Enhancing Students' Creativity Using Biomimetic Parametric Design Approach

Anis Semlali[1] Eka Sediadi[1,*] Tawfiq Fariz Abuhantash[1]

[1] *Department of Architecture, American University of Ras al Khaimah (AURAK), Ras al Khaimah, UAE*
[*]*Corresponding author. Email: Eka.sediadi@aurak.ac.ae*

ABSTRACT
This article presents a pedagogical experience about the integration and use of parametric environment and tools in the context of the architectural design studio in the American University of Ras al Khaymah. Our goal was to highlight the opportunities offered by this approach in the renewal of the design possibilities and representational approaches among architecture students. The biomimetic approach was selected as a diverse sustainable methodology in architectural design that could inform and structure students' parametric digital approaches using Dynamo Revit to design a high-rise building in Ras al Khaimah.

Keywords: *Parametric design, Biomimetic architecture, Architectural design studio.*

1. INTRODUCTION

Nowadays, digital technologies and their applications have gained an important place in our professional, teaching, and research field [1]. The conventional tools such as pencil, paper, and traditional drawing tables are being progressively replaced by digital tools [2] opening the door for new possibilities for the ideation and the communication of design projects in our academic and/or professional activities. These tools have become the primary working instruments in practicing and teaching design and architecture because of their massive development in both hardware and software capabilities and their growing affordability allowing wider access to these tools and their use on a larger scale. Their high degree of reliability and precision combined with the ergonomic and well-studied interfaces that they offer has pushed designers to progressively combine traditional work tools with "digital" approaches in the different phases of the architectural project.

Most CAD (Computer Aided Design) software offers a set of functionalities allowing the two and three-dimensional representation of a model or a part of it. They are used to represent conceptual intentions to evaluate them visually, i.e. in an intuitive way, based on implicit expertise. These intentions result from the use of functionalities and geometrical primitives made available through the interfaces of standard modeling software. Once the geometric shape is built, various rendering methods are used to give it a more realistic appearance by adding colors, textures, light, and landscape. Priority is often given to realism, image quality, and processing efficiency.

Digital technology is defined as a culture of the moment [3] that has changed lifestyles around the world. The question then is no longer whether this digital culture is good or bad, but what direction architecture as a discipline and as an educational field would take under its influence.

2. CONVENTIONAL VS PARAMETRIC APPROACHES IN ARCHITECTURAL DESIGN STUDIOS

The fact that the computer tool is conferred today mainly to the tasks of representing objects in their final appearance has historical reasons. The works of Tidafi and De Paoli and others demonstrate that the practices of representation in architecture introduced in the Renaissance have operated a semantic reduction of the represented object. Thus, the discovery of perspective and the mastery of orthogonal projections have led, over the last 400 years, to the development of increasingly sophisticated techniques for representing architectural objects. We consider that these developments, which at the level of computer tools are now materialized by techniques of drawing and production of computer-generated images, are at the same time the source of the current difficulty to support the process of designing using computer tools. Researchers have tried to integrate both geometric systems and knowledge-based resolution systems within a unified model of the object to be designed.

Modeling is about establishing models that differ according to the level of abstraction necessary for their design: visually reproducing geometric shapes, cross-referencing knowledge, explaining constitutive processes, theorizing systems of understanding. The tools used are also not the same: while to visualize a shape, students will have recourse to digital imaging techniques; to explain this shape, they will have, in part, to analyze, apprehend, manipulate and simulate using various programs.

If modeling corresponds to the establishment of models, in the respect of the differentiation which has just been operated, it is possible to apprehend it in various ways: the modeling of objects, the modeling of knowledge, and the modeling of the process: the modeling of the architectural project passes by a 3D representation; the modeling of knowledge is based on the development of tools to manage available information; the modeling of process is based on the modeling of the actions attached to the design of an object to simulate it. Thus, the understanding of complex phenomena requires the use of models that can take various forms, depending on the degree of abstraction undertaken:

- A model can correspond to a replica of an object.
- A model can be conceived as an explanation which is ideally the consequence of a connection between available data and hypothetical interpretations of the mechanisms at play.
- A model can be conceptual if it is equivalent to possible strategies by which it is planned to solve a problem, such as the understanding of the different actions that define the process of conditioning a material phenomenon.

In other words, the contribution of the computer tools in architecture projects could be organized into three main areas: a drafting approach, an organizational approach, and a reflexive approach (REF). These approaches clearly demonstrate a transition towards a new modeling paradigm: the representation of the object becomes secondary compared to its semantic approach. Thus, the keyword "drawing", so long and often associated with architectural representation and communication, is slowly being replaced by a new term, "modeling". While drawing promoted a culture of representation, in the sense that it allows the description of the design development and its results, the computer possibilities also support a culture of the architect's "know-how" at the origin of the production of an object or a building. The computer tool, therefore, goes beyond the stage of being a simple representational tool and takes on a full-fledged role in the design process. This allows it not only to represent know-how, which can help to better understand the conceptual genesis of an object or a building but above all to allow the designer to operate from the first phases of the design process. This new definition contributes to a paradigm shift, towards a new vision of architectural representation.

From a pedagogical point of view, this substitution of terms seems to us to be far from being insignificant and can hide a revision of the concepts and approaches at the level of the methods and the finalities being pursued. This new vision brings students in architectural programs towards systems that manipulate knowledge, geometric and semantic properties within the framework of research on the design process itself. These new systems will be based on high-level languages characterized by deductive reasoning and on the use of a model-based approach rather than numerical calculation. Following this approach, the model is not the result of a solution, nor a list of functions, but the result of a dialectical activity, where the students will become the creator and the "verifiers" of their architectural and conceptual models and ideas [4].

In this article, we will present a pedagogical experience in which the students in Architectural Design Studio 4 were instructed to use and experiment parametric tools (Dynamo Revit in this case). The main goal was to demonstrate the innovative opportunities offered by this approach to enhance students' creativity.

3. PARAMETRIC MODELS IN ARCHITECTURAL STUDIOS

Etymologically, parametric design is a paradoxical term. The adjective "parametric" refers to the parameter, which comes from the Greek "para", meaning a subsidiary or assistant, and the word "metron", meaning "measurement". This in turn opens two windows on its meaning - one which is particularly mathematical, reflecting a measurable factor that defines a system or sets the conditions for its operation, and the other which is more general, describing the boundary and scope of a specific process or activity.

On the other hand, the meaning of the word "design" is diametrically opposed to this concept of precision. While its origin comes from the Latin word "designare", meaning "to design", it often implies an unpredictable activity dealing with "undefined" problems. The nature of design emphasizes the impossibility of definitive formulations. Therefore, some researchers like Peter Rowe argue that designers should be observed at work where they must "move back and forth between the problem as it was given and the tentative proposals they have in mind. Nigel Cross uses the term "designerly way of thinking" or the designer's own way of knowing to emphasize this unique characteristic of the design. In addition, the nature of design often forces designers to think more about how to find and pose the problem rather than focusing on how to solve it.

So, on the one hand, the nature of design is arbitrary, and on the other, there is a precision called "parametric." Therefore, parametric design describes a design process with design variations interactive and replacing singularities with diversity in the design process. Fifty years since Sketchpad, Robert Aish and Robert Woodbury [5] say that parametric modeling will reduce the time and effort required for change and reuse.

4. CLASS METHODOLOGY

Within the framework of the architectural design studio 4 at the American University of Ras al Khaimah, students were given the opportunity to experiment a different approach. The design brief engages them within an in-depth investigation into form/function, form/structure, and form/space expressive architectural language and its connections to meaning, expression, geometry, context, and materiality. This project aims to initiate a design process focused on a biomimetic approach. This approach is a sustainable way of architectural design that can inform and structure parametric digital methods and tools. Biomimetics is applying the biological principles underlying the morphology, structure, and functionality of physical entities to artificial designs. It is “an engineering discipline that imitates natural designs and processes to create a healthier and more sustainable planet” [6]. By analyzing and viewing the living world, students will become aware of Forms, behaviors, and systems that can imitate to create and maintain a resilient and adaptable built environment and increase their capacity to regenerate ecosystem health. Finding solutions to design problems by taking inspiration from nature is one of the innovative approaches that this architectural studio wants to introduce.

The studio was organized through 3 main phases:

- Understand
- Implement
- Simulate

4.1. Phase 1: Understand

Along with this “Understanding phase”, students researched Biomimicry, as an approach in the design process. They were introduced to biomimicry and its applications in design et how this approach could be adopted to define a human need or a design problem [7]. Each student started by choosing a biomimitecial organism or ecosystem and understanding its particularity and characteristics from a formal, behavioral, and/or functional point of view.

Through manual sketching and using the understanding gained from the briefing, the formal analysis, and the in-class discussions, students started developing their biomimicry design attributes and parameters to be considered in the next phase. This phase was quite challenging for the students considering the high level of geometric analysis and understanding needed to prepare for the next phase (See Fig. 1).

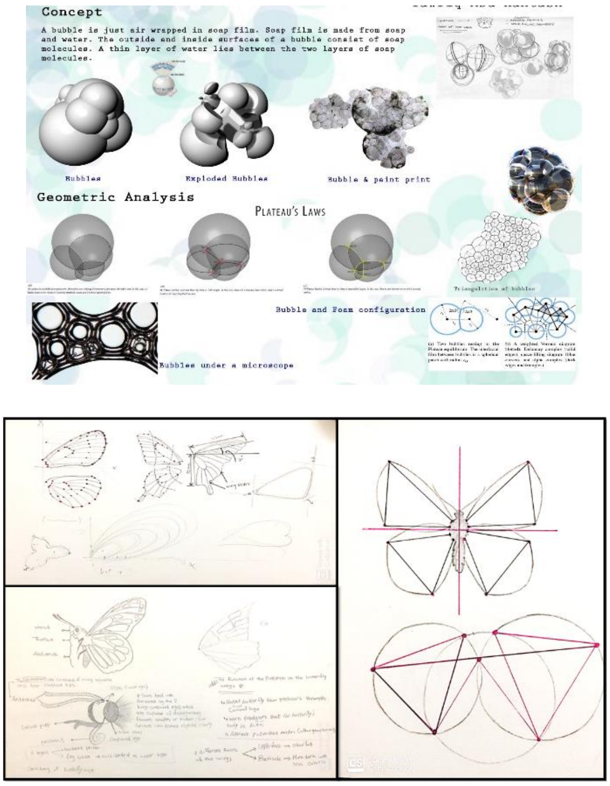

Figure 1 Examples of students’ analysis (Bubble by ©Jovika Vijayakumaran and butterfly by ©Donia Mandour).

4.2. Phase 2: Implement

In this second phase, students used parameters to define their biomimetic object. The developed parametric model was a computer representation of their biomimetic analysis developed in phase 1 made with geometric entities that have attributes (properties). Some of these attributes were fixed and others can vary. These variables are called parameters and the fixed attributes are called constraints.

During this phase, students had to carefully think about how they had to build a sophisticated geometric structure embedded in a complex model that could be flexible enough to accept design variations. Therefore, students had also to anticipate what types of variations he or she wanted to explore to determine what types of transformations the parametric model should allow. This was a very challenging task due to the unpredictable nature of the design process (See Fig. 2).

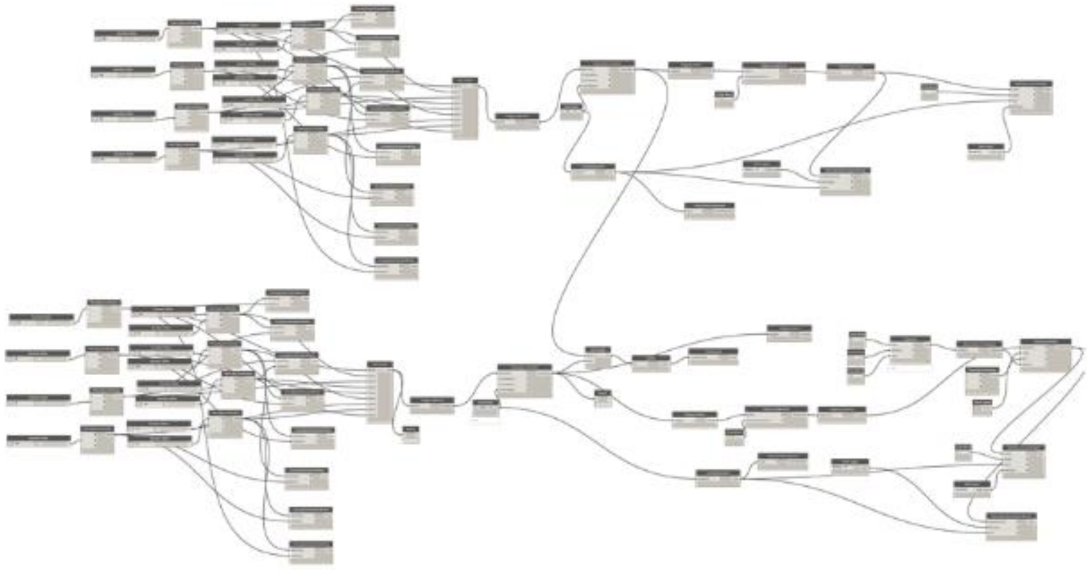

Figure 2 Example of students' visual code on Autodesk ® Revit Dynamo (©Abdullah Bdaiwi).

4.3. Phase 3: Simulate

In the literature, the concept of simulation is often used indistinctly with that of modeling, but it can be nuanced and used in a more restrictive way. Simulation corresponds here to the process by which a constitutive or cognitive process is reproduced to study its possible results or to anticipate its possible consequences. Simulation is equivalent to modeling when it aims at reproducing a process or action through another process, through a computer program. This is equivalent to experimenting in a virtual way. The computer tool thus participates actively in the construction of the model and most of the time, students during this phase intervene only before and after the simulation in order torment with defining the data, to state the parameters, factors, and constraints to be taken into account in the calculation, to transcribe these procedures in a programming language intelligible by the computer, to evaluate, to compare the results obtained between them and by confrontation with the starting data.

In this third phase, students started to simulate their project according to the brief requirements. By changing the parameters of their parametric model, students were able to search for different alternative solutions to their design problem. Using this approach, students were able to build their parametric model enabling multiple design responses by adapting and/or reconfiguring new parameter values without erasing or redrawing their model (See Fig. 3).

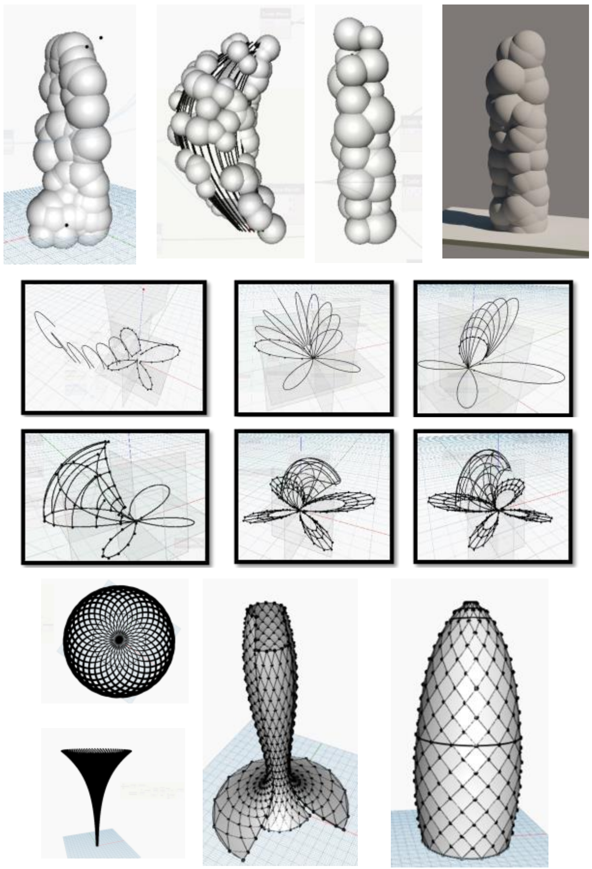

Figure 3 Examples of students' parametric simulation (**Bubble** by ©Jovika Vijayakumaran and **butterfly** by ©Donia Mandour and **Peacock** ©Siham Alsaeed).

5. DISCUSSION

By designing using parametric software, students had to deal with an interactive and three-dimensional interface through which they were able to accommodate real-time variations and have more control and immediate feedback when they changed or modified a parameter. All these features gave them the possibility to modify parameters and relationships that trigger the transformation of interdependent parts of their parametric biomimetic model.

Students can include structures that demonstrate the conceptual evolution of the model through the application of parametric models in architectural design, and the students to return to the earlier stages of the design process and implement changes. The way to make this change is through the dependency chain of the changed parameter. This method allows students to return at any time, change parameter values, and generate several hypothetical design models.

Regardless of the implementation and the complexity of the different projects developed and presented by the students, all their parametric models could be classified into two well-known parametric models types [8]: those that perform variations and those that generate new designs by combining parametric geometric entities.

The Model for parametric variation or variable geometry is the declarative property of the parameters underlying the type of parametric pattern to constrain the shape. The designer creates a free geometric model based on the desired behavior as attribute parameterization. After that, the designer creates a parametric modeling scheme that shows the parameterization characteristics of the geometric model type and how the designer can change the values of those parameters.

The idea behind the parametric variation model is to control geometric elements by changing parameter values or constraints without changing the topology (number of components and their relationships). The parametric modeling scheme is the starting point for parametric variations of the design, and each time the designer changes the parameters, it creates a design instance. A collection of design examples creates a design family because it makes changes made in the parametric model. An essential quality of parametric variation is that the model allows geometry transformations without overhauling it.

The parametric combination model consists of an arrangement of geometric shapes according to the rules that create a more complex structure and is an associative geometric model or a relational model. These models offer another level of complexity beyond the parameterization of geometric components by constructing combinations according to specific rules. In the parametric combination model, the relations and spatial combination rules between the primitive parts are a critical aspect that determines the different compositions. By combining elements in different ways, you can achieve various design solutions (See Fig. 4).

Figure 4 Examples of students' final highrise parametric models.

6. CONCLUSION

This pedagogical experience allowed the students to realize by doing the limits of traditional computer-aided design software and the possibilities offered by the parametric design approach in the first phase of the design process. Beyond the tools manipulating objects and geometric constraints, this new method of supporting the design process allowed the students to focus on the actions and cognitive aspects encountered during the studio. Using parametric approach, students were able to trace design changes and to understand how individual changes impact an overall design It is a new perspective on an alternative way of designing in architecture by conferring to the digital tools an active role and by taking into account the cognitive and interpretative activity of the designers all through the design process.

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