Traditional vs Digital

Understanding Design Process in Architectural Education

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This research brings into question, the ever-increasing role of CAD/CAM technologies in architectural design education. Within this scope, a design workshop for the students of architecture was organized, to investigate the effects of design tools and methods on the design process. Participants were asked to start their design by using traditional methods, followed by developing models with CAD -3d modelling programmes- and prototyping with CAM -3d printers-. Design processes were recorded visually and auditory, during the workshop for protocol analysis. Relationship between design approaches, design tools and design process was analysed in detail by observing the frequency of used concepts, actions and words in both methods. Outcomes of the research showed strengths and weaknesses of design methods for different approaches.

Keywords: CAD, CAM, Architectural design education

INTRODUCTION

The fact that architectural design has turn into “a computer-driven, form-based design and global practice” from a “manually driven, tool-based design and mostly local practice (Terzidis 2006) has been widely accepted in last four decades. This transformation in technology, creates a constant information flow from a continuous dialogue between design and construction, which rapidly expand conception of form, material, function and technics (Iwamoto 2009, Dunn 2012). As, this shift changes what is conceived to be possible, examining the use of CAD/CAM in design process and comparing it with traditional design methods become a significant issue for architectural education.

A group of theorists define architectural design as a virtual, not actual process. According to them, traditionally, intuition is the basis of the design process. Architecture is about something vague, indefinite and uncertain, which is a combination of thoughts that lead to the inception of a form. In contrast, another set of theories define the design process as a problem-solving process (Terzidis 2006). Several studies have shown that design process often starts with traditional design methods as working with sketches, drawings and physical models. These methods have a great impact on revealing the intuitive aspect of the design idea in early stages of design (Wiegers Vergeest 2001, Dunn, 2010). They are architect’s medium to organize ideas, resources and space. The critics of such design approaches claim
that non-traditional design methods disconnect architectural output from its context and its users, and lead to a decrease in spatial quality and a building’s integration within the urban environment. Furthermore, some argue that a totally computerized approach leads to disconnection from physical modelling and drafting techniques and so risks the loss of quality in architectural education (Terzidis 2006). On the other hand, the traditional design is an additive process, in which complexity is achieved by overlapping layers on paper. Therefore, associative relations can’t be managed, the internal consistency of a drawing is not guaranteed and the drawing is not a smart medium, but rather, a code based on standards and conventions. Also the additive logic of the traditional drawing excludes physically relevant aspects that drive the generation of forms in the real world (Tedeschi 2014).

Although there is a general judgment that CAD and CAM tools are insufficient at the point of transferring the designer’s intuition, there are also various studies asserting the advantages of these systems for the early stages of design, such as their strength in terms of being able to produce a wide range of forms rapidly independent of material and hand skill (Güney, 2015; İslamoğlu & Değer, 2015). Generating lots of forms that answer the architectural problems in a very short time, is also one of the fundamental aspects of the architectural education and practice. Today, computational tools have introduced innovative form-finding techniques, revolutionizing architectural design and production such as; ‘generative design,’ ‘parametric design’ and ‘algorithmic design.’ With these new design paths in favour of computationally generated complexities, new topologies are developed. So, the emphasis is shifted from ‘form making’ to ‘form finding’ (Kolarevic 2003). Advanced modelling software has enabled architects and students to make designs that would be very difficult to develop using traditional methods (Dunn 2012). Also, using these kinds of tools to design and construct digital practices have the potential to close the gap between drawing and building. Just as traditional method, digital production is a generative medium that comes with its own host of restraints and possibilities (Iwamoto 2009). Development of numerous CAD software, the variety of design processes available to architects, and digital fabrication of architecture and its components, are greater than ever.

However, this transformation has not yet reached its full potential, mostly because of the lack of computational education of architects. Despite the growing attention given to the digital fabrication it is still in experimental stage. Although there are various workshops and research programs on digital fabrication, it is still not fully integrated in architectural design education and practice. To obtain a more integrated approach, more research is needed. Within this scope, a short-term design workshop for the students of architecture was held at Maltepe University, aiming at both introducing digital fabrication to students and investigating the effect of the digital design and fabrication tools on the design process. Expanding the scope of such research will lead to a deeper understanding of the relationship between the design tool, design process and the creativity of the designer and a more integrated education model.

**ATOLYE 3DONUSUM WORKSHOP**

*Atölye 3 Dönüşüm: Design, Prototype, Produce* was planned as a four-day workshop, concentrated on a bilateral design process that carried out with traditional and digital tools and fabricating the designs in different scales by 3D printing. The theme was selected as a small-scale architectural element, urban furniture, for enabling the participants to focus a much more detailed design in all scales. In order to encourage the participants to explore the potentials in different forms of design and production with their original ideas and concepts, urban furniture was not pre-defined by the instructors during the workshop. Participants were selected with an open call to Maltepe University Architecture and Design Faculty. Before the beginning of the workshop, a brief lecture about 3D modelling and 3D printing technol-
ogy was given to participants, to make them familiar with these technologies.

**Method and Framework**

<table>
<thead>
<tr>
<th>#</th>
<th>TRADITIONAL SKETCHES AND PHYSICAL MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2</td>
<td>DIGITAL 3D MODELLING CAD PROGRAMMES</td>
</tr>
<tr>
<td>#3</td>
<td>PROTOTYPE 3D PRINTER</td>
</tr>
<tr>
<td>#4</td>
<td>EXHIBITION VOTING</td>
</tr>
<tr>
<td>#5</td>
<td>PRODUCTION 3D PRINTER, 1/1 SCALE</td>
</tr>
</tbody>
</table>

The main aim of the workshop was making an evaluation on the interrelations of design tool/method, production technology, the design process and the final product. The workshop planned as a 3-phased process ending with an exhibition of projects accompanied by 3D prototypes, to be voted by Maltepe University members. The project with highest vote was produced in 1/1 scale by 3D printer (Fig 1).

- **Phase 1** - Participants were asked to create a scenario about the function and concept of an urban furniture. The first ideas on principles of form and use were decided and represented by traditional design tools such as sketching and making physical models (Fig 3).

- **Phase 2** - Participants were asked to develop their design ideas by using 3D modelling programs they are familiar with such as; 3DsMax, Sketch Up and Rhino (Fig 4). Reproduction of designs via CAD tools, made it possible to create more complex geometries freed from the limitations of material properties, and a large number of design alternatives in this phase.

31 participants of architecture students from Maltepe University were divided into 9 teams of 3 or 4 students, according to their grade (2nd-3rd-4th). Teams were split into 3 main groups, with one group from each grade. To every main group a different design approach -modular, fragmented or integrated- were assigned, and design teams were named according to the method they would use (Fig 2).

The three-phased design process started with traditional design methods - such as sketching and
Phase 3 - Completed digital models were controlled and revised - if necessary - in terms of applicability with 3D printers. Final models for prototyping were tested with MeshMixer to arrange optimisation of printing time and use of material. The design process ended with printing the prototypes by 3D printers (Fig 5), making the post production as; cleaning, sanding, fitting etc., and preparing the posters.

In order to monitor and observe the transformation of design thinking in regard to the use of different design tools in each design phase, participants recorded their working process while expressing their ideas by simple words and actions at regular intervals. Documentations were made as 10 minutes of video and audio recording at 1.5-hour intervals for 3 days, from the emergence of the first design idea to the final product.

Analysing Traditional vs Digital

Atölye 3D dönüşüm: Design, Prototype, Produce was designed to understand the relationship between design approach, design tool, design process and production in different scales. Therefore, video and audio documents recorded by the participants during the process were deciphered and classified in terms of phases and approaches, to observe the frequency of used concepts and actions.

The design ideas of modular approach group (A), basically was shaped around allowing the users to define the form of urban furniture themselves. Multi functionality, mobility, inter-changeability, transformation, convergence, flexibility, inserting-removing, nesting, separating-joining, adding, prisms, fullness-space are the most used concepts in this approach. All teams of group A designed furnitures, that can be used in different forms by combining small modules. For the modules, all teams decided to use solid geometries because of the material limitations on physical modelling.

They did not face any problems in representing the forms by hand but manual production of the identical modules repeatedly was considered by the teams as a problem. Because of simple form choice, 3D modelling programs did not have any significant effect on the transformation of the form of the designs. However, 3D modelling programs made it possible to produce different variations in a short time (Fig 7). Main verbal definitions used by teams of group A were:

- Physical modelling process: cut, paste, add, draw, attach, rotate, open a gap, join, stick, close,
In fragmented approach group (B), form was defined mainly by function. Curvature, slope, underneath, shell, balance, simplicity, functionality, gathering, mobility, space and tangent are the highlighted concepts in all teams of this approach. Teams of group B developed their design with the main idea of putting different pieces together in various combinations. They stated that the difficulty of designing ergonomics and geometries of the forms they wanted to reveal when making a physical model. In the digital model making process, using a 3D modelling program solved the problems of Group B, which were mainly the ergonomics, scale, measurement and form definition (Fig 8). Definitions used by teams of group B to express their actions were:

- Physical modelling process: cut, paste, add, cutting strips, open gap, lengthen, tie, stretch, bend, deform, turn upside down, integrate, wrap up, balance, texture, notch, support.
- 3D modelling process: copy, rotate, draw, slide, scale, move, angle, tug, unstable, thickness, open a gap, lengthen, surface, deform, curve, soften, make oval, curl up, extract, break, embed, curvature, chamfer, balance, cut in circles, dimension, draw section, section and elevation.

After the selection of the winning project (B2), additional recordings were made with team members during the transformation of the design (Fig 10) from 1/10 to 1/1 scale. Although the model was suitable for 3D modelling, limitations that stemming from 3D printer and material, forced B2 team members to redevelop their model according to the production restrictions.

In integrated approach group (C), the characteristic of design ideas was mostly defined by using organic surfaces. Interior space, organism, curvature, asymmetry, fluidity, bending, non-sharp forms, surface, shell, angle, closure, and drilling are main concepts. Because of amorphous form trials, these teams had difficulties and restraints in designing and expressing their ideas with physical models. The sketch models were inadequate to explain their form and desired functions. Unlimited possibilities that are offered by 3D modelling program has made evolutionary changes in formal aspects of the design. Every team of group C transformed their initial design idea, into a new form that could not be produced easily by making sketches and physical models (Fig 9). The words they used during process were:

- Physical modelling process: cut, paste, add, open a gap, carve, fold, tear off, reinforce, lighten, put together.
- 3D modelling process: copy, rotate, draw, join, delete, tug, unstable, thickness, open a gap, lengthen, surface.
Team B2’s design was made of 3 different pieces, that offers different combinations of use by moving and rotating them. Length of the pieces ranged between 180cm and 240cm. The production was planned to made by a Builder Extreme 1500 PRO 3D Printer with a print volume of 1100x500x820 mm. Therefore, the first thing that designers need to think of was shortening lengths, due to the printing size of the printer. Another challenge stemmed from the material, recycled filaments. The inconsistency of that kind of filaments made the designers think about the structure and stability of the design. With all these aspects, team B2 decided to shorten the furniture, eliminate one piece and divide the design into pieces for printing. After these revisions, the time of printing was calculated as 3 months. Since this timing is too long for the programme, designers decided to create a pattern with holes at the solid parts of design, not only to decrease the printing time but also to create additional spaces for animals to live. The final design took a month to print, with 36 pieces that were installed by all participants of workshop, and 52 kg of recycled filament (Fig 11).

RESULTS AND DISCUSSION
The 31 architecture students from different grades were selected according to their 3D modelling knowledge. None of the participants were using the CAD programmes in an advanced mode, and some of them were beginners. In addition, all of the participants never used a 3D printer or designed a product to be printed by one. This test group selection was made on purpose to see the real effect of using a digital tool versus a traditional one.

Because of the lack of ability in using CAD programmes, the first assumption was, traditional methods to be more useful in showing participants’ creativity. Independent of design approach; every group frequently stated that they had difficulties in the physical model making while representing their idea. According to recordings, all groups used common actions as; cut, paste, add in physical modelling process and preferred similar tools for 3D modelling as; copy, rotate and draw.

Also, all teams expanded their concepts by using elements for playing games, animals, comfort, ergonomics, and structure, in addition to basic functions of an urban furniture such as sitting, resting, working. Although there was a similarity in terms of functional aspect, analysis showed that the design method did not only determine the form, but also defined the proposed functions. The constraints of design approach had a significant effect on the very first design ideas. Teams of group A and B considered the urban furniture in a dynamic and flexible context, due to the modular and fragmented design approaches that enables to rearrange the modules. On the other hand, teams of group C considered the urban furniture concept with pre-defined functions that would not give users to change the form for their needs.
One of the most important outcomes of recording analysis was defining the similarities and differences in words and actions between different approaches and different design tools (Table 1). Despite of the changes in forms and functions, verbal expressions showed similarities in traditional and digital design, sometimes using the exact same action. On the other hand, the function of the action differed according to the approach and tool. In all design teams, it is observed that students used a more various range of actions and form trials when working with digital models, than working with physical models. With this outcome, it can be assumed that CAD programmes lets the user to be more creative and encourage them to search for alternatives, even if they are non-professional users.

The majority of the actions that teams performed at the early design phase seem to be specific to the design approach they use. Teams of A performed actions such as; drawing, joining, attaching, sticking, passing, depending on producing of a large number of equivalent pieces. Teams of B talked about actions such as carving, folding, and tearing off, in relation to the fact that their designs consisted of less pieces. Teams of C expressed various actions that are not specified by other groups such as flexing, bending, breaking, balancing, notching, giving texture, aiming to mitigate the mass effect of design and making the form more dynamic. A and B groups intersected in the actions of “bringing together” by joining and deleting, whereas, B and C groups were intersected in “opening a gap” by tugging, playing, thickening, opening, space, lengthening, creating surfaces, and A and C teams were intersected in the actions of moving and angling. In this context, it was determined that the highest number of intersections are between B teams, using the fragmented approach, and C teams, using the integrated approach.

Another important outcome was the adaptation of students to the tools which they are not familiar with. Although none of the students used 3D printing technology before, with a little explanation, they all integrated to a design thought of developing their designs to adapt this technology of prototyping. More importantly, when the winning team adapted their design for production, it was remarkable to observe 2nd grade students making decisions about the production time, material and design optimisation. The chance of producing a real design made students more cooperative and interested in the process.

High-end CAD and CAM tools made architects increasingly concerned about the possible loss of control over their designs due to the complicated nature of computers. Yet various techniques similar to CAD on working principle, existed in architecture before the digital revolution. Designers such as Frederick Kiesler and Frei Otto, were applying design methods that were very similar to today’s computational approach at the beginning of the twentieth century. Therefore, computational design techniques are not as new as they seem, nor impossible to practise without the use of CAD. There always been schools of thought that have encouraged a design process based on initial stimulus and others have promoted a design method, based on rules rather than
intuition, and many now argue that design methods are necessary for architects to deal with complex designs. Today, some researchers affirm that emerging computational design and fabrication tools are changing the architect’s role, making design methods a necessity (Agkathidis 2015). This concern has divided architectural thought into a wide spectrum of speculations about the effect of computers on design, that ranges from complete rejection to worshipping. In spite of these many significant and distinguishing differences, there is one main idea that stays the same; the assessment that there is something unprecedented and extraordinary about the computer as it compares to manual tools. Traditionally, the dependency of tool is controlled by the human designers, who decide the range of possibilities a tool has for resolving and accomplishing a design task. In the case of a computer as a tool, the results may be unpredictable by the users themselves, which may be enlightening or undesirable. However, such design process may lead to alternative ways and results often superior than intended.

Overall, the similarities and differences showed that; design processes using traditional design tools and computer aided design tools could not be handled independently of the design approach and thought. In addition, the research revealed that concepts such as function, ergonomics, size, scale and structural system are both common aspects of the design and independent of the design tool. Digital design accompanied by digital fabrication made it easier and more effective to express the ideas for the designer. Therefore, contemporary architectural education system should have courses related to digital design and production methods and students must be encouraged to use those new techniques. Expanding the scope of such research will allow for a more detailed and in-depth reading of the relationship between the design tool and the design method and pave the way for a more-integrated architectural education.

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