Integration of Digital Fabrication in Architectural Curricula

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Abstract
Many design schools around the world have been adapting digital design concepts in their curricula. In relation to design education and pedagogy, researchers studied theoretical, computational and cognitive approaches of digital design. In this paper, we present two case studies, which include both components of solving a design problem such as in a design studio and software learning focusing on the implementation of the skills on a design task.

Keywords
Digital Architecture; fabrication; design teaching and learning; form finding

Introduction
With the recent developments on the computer aided design and manufacturing technologies, there have been a transformation of the current processes of architectural design practise. This transformation requires an understanding of the design realm by facilitating the creation of complex free-form geometries, with greater precision, quicker finishing and improved automation. Some of the well-known designers of our time illustrated the potentials of algorithmic programming, generative design and parametric design for architecture through their works. For example, Gehry Partners, Greg Lynn and Herzog de Meuron developed an unique and innovative approach to the process of delivering complex building projects

Figure 1 Tulic s., Ajanovic Dz. and Alibegovic S. Section Injection Chair on site. Idea started from one straight line, refined and transformed into curves. Final design is organic shape chair presented as addition to the walls of abandoned place.

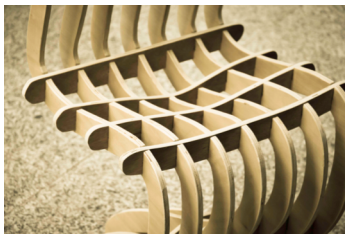

Figure 2 Section Injection Chair detail.

and design artefacts. CAD/CAM (Computer Aided Design / Computer Aided Manufacturing) tools and CNC (Computer Numerically Controlled) technologies started to be used in design profession, providing many new possibilities for the development of industrial manufacturing, creating free-form complex design artefact and building components. In particular, the relationship between architect and material through the means of digital fabrication have significantly enhanced and altered by the employment of the CNC technologies. The positive changes in this employment will further influence the way people work, communicate, interact and collaborate. As digital technologies are gradually redefining and reshaping the environments we inhabit, the further applications of these emerging technologies in design will provide new opportunities as well as challenges for future practice. For future generations of designers, the integration of these technologies as new design languages and resources with the skills of designing with these new technologies become the vital requirement [1].

As a result of the present situation of architectural design practise, there have been substantial changes in architectural curricula to accommodate new demands, opportunities, processes and potentials provided by the advance CAD / CAM technologies and the fabrication-based design techniques. In accordance with this new demand in design education, new subjects have been introduced in architectural curricula assisting the investigation of free-form / complex design artefact, building components and material attributes. These new subjects include both components of experiencing the digital design processes and the processes of production. In this paper, we present two teaching cases which include both components of (1) problem solving as in design studio and (2) software learning focusing on the implementation of the skills on a design task. The first case is implemented at the Department of Architecture in the International University of Sarajevo (IUS). The second case is a short-term intense workshop at the Department of Architecture in the TOBB University of Economics and Technology (TOBB UET)(Ankara).

Case Study 1: Teaching digital architecture and fabrication in IUS_ Project: Citizen Attractors

Like in many other cities, in Sarajevo, there are abandoned places weaved into the city tissue. For the purpose of this course, students were supposed to explore the past, present and to propose for the future of the abandoned city courtyards. Through history, Sarajevo was faced with two types of courtyards, one coming from Ottoman period; dating courtyards of family houses divided into two parts, man's and woman's courtyards.[2] From Austro-Hungarian period the city's urban pattern was organized of building blocks that were enclosing an inner courtyard. The majority of the Sarajevo's city courtyards through history have lost their importance. The students are asked to investigate, document, design and build elements, which will re-activate the life in the city courtyards.

The objective was to provide a set of experiments about exploration of forms and to understand how these forms could perform the role of activator in everyday life of the citizens. After the first set of experimentation on form finding, certain functions, realistic (Figure 1 & 2) or more abstract ones (Figure 3 & 4), were added to the morphs for further experimentation. The students started with the digital experimentation of form finding and continued with the physical exploration of how to reshape materials that were purchased for fabrication of the final model, mainly wood. The cycle, from digital to physical and vice versa, was repeated in order to adapt the form to a certain performance. The process of this work that is lasted one semester long, started with the research of the history and importance of the central courtyards in the city of Sarajevo. (1) It continued with form finding and research of available materials, their properties,

Figure 3: Aganovic I., Kunic A. and Hodzic M. Their intention was to design an element that is going to adopt to two different historical periods Ottoman and Austro Hungarian, which are two different styles. This element, form, is to stand as a sculpture but as well to have a meaningful function. Our aim was to design something recent which would contrast the styles in definitely, not to abrupt it but to supplement it with a broader meaning, to elaborate the overall function just by adding these structures.

Figure 4: Aganovic I., Kunic A. and Hodzic M.; Fabrication Process

sizes and behaviors while treated with different cutting tools. (2) Then proceeded with the adaption of the form and the preparation for the fabrication; alignment with x and y axis; making 2D drawings out of 3D; nesting and cuttings by the standard or advance fabrication tools; and assembling. (3) The presentation, which included plans, sections, 3D representations renders, and smaller scale prototypes. (4) For the final stage students are asked to make 1:1 prototype. (5)

The participants of this class discovered 3D printing technology; learned how to export digital files to be fed to the advanced fabrication machines; and learn to operate with CNC Milling Machine and Laser Cutter. They are also introduced to the new methods of the entire process of design, which is critical to make breakthroughs in field of architecture.

We are now able to materialize, so far inapprehensible images from the virtual world. The challenging question that is rising to the future architects is how to advance the architectural design? The students of today, and the architects of tomorrow, are the first generation entirely raised in a digital culture.[3] Their task is to learn how to use the information, data, presented through digital media, and how the "new forms" operate and advance a quo ante environment. The role of the teacher is to teach how to mediate, not just between built and natural environment, but also new built and already existing built environment. The existing built environment becomes a stage for the new reality. The course of Digital Architecture and Fabrication was enabling students to become builders of their own ideas and to get closer to the final product. By this we mean trying to overcome a detachment from the final product, as a result of disruption and division into a series of specialization. In the process of design we have to have in mind the environment, followed by the idea of smartness, responsibility and flexibility in which we will perform the process of bringing things together, process of aggregation. The process of aggregation is a link between virtual and real environment, which could provide wide possibilities in design thinking, and perception. The detected problem was in acceptance of non-standard forms as a design elements and concern of participants of the impossibility to design and prefabrication complex shapes. It is necessary to introduce the students to the new level of interests in geometric complexity through "non-standard" and "free forms" in architectural design.

Case Study 2: The workshop of digital decomposition and physical assembling in TOBB UET

A week intense workshop is introduced to students to facilitate the understanding of the digital design processes including experimenting on the parametric - algorithmic design processes using and experimenting with the attributes of the materials. The given design problem is to come up with an object design in the TOBB UET campus in Ankara. The students are encouraged to work in groups and to address some of the usability problems of the spaces in the campus.

The aim of this workshop was for students (1) to understand and develop the essential skills and knowledge of digital design and fabrication; and (2) to develop the understanding and hands-on experience of fabrication technologies. The understanding of processes and production is essential thus, firstly, relevant techniques and concepts such as sectioning, contouring and tessellating based on[4] were introduced and discussed. Secondly, students were provided intensive tutorials in terms of understanding of form generation in Rhinoceros 5 and scripting in Grasshopper (learning operation of commands, 3D surface making commands, NURBS, solids, surface manipulation and analysis, scripting and Panelling tools etc.) in the studio.

Figure 5:Özen, N.E., Öziş, A.Z. and Kulak, S; Lying under the green installation.

Figure 6: Kısaer, E.M., Ekşi, Ö., and Çoşkuner, U.; A canopy design in the middle of the courtyard as a multi-purpose space

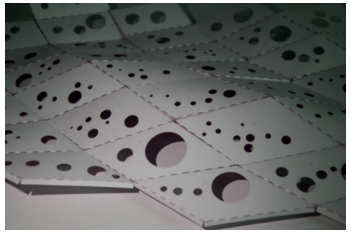

Figure 7:Görgülü, L.S.,Biçer, H and Boz, M.; A suspended ceiling design.

Most of the students have chosen the circular courtyard of the Main Campus as the site of their design because of its frequent pedestrian circulation. The existing axes of the surrounding buildings formed a reference to their designs to emphasize the movement directions of people in the Campus as shown in Figure 5. One of the groups designed a canopy where the flora can grow on the surface of the structure that is formed based on a module. The module was a 3D structure that has voids for the plants to grow in (populated with the Paneling Tools). The students also attempted to emphasize the functional usability of the design by integration the structural aspect of the form creation as shown in Figure 6. They leave the interior space of their design empty for the users to organize it as they wish. Another groups of students preferred the interior spaces such as creating a focus point at the large glass stairs connecting the main entrance with the library. There was also a proposal for the suspending ceilings of the building creating dynamic ceilings to make the space more attractive as shown in Figure 7. Students produced the representational models of their design using Laser Cutter technology.

Studies show that working with the digital medium requires a different kind of thinking. Our observations points out that the basic methods of design teaching such as typologies, graphical representation, contextual and conceptual design explorations are not the same as the traditional design pedagogy. Digital design requires teaching the students algorithms, computing, morphogenesis, form explorations as well as materialization and production techniques. Students should be exposed to the concepts and techniques of digital design and fabrication by giving a chance to explore design artifacts in digital and in physical form.

Here are presented two projects and although they have same aspiration, to activate abandoned city areas; one is driven by the idea of functionality, while the other defined its functionality through the use of end-users.

Concluding Remarks

The theoretical, the computational and the cognitive approaches of digital design and computation in relation to the design pedagogy have become a new subject studied by many researchers. Our digital design teaching pedagogy includes the combination of the followings: (1) offering the subject adjunct to a design studio and (2) offering the subject independently of a design studio. We believe the digital design and fabrication subjects should offer students new learning experiences and learning new skills of using software - prototyping tools and implementing this knowledge and skills on a design task at the same time.

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