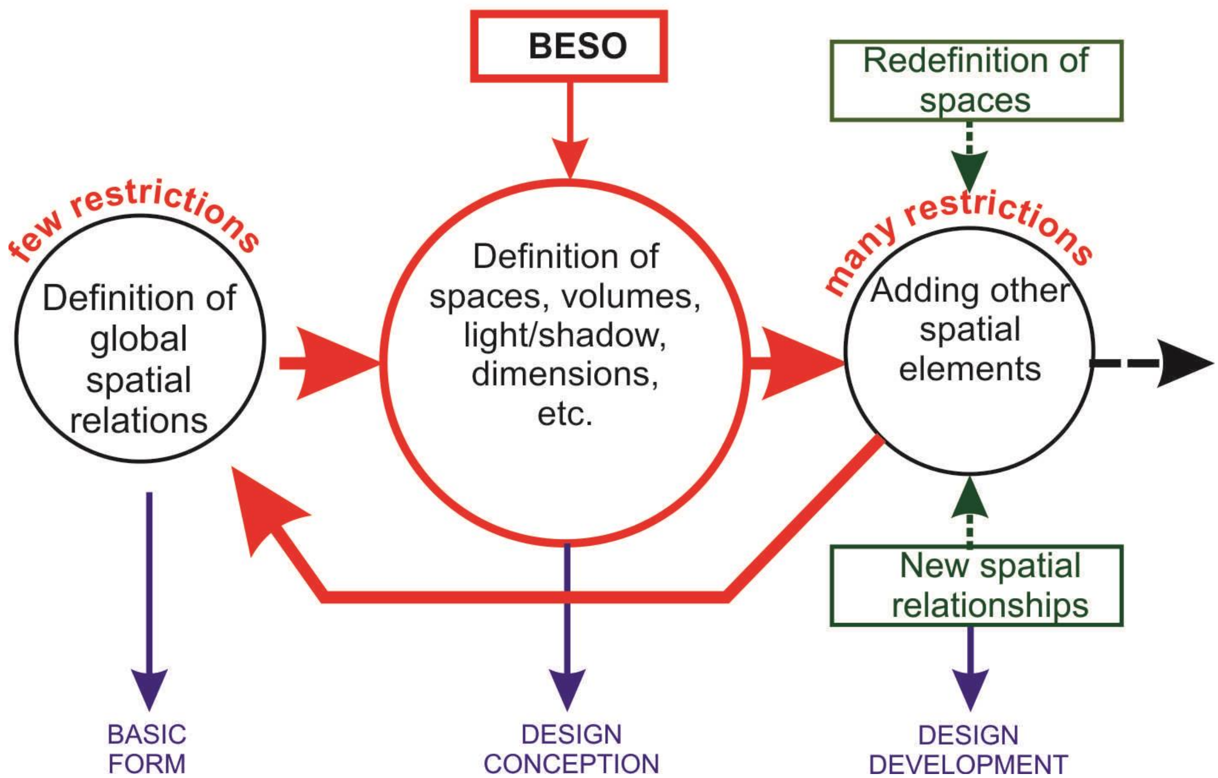

Figure 7 Form generation process based on BESO method.

Experiments with the method: allowed to create a considerable number of design solutions within a solution space; easily used digital tools; enabled the realization of a large number of cognitive actions in a short time; valued formal exploration; enhanced structural performance as engine for generating the shape of the building.

The experiences of design reported in this study showed that, despite the limitations and restrictions contained in the practices of design studios of architecture course, design processes based on digital performative methods can be applied effectively in this universe. Its use can stimulate shape generation in a creative way and enable experimentation with multiple formal possibilities.

What is noted is that this experiment was characterized by a digital design process defined by the use of fully automated decision sequences stages interspersed by manuals decision sequences stages. In this method, the implementations in BESO constitute the completely automated stages. Sketches, freehand sketches and drawings on the computer represented the manual sequences (no automated) stages. Moreover, the method implemented was topological and evolutionary, which are features of the performative design (Andrade, 2012).

Collaborative practices and interoperability also occurred, but at an abstract level. The absence of the explicit use of collaborative practices, which is one of the assumptions of the Performative design, was only possible because of the method is associated with the use of a computational tool (BESO3D for Rhinoceros), which, by virtue of its internal mechanisms, enabled perform sophisticated structural analysis from a few input data.

“Replaces up”, therefore, the structural engineer in dialogue with the architect by computational mechanisms present in BESO. These computational mechanisms, internal to BESO, allowed dialogue with a graphical interface and transform geometry in information, which, in turn, flowed between the mechanisms who carried out the analysis, optimization, generation and representation of the proposed solution. All this occurred automatically inside the digital tool (Figure 8). Thus, interoperability issues were internal to the system, and the role of the engineer in a collaborative process was replaced by the graphical interface presented in BESO tool, serving as a channel of communication with the architect (student).

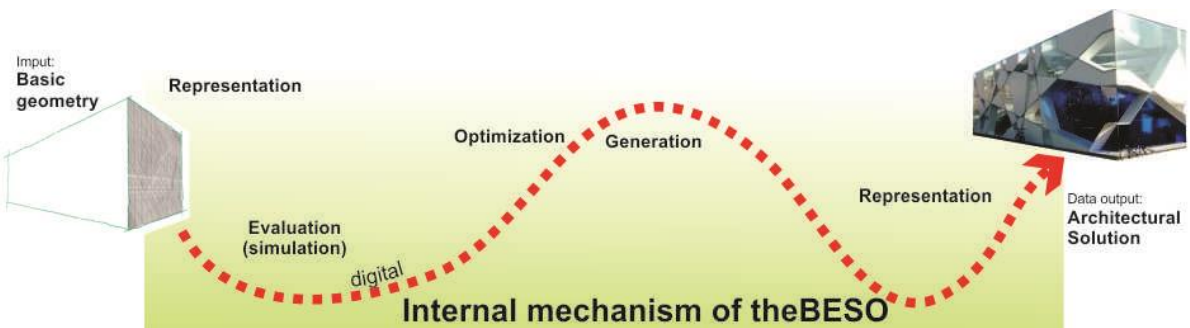

Figure 8 Design process using BESO3D (for Rhinoceros) software.

Note: In green is shown the internal mechanism of the BESO contemplating the stages of decision (evaluation, optimization, generation, representation) in an automatic manner.

To summarize what is observed is that the method implemented in the learning experience is: "collaborative"; includes the simultaneous use of analog and digital design techniques, which results in the co-existence of automated decision stages interspersed with manuals decision stages; is based on a topological design, replacing a tradition typological design process; takes as its premise interoperability, which is internal to the system. Therefore, the method is capable of reproducing a structure that resembles the Conceptual Framework of Performative Design (Andrade, 2012). Therefore, it can be considered as based on Performative design method.

5. CONCLUSION AND LIMITATIONS OF THE METHOD

The experiences of design reported in this study showed that, despite the limitations and restrictions contained in the practices of design studios of architecture course, design processes based on digital performative methods can be applied effectively in this universe. Its use can stimulate shape generation in a creative way and enable experimentation with multiple formal possibilities.

The main aspect which also limits the BESO method was that is restricted to a unique performance solution space that is of the structural nature. Therefore, emphasizes the structural point of view of solutions generated and reduces the possibilities of exploiting the architectural problem. Thus, although efficient, which was proven in teaching experience to be it is limited, for it is restricted to only certain type of solution. For other design performance emphasis solutions, other performative design methods are needed.

Among the limitations of the experiment presented in this paper are: the quality of the sample, which was not significant (there were only 5 teams) and would need to be expanded to make the results more reliable, the lack of confirmation that the resulting structures are the most efficient those forms, in other words, is necessary verify the validity of the BESO Method.

Some recent experiments that compare BESO with other topology optimization method show that the BESO results in a high quality topological resolution, with excellent computational efficiency, and use an algorithm easier to understand and simpler to implement (Sasaki, 2005; Huang; Xie, 2010). Moreover, the testing efficiency can confirm the structural quality of the method for the generation of complex shapes.

Although authors such as Lawson (2005) show that the architectural design process presents common features, the method of investigation may indicate variations in how a problem is solved. The use of different methods should not always be considered the best way to compare the results in an experience of architectural design. The use of a method for an inexperienced designer can be very effective for solving a given problem, however, can be unsatisfactory for an experienced designer. On the other hand, systematic testing in a population can serve as an efficient validation of the method.

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