Well Beyond the Box: Digital Fabrication and Mass Customization at very early Architectural Education

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Introduction

This paper describes the ongoing experience of integrating 3D computer modeling, digital fabrication and mass customization into the first-year design studio at the Faculty of Architecture and Urban Design, University of Brasilia. This teaching project takes place in the second term of our first-year undergraduate architectural program.

This experience has now been carried out for five consecutive semesters and it has involved around 140 students so far. The use of form•Z, with its easy-to-learn interface and powerful modeling tools, suitable for free form explorations and digital fabrication, has been paramount in this teaching project. Significant obstacles had to be overcome in order to implement and develop this teaching approach. However, we found out that most of these were not related to technological limitations, but rather to philosophical misconceptions and fallacies.

The very early introduction of computing in an architectural curriculum is often met with resistance by many faculty members. The most common argument against this approach is that students must learn how to draw by hand before being introduced to computers (Lyn and Dulaney, 2009, p.24). It is believed that students' skills will be hampered if computer techniques are taught before learning hand drawing. Another common argument is that such early teaching of computing necessarily leads to less creative designers. This argument is usually connected to the first one, in which the ability to draw by hand is confused with the very ability to design (Lyn and Dulaney, 2009, p.24). In other words, if you do not draw by hand you are not designing properly. This seems to us a reductionism. Firstly, drawing is not the only way to design and it has never been. The architect's predecessor, the master builder who existed until the end of the Middle Age, used many design tools. The historical evidence up to this period of time does not support the claim that drawing was always the prevailing way of designing and building (Robbins, 1997, p. 11).

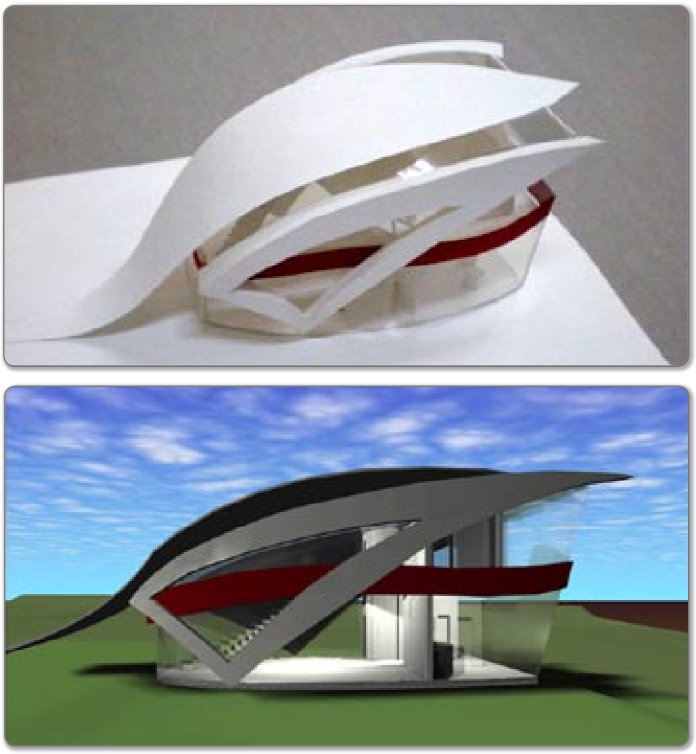

Figure 1: Exhibition Pavilion by Laura Camargo.

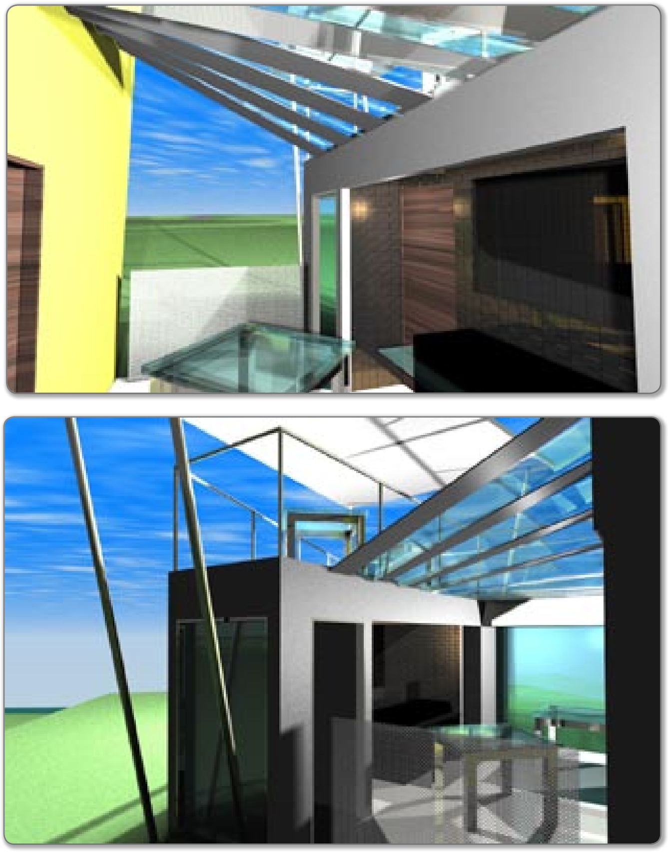

Figure 2: Cafeteria by Marcia Birck.

Secondly, there is no evidence that early teaching of computing necessarily leads to less creative designers, on the contrary; the student work displayed in Figures 1 to 6 show that their creativity actually increased as they became more proficient with 3D interactive computer modeling along the course. The more they mastered computing, the more venturesome they became.

The argument that computers can hamper the learning of hand drawing is also an anthropomorphic statement. It seems to view the computer as a designer rather than as a tool. We believe that the computer is a design tool, a machine to execute sequences of instructions, not a designer. The best way to illustrate this is the fact that the computer will take no designing action before told to do so by the user. Sit in front of it and cross your arms and nothing will happen until you tell it to do something. If properly mastered, every shape or form a computer models is the product of the user's sequence of inputs, choices and decisions. The human designer remains the creator.

Surely, the advent of computers did cause the demise of the technical drawing pen and tracing paper in architecture and in engineering. However, it must be stressed that this decline can only be attributed to computers if constrained to the manual production of 2D orthographic design documentation (Stacey et al, 2004, p. 6).

Another assumption is that computers only automate activities and procedures that would otherwise be carried out by hand; as if they just add in speed and precision, but do not allow the user to do different things in relation to those which were done by hand. Well this might have been true regarding 2D computer-aided design tools, but it is a different matter when we refer to interactive 3D computer modeling. We can only compare similar things. Hand drawing has many things in common with 2D computer graphics, but has substantial dissimilarities with interactive 3D computer modeling. Although they are both intended to represent design, the way they do it makes them two very different things; they do not perform the same roles. They are two different representational systems that allow for different perceptions and analysis of the proposed building.

When a student is introduced to interactive 3D modeling in a computer, he or she is learning to do different things from those that could be achieved by hand drawing. A virtual three-dimensional model is not just an equivalent to a hand drawn representation or even to a scaled model as it has been believed by some in the past (Lawson, 1994, p. 143). Besides representing the "four dimensions of architecture", width, height, depth and time (as described by Zevi, 1957, p. 26), it allows for experimentation and analysis that cannot be provided by a hand drawing, a scaled model or any other traditional medium. A virtual 3D model offers many exclusive resources such as interactive walk-through, real scale and immersive perception of the proposed space, design of complex non-Euclidian geometries (Kolarevic, 2003, p. 13-28), solar animation, global illumination calculation, object animation, digital fabrication and mass customization (Kolarevic, 2003, p. 31-53), just to mention a few. Therefore, it cannot be understood as just another way to do the same old things.

A very early introduction to digital design and construction in architectural education

At our School of Architecture we have decided to challenge those misconceptions. We have decided to introduce very early into the design studio not only in-

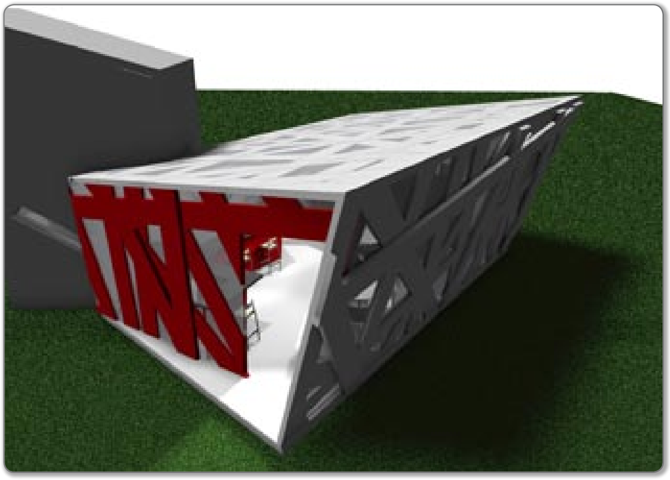

Figure 3: Cafeteria by Talita Cordova.

teractive 3D computer modeling, but also the concepts of digital fabrication and mass customization. Our decision was driven not only by the conviction that those assumptions were fallacious, but also by our previous experience in teaching interactive 3D computer modeling to third-year students in our school for more than nine consecutive years. During all this time the only type of computing that was taught mandatorily in our school was a 2D drafting system. 3D modeling tools could only be taught in an elective course in the third year of our undergraduate program. Students taking this course have consistently shown great resistance to designing in a three-dimensional environment because the habit of representing in 2D orthographic projections had already become too ingrained into their minds. This led us to the conclusion that the earlier the better for introducing interactive 3D computer modeling.

We decided to do so by adopting a problem-based learning (PBL) approach (Maitland, 1997). The chosen point in the curriculum was the second term of the first year of our undergraduate program. Adopting a PBL approach meant that different courses had to be integrated around the design studio of that semester. Therefore, we started to implement a project integrating the teaching of interactive 3D computer modeling within the second term design studio.

A very important issue we wanted to bring to the knowledge and consideration of the first-year design studio students was that of digital fabrication (Iwamoto, 2009; Kolarevic, 2003, p. 31-51) and of its practical implications for architectural design and construction. The most important of these implications was the paradigm shift from mass standardization to mass customization in contemporary architecture (Schodek et al, 2005, p. 339-344; Kolarevic, 2003, p. 52-53).

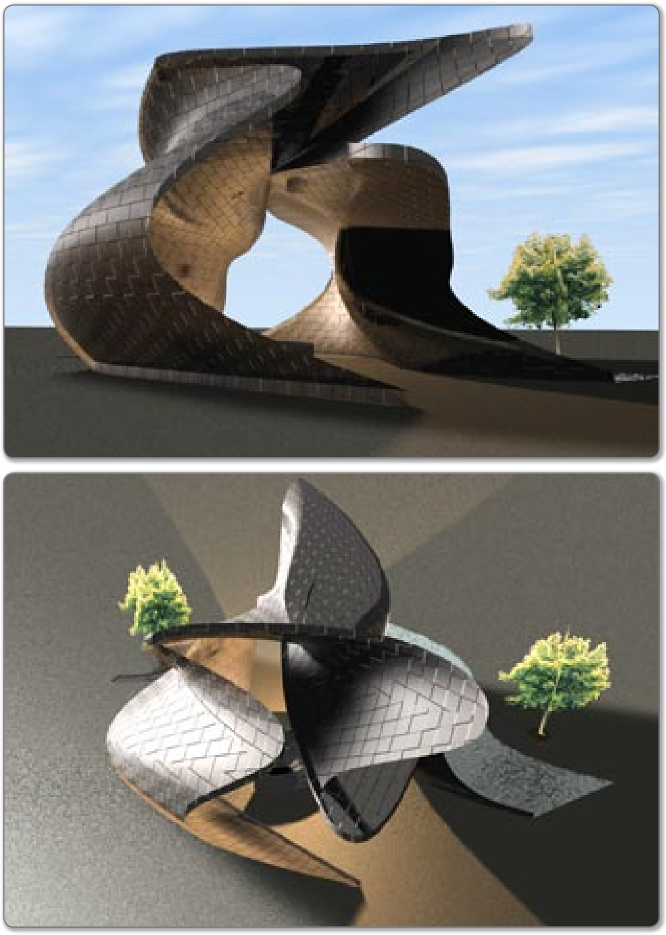

Figure 4: Exhibition pavilion by Caroline Barreto.

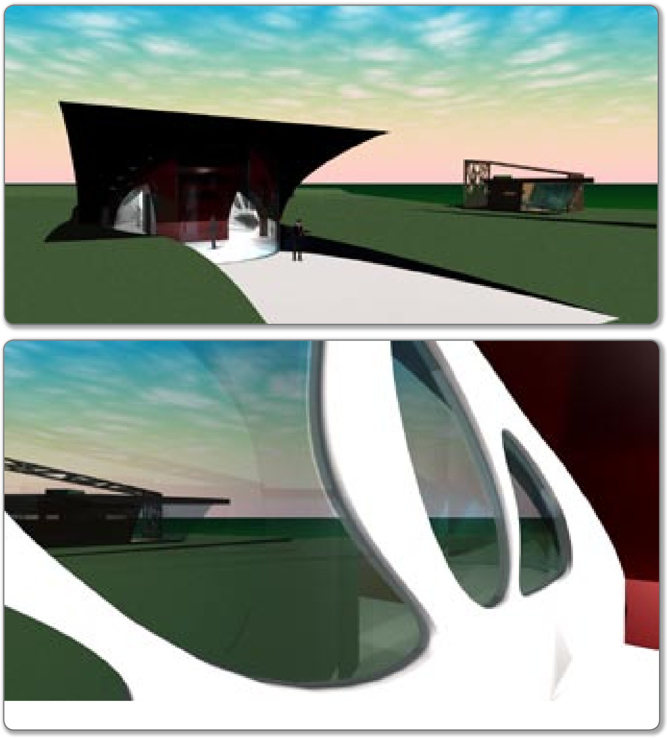

Figure 5: Exhibition pavilion by Viviane Moreira.

The students of the first-year second-term studio have been required to develop three projects for a small cultural and entertainment park. The first one is a small administrative building, the second one is a cafeteria/ snack bar, and the third one is a small exhibition pavilion.The theme of the chosen design studio is architectural languages and expression. For this reason a set of requirements and restrictions was established for each of these design projects comprising not only functional, constructive and environmental aspects, but also formal requirements. The objective of this was to encourage the students to develop three projects exploring the possibilities of three different architectural languages.

The first, with predominantly orthogonal planes and using prefabricated standardized components, leads to a cubistic and minimalist architectural language. The second project, with shapes derived from the dislocation of points, segments and faces and using a mix of standardized and customized components, leads to a deconstructive architectural language. The third and last project, with shapes derived from deformations or made out of meshes and NURBS and using predominantly customized components, leads to a curvilinear contemporary architectural language. The students have been also required to design three-dimensionally by simultaneously making physical and virtual models. The physical models are more often handmade, but rapid prototyping (RP) is also used, either through the milling (Figure 7) or through the 3D printing (Figure 8) of the most complex works produced in the design studio course. In all cases the role of rapid prototyping is, as a minimum, to inform and to show the students the existence, the feasibility, and the potential of digital fabrication technology.

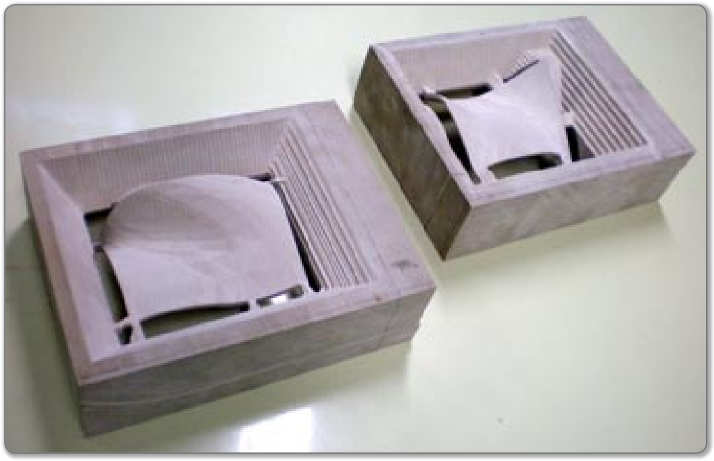
Figure 7: RP Model: Exhibition pavilion by Caroline Barreto.

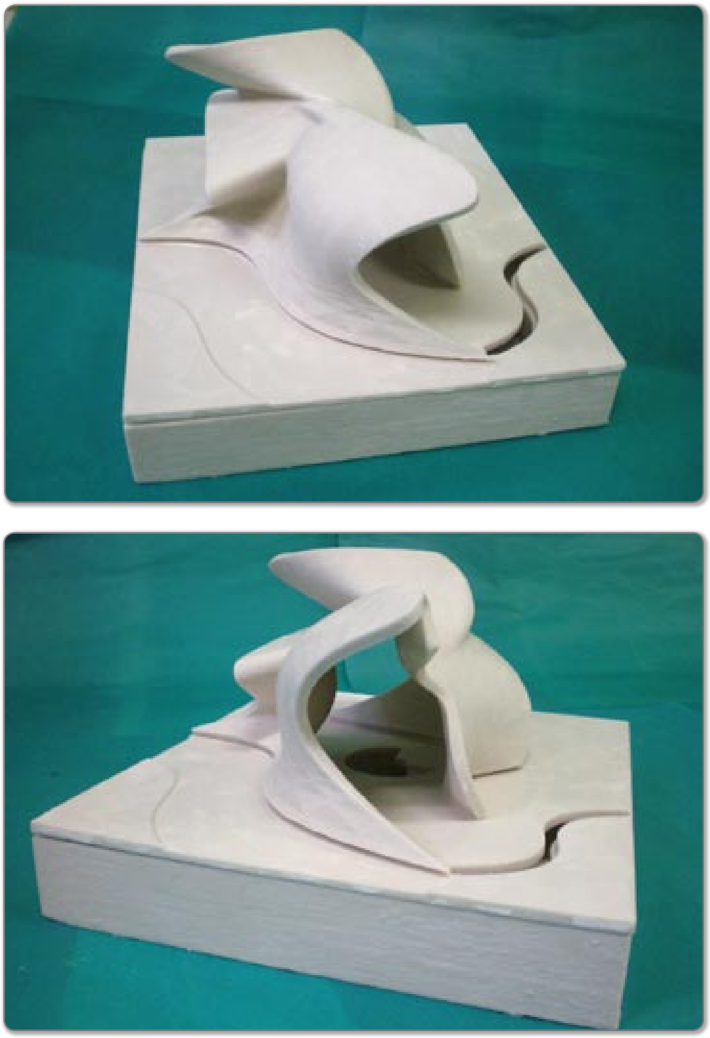
Figure 8: 3D Print: Exhibition pavilion by Nagila Ramos.


Figure 6: Cafeteria by Giulia Igliori.

The main objective of those three projects with three different languages is to provide the students with an opportunity to gradually develop and apply their computer modeling skills in design, from simple to complex forms and from small to large buildings, while at the same time gradually breaking the boundaries of mass standardization and shifting to mass customization.

Conclusions

We believe our contribution resides in the introduction of 3D interactive computer modeling together with digital fabrication and mass customization concepts and processes in very early architectural design education. We believe our research showed promising results: we found out that the students did manage to design beyond the boundaries of cubistic and minimalist architectural languages; there was no evidence of less creativity or of more repetition. In fact our students' projects showed a large degree of creativity through new and complex forms, no fear of experimentation and a venturesome attitude.

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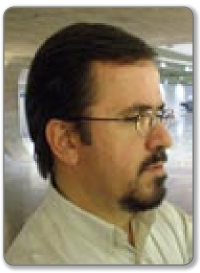

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Ecilamar Lima is a researcher at the Laboratory of Architectural Design and Digital Fabrication, University of Brasilia, Brazil. She holds a Master's Degree in Business and Administration from the University of Brasilia. She has carried out research in the areas of public education funding, institutional assessment, distance learning in architectural education, problem-based learning and education in computer-aided design. She has been a teacher of research methods and learning processes in the post-graduate diploma course of Computer-aided Architectural Design which has been offered by the Faculty of Architecture and Urban Design of UnB for nearly ten years. She has supervised several of this course's students. Her main research interests are: learning theories, learning processes, problem-based learning, design process and protocol analysis.