COMPUTATIONAL THINKING AND ARCHITECTURAL EDUCATION: AN EVALUATION OF NEW FORMATIONS IN TURKEY

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ABSTRACT

COMPUTATIONAL THINKING AND ARCHITECTURAL EDUCATION: AN EVALUATION OF NEW FORMATIONS IN TURKEY

A significantly positive change has been noticed in the conceptual frame of the digital design and its influence on the related studies since the mid 60's. The influence is quite noticeable in various research areas based on design theory such as architecture, biology and mathematics, etc…The same influence is also detectable on some theoretical cognitive and computational approaches. Instead of being seen mere means of visual presentation, digital tools are redefined as actual design areas in which the design process is formed. As a result, a variety of concepts known as computational design, computer aided design and digital architecture have come into existence. As expected, this change brings about a kind of paradigm in architectural education. On the other hand, it influences the design knowledge and causes changes in the educational models used for the teaching of design. As a consequence, architectural education bears the responsibility of reflecting the potential of both conventional and digital design methods in the designing process. Accordingly, instead of being only used for creating visual effects as in their early days, in this process of forming an architectural concept, digital tools begin to be used as complementary elements in the basic design learning process. In short, when the architectural education system undergoes a change in order to support the digital methods, the digital platform is not perceived only as a means of visual presentation. It accommodates the entire process of conceptualizing, creating and presenting. Accordingly, this dissertation attempts to question the evolution in the formation of design theories together with its impact and reflections in the education, and this thesis also aims to reveal some evolving educational models in the field. It also underlines the possible future of this particular educational model, and how the potentials of these models will be realized and perceived in their attempts to live up to future expectations.

Key words: architectural design, architectural thought, architecture education**,** computational design, computational thought.

ÖZET

HESAPLAMALI DÜŞÜNCE VE MİMARLIK EĞİTİMİ: TÜRKİYE'DEKİ YENİ FORMASYONLARIN BİR DEĞERLENDİRMESİ

60'lı yılların ortalarından itibaren dijital tasarım teorisi'nin kavramsal çerçevesinde ve etki alanında önemli bir gelişim görülmektedir. Tasarım teorisini esas alan pek çok araştırma alanında (mimarlık, biyoloji, matematik, vb…) kuramsal, bilişsel ve hesaplamalı yaklaşımların üstünde pek çok etkisi görülmüştür. Dijital araçlar, sadece görsel bir sunum amaçlı kullanımdan çıkıp tasarım sürecinin kendisini oluşturur tasarım ortamları haline gelmiştir. Böylece, Hesaplamalı Tasarım, Bilgisayar Destekli Tasarım, Dijital Mimari gibi farklı şekillerde tanımlanan oluşumlar ortaya çıkmaktadır. Bu değişim mimarlık eğitiminde doğal olarak bir paradigma yaratmakta, tasarım bilgisini etkilemekte ve tasarım bilgisinin verildiği eğitim modellerini değişmesine neden olmaktadır. Bu nedenle mimarlık eğitimi, hem dijital hem de geleneksel tasarım metodlarının tasarım sürecindeki potansiyelini göstermek yükümlülüğü içine girmiştir. Bu bağlamda kullanılmaya başlandığı ilk dönemlerde olduğu biçimi ile dijital araçlar sadece görsel sunum için kullanılmak veya form oluşturmak gibi görevler için kullanılmak yerine, mimari düşünceyi oluşturma sürecinde temel tasarım bilgisi öğrenim sürecini de kapsayacak biçimde kullanılır olmuştur. Sonuç olarak mimarlık eğitim sistemi, dijital metotlarda potansiyel sağlamak için değiştiğinde dijital ortam sadece görsel sunum aracı olarak kullanımdan çıkmaktadır. Tüm konsept sürecini, oluşturma ve sunum süreçlerini kapsamaktadır. Tez bu bağlamda, tasarım düşüncesi üretimindeki bu değişimin eğitimdeki karşılığını sorgular ve değişen eğitim modellerini açığa çıkarmayı hedefler. Bu eğitim modelinin nasıl olacağını ve gelecekteki beklentiler için bu modellerin potansiyellerini nasıl kavrayacaklarını açığa çıkarır.

Anahtar kelimeler: mimari tasarım, mimari düşünce, mimarlık eğitimi, hesaplamalı tasarım, hesaplamalı düşünce.

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CHAPTER 1

INTRODUCTION

1.1. Problem Statement

Architectural education has been an issue of discussion for a considerably long period of time. Since the beginning of the realm called architectural education, the search for a better understanding and teaching has never stopped. The learning environment was one of the initial points of approach for better education in architecture. Subsequently, relevant courses, lectures, learning and teaching methods came into existence. Most of them achieved a considerable amount of recognition regarding the way Architecture is perceived. However, with the rapid progress of technology, the requirements for new learning tools and models have become more vocal as well. Structure of education and pedagogical approaches has always been subject to change in the history of teaching methods which would continuously seek for responsive pedagogical forms in architectural education. Again, with the rapid progress of technology, the operation speed has increased and the software area has improved significantly considering the computer technology. These new momentous software systems have become available to everyone through the use of personal computers. Therefore, the integration of technology/computer and architectural education was inevitable in that sense. It seems that an ideal way for computer integrated architectural education might be one that merges computer technologies into existing courses. However, a computer technology based on new design tools has many more advantages than traditional design techniques do. Hence, it may appear more appropriate to create a brand new model of education in order to integrate computer into Architecture.

Dating back to the early years of practice, architectural design would aim at constructing more efficient and complicated buildings. In addition, the concept of the design depending on complexity has remained the same from the past to the present. Under the influence of improvements in the computer design, artificial intelligence provides new tools to create the necessary basis to support the architectural design. The first examples of the design tools, which came along with the developments in the computer technology, focused on model building except for some design systems. They would rather underpin the graphic significances of conventional architectural representation. Computer aided architectural design has been practiced in the field of architecture for more than ten years. Well, currently, it has many more potentials than it did when it was first introduced. However, these potentials have not been fully understood, and for this reason, the advantages of exploiting computer aided architectural design tools in the design process are not very much appreciated by students of architecture in the department. This situation can be compared with or connected to problems like overabundance, or in other words, plethora which can be exemplified as inadequate logistics for the teaching and practicing of computer aided architecture design, the lack of professors and instructors with the knowledge of computer aided architectural design, the complexities in the user interface of computer aided architectural design tools and the insufficient amount of creativity in the development of computer aided architectural design. The concept of architectural design education is fundamentally a mixture of the traditional methods of using the tools like drawing board and T-square and the use of computer aided architectural design tools in the design process.

The future of architectural education has become an important issue of discussion among the people in this field all over the world as a consequence of the increasing use of the computer technology in the designs. The technological developments, the recent ones in particular, have played a determining role in the growth of construction industry. The progress in this field led to building constructions based on climate conditions and the use of heating, cooling and air systems. Since its very beginning, the process of architectural design has aimed at the production of 'complex' buildings. The process itself, the teaching of design, and the evaluation methods and criteria are subject to change and depend on the state-of-the-art in research and technology. The concept of abstraction (or modelling) in architectural design is historically linked to the level of complexity of the design product. It involves the representation of existing structures and can be described as an attempt to recreate reality. Developments in the field of computer modelling, computer graphics and more recently in cognitive psychology and artificial intelligence provide the theoretical basis to build fundamentally new tools to support the architectural design process, in particular for design abstraction and evaluation. The first generation design tools that have emerged from the early computer technology development have mainly concentrated on model building for drawing production, with the exception of few design evaluation systems. These were underpinning the graphic characteristics of traditional architectural representation, where generally the abstraction hides most of the meaning of the drawing -not to the designer, but to the computer. It is the ability of a computer aided design system to 'understand' the implicit information contained in a drawing, that gives it the 'competence' to support 'intelligent' modelling and evaluation (Belhadj, 1989).

Recently, information technologies and computer aided design education have been playing a more important role in design as a profession. They are widely used to develop teaching techniques. Not only technical changes but also new curriculum occurred in many schools of architecture in the world. ‘Emergent Technologies & Design’ MSc/March program in AA School of Architecture, and ‘Architectural Computation’ MSc program in The Bartlett School of Architecture can be noted as good examples. After a long delay, new programs began to be introduced in Turkey as well. Despite the fact that architectural design with computer technology is a very difficult and complex procedure where technical resources should be planned, teaching and learning concepts have advanced very distinctly. Modern computer education and distance learning methods will take the place of classical education methods in the near future. Concerning this new educational style, all disciplines require evaluation and improvements. In other words, computer aided techniques in architecture design is quite crucial.

In debatable architectural education, first of all, it is substantial to clarify how Architecture can be perceived by the individual because architectural education is obviously different from other educational sciences. The nature of architecture involves important social, technical, economical, ethical and ecological questions. The problem remains unchanged even if some identifies architecture as a form of art, for the art of building and planning certainly needs a broad understanding that at least does not exclude any of the dimensions just referred. However, the best way to make people sensitive to aesthetic qualities of Architecture might be initiated with other elements of daily life like economy. From this point of view, during architectural education, a student must have enough experience with technique, engineering, economy, law, sociology etc.

Advances in technology are introducing new demands on the building industry. Some of these demands are the need for progress in computer software, building, assembling and material methods. Architectural practices need to adjust to the evolving context of technology. Computer technologies provide new opportunities and challenges to Architecture as a profession. The enhancing use of computer technologies is changing the way on which many architectural applications are working. It is a kind of improved design process, forcing a collaborative and interdisciplinary way of working that ensures that all parties are included, and all changes are recorded in the process of the design and building.

In this context, architectural thought and computational thought get connected to introduce new models of architectural education. Hence, it is essential to understand the transformation of these educational models. Accordingly, this dissertation discusses how these educational models might be achieved and what the potentials of these models for future expectations are.

Architectural education in Turkey stands somewhere between traditional education models and the recommended ones based on design technology. Relatively, Turkish education system has begun to shape itself as a structure that uses the programming language and relevant design-based operations.

1.2. Aim and Scope of the Study

This thesis is mainly about the computational design in architectural education and the history of the computer aided education, and it also tries to show how this particular educational tool emerged and evolved. It also focuses on the development of an educational model based on this tool. The aim is to understand how computational architectural thinking might be adapted to education and how it can be used to organize future goals of architectural education models. The overall observations show that computer aided design and thus architectural education has a plus advantage. For example, it seems that it allows students to think in a more creative and problem solving way because computer technology has perks like forming easy and fast solution models. Thus, in order to develop students' education pedagogically, computers became a compulsory tool in everyday life. Information technologies and computer aided education models have been playing a very important role in daily practices for a long time. The computers and information technologies are widely used to offer more teaching opportunities. This thesis, first of all, explains the importance of the newly developed computing technology and shows its evolutionary process on a scale starting with the days when it first emerged and reaching up to the present day. More precisely, the thesis tries to explain the adaptation of these new technologies into the architectural education and the practices in design studios. It also tries to explain the criticism which the application of computer technology to design environment faces from the point of view of academics, professors and mostly students. It draws attention to the evolving process of the architectural education with the help of this computer aided education together with the possible disadvantages that it might bring along, or rather it tries to show how the critics of this educational tool perceive it as a thread to the traditional architectural education which is mainly based on studio classes and design studios because this new technology replaces conventional drawing system and designing paths with an effective use of computer which is usually believed to have a negative impact on the creativity of a student or a designer assuming that most creative attempts are the ones that start with a simple sketch or doodling.

Consequently, some cases or studies show that the students are restricted from using computer aided architectural design tools in the first and second years of their architectural education in order to avoid those so-called negative effects of the computer on their creativity. They are rather obliged to learn the basic hand drafting and graphic communication skills and other forms of traditional architectural design education in order to pursue the creativity they are expected to apply into their designs and design processes. However, starting with their third year of architectural education, students are encouraged to use both conventional methods and computer aided drawing and design methods. However, because the transformation from conventional methods to the computer aided drawing design methods is not properly staged, some architecture students are left with the disadvantage of not being able to use computer aided architectural design effectively in their design process, so such students are in a way deprived of the several benefits of using computer aided architectural design. A major advantage of this method is that students are introduced to both methods of architecture design education and are able to implement either or both methods when needed. Computer aided architectural design is the solution. "Computer aided architectural design offers the means of evolving design ideas in a three Dimension (3D) space that addresses all design issues that would have otherwise been ignored in two Dimension (2D) drawings on the sheet. Computer aided architectural design tools enable the architect to better understand the various components of the project, its structural integrity, Heating, Ventilation and Air Conditioning, analyzing the environmental performance of the building and performing real life simulations in virtual reality systems." (Botchway, Abanyie, Afram, 2015)

Referring to the purpose above, the paper aims to answer the questions such as;

1- How computer has become one of the most useful and compulsory tools in architectural education

2- In what way computer technology in architectural education affects students and professors considering their view of perspective.

3-How lectures and courses affect the development and evolution of computer through architectural education.

4-Have the classes based on computer aided design become successful regarding the design progress and presentation?

5-The computer technology has merged through educational model, so how did it become a compulsory tool of architectural education?

6-Do the digital modelling and CAD programming improve the representation skills of the students of architecture?

7-How does the computer aided design affect the architectural education in Turkey?

In short, the aim of this thesis is to raise awareness in a Turkish context regarding these questions and the answers given. Moreover, this dissertation tries to introduce elaborative lesson contents for computational design and computer aided education versus traditional architectural education. The introduction of computational design is explained step by step.

The thesis is mainly concerned with the area of architectural education and how it might actually support the education. It also tries to answer the question of “is it really an obstacle in the way of the design creativity?”. In educational terms, computer technology is a kind of unconventional innovation; thus, the relation between education and the technology is argumentative. Not only in the education but also in the academic world of architecture, the computer technology faces a severe criticism from professors and architects. Yet, the criticism regarding the relation between architectural education and the computer aided design is limited with the traditional way of designing.

1.3. Methodology

Literature review is done to understand computational thinking and architectural education. As a result, it became essential that the common situation and practices in the world need to be determined. The number of computers used in architectural education has been searched and noted. Posture and schools in Turkey are exemplified. The course schedules and course content of all universities have been examined. How many courses are related to computational design and how computational models influence the programs of the lessons has been analyzed. The situation in architectural schools after 90's has been studied through interviews with schools and information on their web sites. It has been found out that that Middle East Technical University, Yıldız Technical University, İstanbul Technical University and İstanbul Bilgi University have already offered new programs based on computer aided architectural design. As a result, these four universities are selected for the study based on the criteria of; computer usage, computer thinking, and adaptation of the curriculum.

The study includes interviews with instructors at the selected universities which are Middle East Technical University, Yıldız Technical University, İstanbul Technical University and İstanbul Bilgi University. The interview questions are listed below. It also includes interviews with students registered in the graduate programs of these universities.

Table 1.1. Interview questions for instructors

Can students demonstrate a design generated from the analysis of the complex internal requirements in digital area? (structure, materials, form, program etc.)
Can students conduct a design based on a development process which is constant, critical and iterative in its nature?
Can students demonstrate a critical and independent design thinking?
Are students able to understand, interpret and evaluate architectural concepts and theories in digital design?
Do students use computational methods for generating innovative, creative and original architectural design solutions?

(Continues on next page)

Table 1.1. Interview questions for instructors **(Continues)**

Can students execute critical analysis, synthesis and evaluation of new architectural design approaches introduced by computational methods?
Does the studio practices have any stages like concept process, design process, presentation, etc…?
Which programs do students use in entire design process?
Which programs do students use in entire presentation process?
Can students consolidate their previous digital knowledge and skills with their design education in this studio?
Can students develop their projects in a digital design process?
Which of the following topics can be selected for this studio? Design Cognition Systematic Enumeration Representation and Space Transformation Generative Algorithms Emergence Design Optimization/ Performance Based Design Non-standardization Interactivity and Responsiveness Design Thinking Visual Computing Computation in Design Education Information Technologies for Building and Urban Development Integrated Design and Delivery Building Information Modeling Green Building Design and Delivery
Can students understand the interdisciplinary character of architectural design elated computational methods and use this knowledge for proposing new design tools, methods and solutions?
Is the medium of architectural representation questioned in terms of architectural thinking environment?
How do students question the relation between the model making and digital thinking?

ITU, YTU, and İstanbul Bilgi University are located in Istanbul. METU is located in Ankara. All departments of Architecture function under the Faculty of Architecture. Their undergraduate education is designed to be completed in four years divided into eight academic terms. Their graduate programs are two-year programs of four academic terms. This study focuses on the undergraduate programs of İstanbul Bilgi University, M.Sc. Program in Computer Aided Architectural Design in YTU, and M.Sc. Program in Computational Design and Fabrication Technologies of METU.

1.4. Structure of the Study

The first chapter is a brief introduction, and it focuses on the computational technologies and its influences on the architectural design education. Chapter 2 presents a literature review of the importance of computational thinking in architectural education and this is explained under two subtitles. The first part examines the following topics of computer-based thinking and architecture, CAD lesson content, and new compulsory lessons to go along with studio practices. The second part focuses on design studio practices affected by computational design.

In Chapter 3, the research is computational thinking and architectural education in Turkey. This part is divided into two main sections: CAD based architectural design history before 1990’s and computational design techniques after 1990’s because the 90’s are the pin point for the adaptation of the computer technology into the architectural education in Turkish context. There are some examples like the first usage of AutoCAD in some universities as a presentation tool and a design tool.

In Chapter 4, case studies are examined in terms of their curriculum. The examples discussed in Chapter 2 and Chapter 3 are explained in detail.

Finally, in Chapter 5, current educational models used in architectural education in Turkey are explained with a thorough examination of their advantages and disadvantages.

CHAPTER 2

COMPUTATIONAL ARCHITECTURE EDUCATION

2.1. Computational Thinking and Architectural Education

Early experiments on computer-based learning are conducted by Papert (Papert, 1980) who introduced a specially designed language to be used in a children teaching program called Logo. He claimed that teaching computer skills to others needs an extensive comprehension of the subject to be taught because the most efficient way of learning something has a lot to do with teaching others and designing things. Therefore, before designing the program as a whole, it is necessary that all the information should be brilliantly regulated and simpler-subproblems should be composed from the main problem.

Computation deals with solving problems on computational models while using an algorithm. Based on this definition, design computation deals with solving design problems on computational models. This includes any design problems that could be identified in computational model; in other words, a problem in a precise model where the problem is epitomised with a set of changeable and a set of logical connections between them can be solved by techniques based on these methods.

In the field of Architecture, computational design has become a sub-discipline of Architecture that is multidisciplinary in nature and wields improved, progressive and advanced computing abilities to find out and deal with complex and difficult problems of the architectural design. It ensures procedures for an architect/ designer/engineer in harnessing a more deliberate and informed opinion process in the design.

Almost all architects in the world use algorithmic thinking instead of design tools. This algorithmic thinking is an interaction with computational desing thinking. There is algorithmic thinking which is deterministic, systematized, factual and consistent. Most algorithms are symbolic and get accustomed automating manual methods through formal languages. Computational design thinking can be identified as being algorithmic. Computational design systems and techniques are reproduced relying on computational design thinking.

Later in the 80's Harel and Papert (Papert, Harel, 1991), in theory of Constructionism, suggested that computers should be used as a learning tool rather than a teaching tool. By generating his own software tools, a computer user would be active on computer use and that provides an enhancement. Their proposal was to create a "convivial" word as a tool for computer use. Well, apparently they thought that an active use of computer is more advantageous considering the enrichment that would allow comparing passive usage of it. "Their pedagogically successful experiments, led to what became known as Papert´s principle: some of the most crucial steps in mental growth are based not simply on acquiring new skills, but on acquiring new administrative ways to use what one already knows " (Minsky, 1988). Following their successful experiments, in the 90's, Mithcel Resnick proposed new approaches in learning process. He emphasized the significance of object-oriented programming to simplify the creation, maintenance and understanding of programs and also the decentralized systems, parallel computation and parallel programming languages. Mitchel suggested developmenting a new software and described it with his own words as a means to stimulate the creative processes of the designer's mind. (Resnick, 1994)

2.1.1. CAD Lesson Content Changes for More Focus on Program Logic

As Papert and the studies of his successors show it is essential to make a distinction between the passive and active learning processes in computational architectural education and this approach also could be applied to CAD learning processes. "Any design problem that can be described as computational model, in other words, as an abstract model in which the problem is represented with a set of variables and a set of logical relationships between them can be solved by using computational techniques."(Çolakoğlu, Yazar, 2007). During the last 50 years, CAD software has been used more passively and the computer development has influenced the CAD systems accordingly.Hence, it is wise to describe the evolution of CAD briefly.

As it is very relavant to the developments in computer input and output hardwares, the early users of CAD had to do deal with mathematical calculations and data management because the graphical interaction was very limited. The interface of a user was not very well developed, thus programming skills were an obligation for CAD users."The focus then was on the applications of mathematical methods - such as graph theory, optimization techniques and differential calculus - in the design process, boosted by the Design Methods Movement." In the 70's, raster displays, based on inexpensive television technology, "contributed more to the growth of the field than did any other technology" (Foley, Van Dam, Feiner, Hughes, Phillips, 1977)

Later with the introduction of graphic displays with higher speed and resolution and new input devices such as mice, digitizing tables and light pens, CAD software started to become more graphic-oriented. Along the growth of painless interaction and the emphasises on visual presentation, computer-aided design in architectural education originated from the computer graphics. Then, since the 80's, most architecture schools have added courses of the computer rendering techniques to their curriculum. Currently, remote collaboration and online information sharing possibilities have led to new trends on CAD education. Collaborative CAD tools have provided the opportunity of sharing drawings in different places to users and with this innovation, CAD curriculum of architecture schools has changed to include remote collaboration courses.

Figure 2.1. Computer development
(http://siripan2.blogspot.com.tr/2015/07/5.html)

Well after the development of the telecommunication technologies, they happened to have influenced the development of applications which by means creating the possibility of remote collaboration and by dynamically feeding CAD systems with on-line information. This was the first trend which led to the development of remote collaborative CAD tools that enable users in different places to share drawings at the same time while seeing and talking to each other. Obviously, this was a tremendous developmentf of technology which also produced a new change on the focus of CAD courses, and nowadays many architecture schools are introducing remote collaboration courses in the CAD curriculum.

Having given a recent history of CAD, one also needs to mention the history of a software briefly. Mitchell, in 1990, came up with the categorization of five generations of CAD between 60's and late 80's starting with Ivan Sutherland's SKETCHPAD. "Despite Sutherland's introduction of the concept of ill-specified, "loose" inputs, following developments had a different orientation, and CAD programs were turned into an overly precise tool (Negroponte, 1975)." The 60's and 70's first and second generations of CAD were based on expensive, turnkey systems, operated by technicians'' (Richens, 1992). Those times were suspicious times that architects and students were still not very much informed and kept vague about the use of computers in design. "Their attitude positions ranging from fear to mystification and resentment that computers would diminish humanity in architecture" (Broadbent, 1973).

According to Celani (Celani, 2008); during the 80's, CAD researchers were looking for new methodologies and practices, exemplified as "rule-based and/or frame-based systems that provided the means for codifying the problem-solving know-how of human-experts" (Schmitt, 1988). This decade was a depiction for the parallel development of three different generations of CAD: more accurately, two of them because the third generation was a natural continuation of the previous ones and rather looked like a replica of the two.On the other hand,the fourth generation can be described as a generation in which a simplified CAD was introduced and developed to be used in the new 16-bit IBM and Apple Macintosh personal computers and that would make CAD more affordable for small companies and independent architects. However, the fifth generation was entirely a new kind of development. The fifth generation of CAD was related to the development of a new kind of computers, the graphic workstations, in the 80's: "For these machines, the developers of both mainframe and PC CAD adapted their products, at the same time as special applications were being developed. Their 3d-modeling capabilities led to a discussion about the role of solids modeling in the design process and in replacing traditional bi-dimensional design representation". (Eastman, 1987)

Apart from the technical developments in CAD programming, evolution of the use of CAD in architectural education can be presented by analyzing the three examples from history. These examples, which are taken from books proposing codes that produce architectural forms, basically have a common aim of teaching programming to architects.

First model about CAD education is the book of ‘’Art of Computer Graphics Programming’’ which introduces a variety of exercises to teach Pascal graphic programming to beginners. The goal of these exercises is to embody the issues of design theory and visual aesthetics combined with computer technology. (Mitchell, Ligget, Kvan, 1987) To make the concepts of programming clearer, complex exercises on shapes, parameterized shapes, repetition, conditionals, hierarchical structures and geometric transformations were introduced by authors.

The next example of models is also a book called ‘’Microcomputer Aided Design for Architects and Designers’’. The main goal of the work is described as to ‘’remove the unnecessary mystique surrounding the use of computers for architects and designers’’ by the author, Schmitt. He claims that the microcomputers can be used to develop the creativity through algorithmic and rule-based programs rather than being used as a productivity toll. (Schmitt, 1988)

According to his approach, it is possible to link up between architectural design and languages in the manner of vocabulary, relations, rules and a grammar. Hence a ruled-system consists of a set of symbols and rules between them could be used to define architectural design. He also linked computer programming with architectural programming saying that the idea of which analysis, formalization and generation of requirements and relations are needed to meet the requirements and specifications. Beside those, many examples of programs in Autocad’s Autolisp were introduced by Schmitt. Before making a conclusion, he revealed the advantages of computer-assisted design process. The availability of a huge amount of databases could expand the limits of design problem based on previous design solutions. In conclusion, Schmitt mentions that in order to benefit properly from the computers in design, architects need to get the ability to operate computers.

Schmitt’s book differs from Mitchell, Liget and Kvan’s in that his programs are established inside Autocad and do not need to develop a different modelling software.

The last book called ‘Generative Modelling’ is written by Paul Coates in 1995. His objective was to “introduce the idea of computer generative modeling as a means of exploring key ideas in the design of the built environment, by way of a series of worked exercises which go beyond the standard customizing issues to allow experimentation with the automatic generation of form, or generative modeling" (Coates, Thum, 1995). Similar to Schmitt, Coates defines design as a fact based on words and rules. But the other ideas about how the complexity of architectural systems can be understood by modelling were suggested by Coates. (Celani, 2008)

1950's	•The first graphic system was made. (Semi Automatic Graund Enviroment)
1957	• Dr. Patrick J. Hanratty developed PRONTO (irst commercial numerical-control programming system)
1960	•Ivan Sutherland MIT's Lincoln Laboratory created SKETCHPAD
1975	•Avisons Marcel Dassault (AMD) purchased CADAM. (Computer-Augmented Drafting and Manufacturing)
1989	•Appeared first on Silicon Graphics workstations.
1993	•CAS Berlin developed an interactive NURBS modeler for PCs, called NöRBS.
1998	•Autodesk ships 3D Studio MAX version 2.5.
2012	•Autodesk released Inventor Release 4.
Future	•CAD will develop more technology, which will gives us other options.

Table 2.1. CAD development
(It has been adapted from https://en.wikiversity.org/wiki/Computer aided_design/History,_Present_and_Future and https://prezi.com/a4qewxpfyhdw/timeline-of-cad/)

In short, it can be said that programming enables the generation of new forms. The new focus of programming courses on the CAD curriculum may change from presentation to process of design, not on products such as claimed by Oxman. (Oxman, 1999) Hence, it will be necessary for students to have more programming skills to create their own tools and have the capability to use new parametric CAD software. CAD was apparently the most popular software used as a designing tool at that time. It was utilized as a representation for architectural design rather than a helping tool during design process. It was like a replacement of the the mechanic drawings with pencil and paper with a digital drawing which would result in fewer mistakes and errors. Although CAD was a starting point of computerized era for architectural education, it gradually came to be used as a way of thinking in order to help design process in architectural education. Computer started to be used as a thinking tool. Compulsory courses made it plausible. For example, METU started a compulsory course titled as "Digital Media" in

2010 -11 for second year students. This course included several softwares to be taught other than CAD because CAD started to be taught in the first year summer internship. It was like an introductory course for students to learn how to use computers in design process. After 2000, computer was regarded as a way of thinking and a supportive tool in architectural design.

2.1.2. Studio Courses Begin to be Accompanied with Supportive Courses

When the benefits of the computers used in the design process are considered, it is quite obvious that architects and architecture students need to possess the knowledge and ability of operating computers. Computer based design in architecture, in fact, emerged as a sub- discipline of Architecture and computing capabilities used in order to understand and solve complex problems of the architectural design.So, as a result, initial introductions came in the form of simple experiments, classes, lectures and the books which were actually the teaching tools, or more precisely, they were first applications enabling the use of the computational thinking in the world of Architecture and architectural education. The situation is depicted more clearly by famous names like Pappert, Harrel, Resnick with examples below.

Papert (Papert, 1980) excelled his first experiments on computer based learning at the MIT Media Lab in the 60’s and 70’s. This experiments would show how to program a computer in a specially designed language called Logo. In terms of Papert, the best learning technique was all about possessing the knowledge and designing something. Accordingly, in order to teach computer skills, one needs a complete understanding of what is being taught, and there must be well-organized information needs. Besides, problems must be divided into simpler sub-problems, and the program as a whole needs to be planned and designed.

In the 80’s, Harel and Papert (Harel, Papert, 1991) established a research group. With therir studies and experiments, active using of computer enriched the practices in the field a lot more than passive using of computer could do. So as to be active, computer should create its own software tools.

One of Papert's followers, Mitchel Resnick, suggested the development of a software to “stimulate the creative processes of the designer’s mind”. (Resnick, 1994)

He offered some new methods to use computers in the learning process along with the use of object-oriented programming to make programs easier to form, maintain, enlarge and learn. Furthermore, he offered the use of decentralized systems, parallel computation and parallel programming languages to accelerate the speed and performance.

As it was mentioned before, computational design approach was first introduced in 1987 and became possible with the introductions of several books. Those books would exemplify and clarify the necessity or rather the place of CAD in architectural education. The introductions of the first models of computational design explained and analysed in the books might be seen debatable. However, the initial emergence of computer based thinking needed some guidence for students, professors, tutors and etc. Consequently, Mitchell, Liggel and Kvan became the forerunners of the age of computational design. The book titled as 'The Art Graphics Programming' was a comprehensive introduction to a computer based design. This book was regarded as a distinctive movement in the era of the computational design. It seemed that the book was the beginning of the entire process in computational design. After the publication of the book, studies about computational teaching models increased in number and they served as a source of inspiration for new research areas in the era of computer based design. Under these circumstances, new design courses were developed in order to accelerate the studies and experiments on computational design. In addition, the aim was to analyze the process and theories of this new period in a more comprehensive way. The courses were initiated by Nagakura in 1998. After Nagakura, Terzidis was the creator of another course in 2002. Terzidis was followed by Celani in 2004 and finally by Duarte in 2007. They are seen more like the forerunners of teaching computational design.

The very first course in the field was introduced by Nagakura. Nagakura developed a course named 'Formal Design Knowledge and Programmed Constructs'. The objective of this course was to present the foundations of computational knowledge to the students of architecture in a more practical and theoretical way so that the students would be able to explore and analyse these issues related to the representation of architectural forms and design knowledge. Nagakura's course wanted to teach the programming language to students as basic concepts of programming language. This new programming language was taught through a program called AutoLisp, which happens to be a kind of language used in AutoCad.

The second course to be mentioned was developed by Terzidis. Terzidis initiated a course titled as 'Algorithmic Architecture'. According to Terzidis, the course objective was to create and develop computational methods. The course would suggest that establishing algortihms would comprehensively encapsulate the process which would eventually lead to the stimulation of the new generation which intends to create a meaningful architectural form. This course teaches architecture students a new and different way of codification in design and explains the use of scripting languages. They are introduced in 3D packages; for example, a program named Maya with embedded scripting languages, is called MEL. Another example is a program developed in order to create 3D models, and it is called 3Dmax, which is also enumerated in scripting languages. Those were the programs used in Terzidis' course.

The third course was improved by Celani. The name of this course was CADCreativo. According to Celani, the course was more of an experimental course, and the purpose was to explore the usage in a way of more of a logical operations related with design strategies. In this course, Celani used CAD software in a different way from the conventional usage of it. CAD was utilized not just as a representational tool but also was used as an explorative, customizable design aid for the creative process. The course used a software called AUTOCAD 2000 which is in general, a part of CAD software. However, additionally, this software included VBA development environment.

The fourth and the final computational design course was developed by Duarte's. The course was named as 'CAD II: PROGRAMMING AND DIGITAL FABRICATION'. The objective of this course was to provide the architectural students with fundamentals but more of some practical and theoretical fundamentals in order to guide them in their exploration of computational aspects of architectural form and knowledge. The program used in this course was named AutoLisp in AutoCAD, and, in general, some basic concepts of this program were taught in the course.

In conclusion, all the courses mentioned above were designed for the same purpose. The aim was to create different aspects related to the architectural forms and knowledge. Moreover, the courses had the intention of being a guide for architectural students in this new field and help them in their research and studies in this era of computational design. Since the computational design was defined as a problem solving tool to be used in design problems related to the use of computational models and algorithm, the courses mentioned above had the same purpose with the algorithmic and computational design. This part of the study tries to focus on the description or exemplification of the initial courses in the introduction of computer based design and computational thinking as they are usually accepted as the indicators of developments in computer aided architectural education. Following the courses introduced by Nagakura, Celani, Terzidis and Duarte, new courses were gradually introduced for the future developments in architectural education. Consequently, a huge expectation in the transformation and development of architectural education came into existence.

2.1.3. New Compulsory Courses Along with Studio Practises are Needed

The conventional architectural education system gives the impression of an outmoded approach which is left behind the technological advances of the day. In other words, the conventional approach in architectural education can not keep up with the rapid change of digital design and computational theory.

The computational design and design with algorithms is currently improving and it is becoming more popular around the world. Consequently, the gap between the conventional and the new approaches, and the reality of digital design is getting more visible and harder to compete with.

Students need to be taught a creative use of computer rather than an object manipulation because expecting an architect to be a programmer would be improbable. There are alternatives for programming such as scripting language. Scripting language is relying on the components of higher level programming language and binding them together (Ousterhoud, 1998). Scripting is a language different than programming, and it is actually used for the accelerated development of a program in order to provide and create interactions within the program. Scripting language is much easier to understand for non programmer, and that is the main reason why designers use it. Designers or architects may utilize the benefits of this technology by using new tools and materials. (Çolakoğlu, Yazar, 2007)

There are theories about the existing architectural education and how design should be taught. Therefore, there is a special emphasis on computational explorations and expressions. Barts Lootsma, in his speech titled 'Hybrid Space' explains the new directions in architecture. He says: ''instead of trying to validate conventional architectural thinking in a different realm, our strategy should be infiltrate architecture with other media and disciplines to produce crossbreed.’’

As a result, new compulsory courses are necessary to be developed in order to introduce an innovative design education approach that will enable the emergence of new intellectual and theoretical directions for coming design generations. Under these concerns, a new course named ‘’ Designing the Design’’ is developed. ‘’Designing the Design’’ is developed in order to reconsider the interactions among digital design, design computing and computational design. The purpose is to introduce architecture students the new methods of designing. This new graduate course is rather different from the four initiative courses mentioned before. It puts emphasis on conceptualizing rather than programming as in the name of computational thinking. The course aims to conseptualize the computational thinking to operate in the multiple layers of abstraction simultaneously because computational design thinking is defined as algorithmic thinking. Since algorithmic logic is more of a deterministic, consistent, rational and systematized issue, architects and students prefer to use it in their design process.

The course named “Designing the Design’’ is introduced in two modules. The first module consists of a description of the basic concepts of the computational design. It covers the new computational design methods starting with proper introductions, and it also includes formal explorations and expressions of the formal languages. The second module is rather different from the first module in that the introduction in this module is more practical while the one in the first module was rather theoretical. The second module aims to inform the students of architecture of algorithms and scripting. In order to do that the second module introduces some particular exercises.

Exercises involve algorithmic scripts built on top of existing CAD systems. The process goes with abstract forms and computation of these forms and finally focuses on several architectural problems. And in respect of the software, the course uses 3Dmax with embedded scripting environment. To point out the algorithmic logic and scripting, exercises include class and home assignments and conclude with a final project.

The course starts with the introduction of the principles of programming logic.

- Syntax of computer programming
- Program flow, (loops and conditional statements)
- Variables, operators and transformations
- Custom functions and built-in features of the scripts language

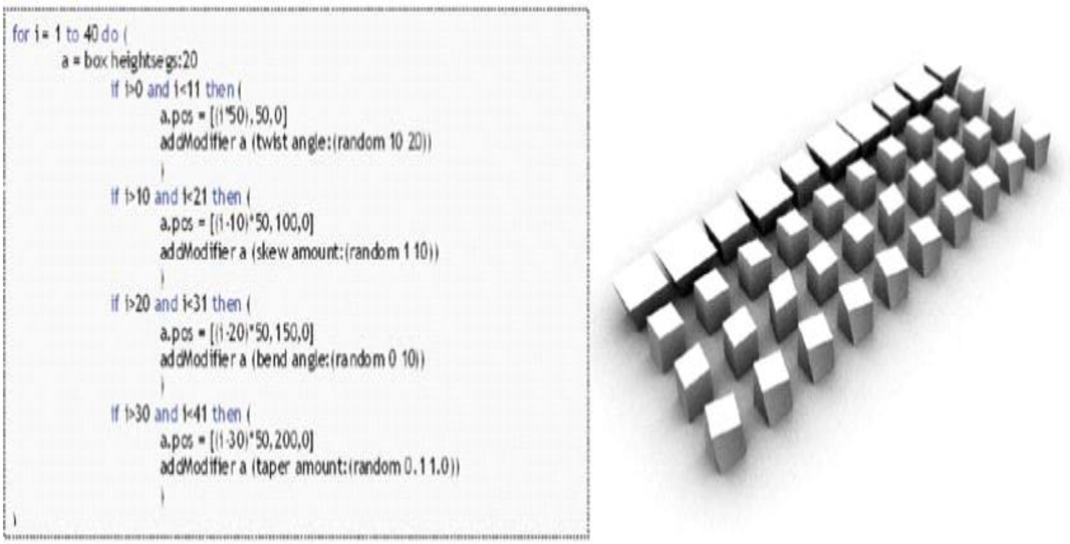


Figure 2.2. An introductory exercise that script codes and output.
(METU JFA 2007/2, 162)

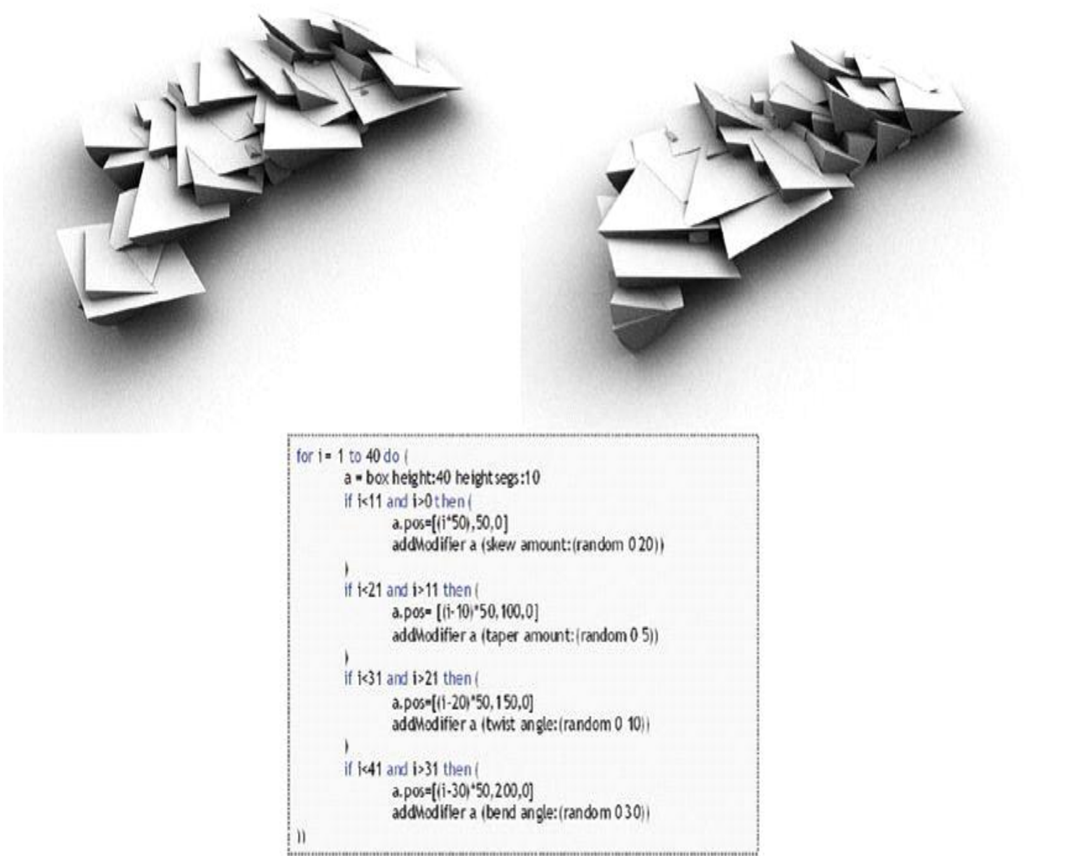
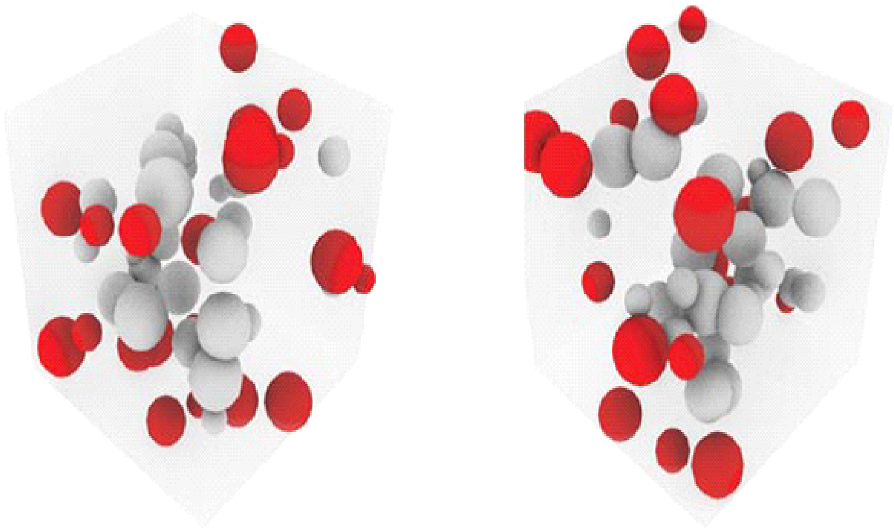


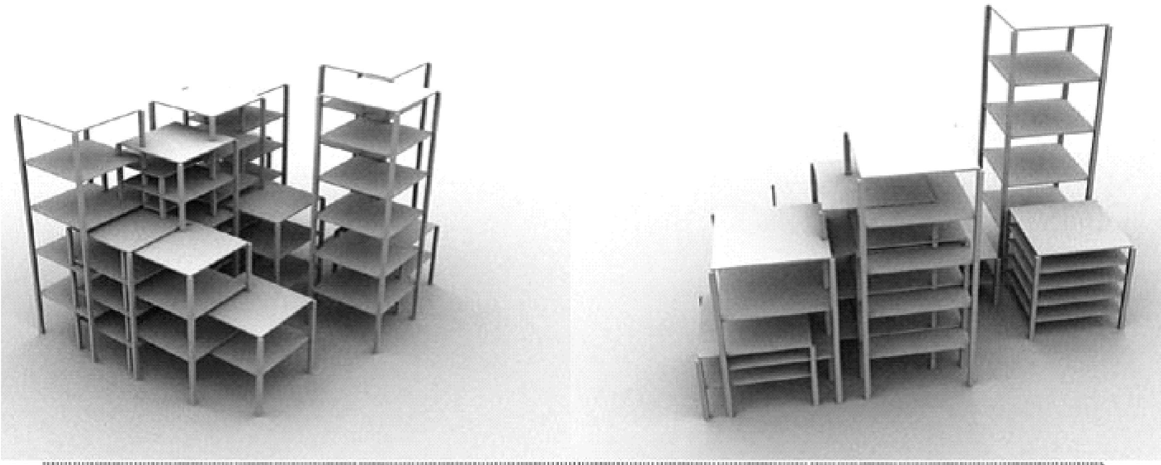
Figure 2.3. An introductory form-finding exercise. The script code and two randomized outputs.
(METU JFA 2007/2, 162)



```
b = box width:100 height:100 length:100 pos:[50,50,0] visibility:false
for i= 1 to 50 do (
        a = sphere radius:(random 5 10)
        a.pos = [(random 0 100),(random 0 100),(random 0 100)]
        a.wirecolor = color 255 255 255
        if (a.pos.x)+(a.radius) > 100 or (a.pos.x)-(a.radius) < 0 then (a.wirecolor = color 255 0 0)
        if (a.pos.y)+(a.radius) > 100 or (a.pos.y)-(a.radius) < 0 then (a.wirecolor = color 255 0 0)
        if (a.pos.z)+(a.radius) > 100 or (a.pos.z)-(a.radius) < 0 then (a.wirecolor = color 255 0 0)
)
```

Figure 2.4. An introductory problem solving exercise. The scripting code and two randomized outputs.
(METU JFA 2007/2, 163)

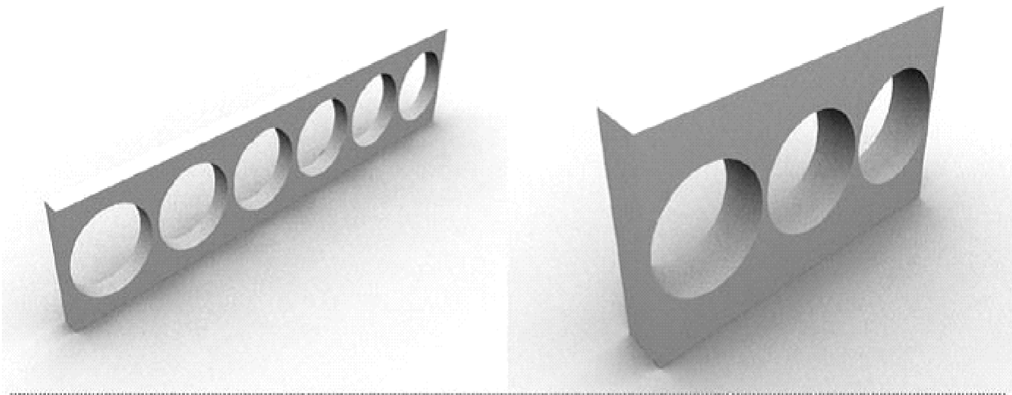
The first exercise intends to teach the logic of relational geometry by providing lots of practice to get experienced in scripting and it does this with exercises involving abstract objects like spheres and parametric boxes.



```
fn bldg ka:3 ky:300 pz:[0,0,0] = (
        for i= 1 to ka do (
                a = box height: 10 width:500 length:500 pos:pz
                move a [0, 0,(i*ky)]
                box height:ky width:25 length:25 pos:(a.pos + [250,250,-ky])
                box height:ky width:25 length:25 pos:(a.pos + [-250,250,-ky])
                box height:ky width:25 length:25 pos:(a.pos + [-250,-250,-ky])
                box height:ky width:25 length:25 pos:(a.pos + [250,-250,-ky])
        )
)
for i= 1 to 15 do bldg ka:(random 2 6) ky:(random 150 300) pz:(random [0,0,0] [2000,2000,0])
```

Figure 2.5. Scripted function that creates frame structures and it's executions with randomized inputs.
(METU JFA 2007/2, 163)

In the next phase, abstract objects are replaced with architectural objects such as, columns and floors. This exercise aims to create some knowledge or an awareness of a relationship between certain parameters and the materialization process of their architectural counter parts.



```
fn window wall nr = (
	window = mesh(); wall2 = copy wall; convertToMesh wall2
	dia = (wall.length/ nr); if dia > wall.height then dia = wall.height-20
	for i = 0 to nr-1 do (
		cylinder height:(wall.width*2) radius:((dia/ 2)-10) sides:32 isSelected:on
		$.pos = [(wall.pos.x),(wall.pos.y),(wall.height/ 2)]
		move $ [-(wall.width),(i*dia)-(wall.length/2)+(dia/2),0]
		rotate $ (eulerangles 0 90 0)
		window = window + $; delete $
		)
	wall2 = wall2 - window
	delete wall; delete window
	update wall2
)
window (box length:1400 width:50 height:300) 6
```

Figure 2.6. Script code and some results of the function.
(METU JFA 2007/2, 164)

The next exercise is an introduction of parametric design. The only parameter of the function is the number of holes to be opened. Here students are expected to deal with and solve the geometric and arithmetic problems.

Exercises of the course mainly proceed as depicted above, but with more of a solid parameter. Finally, students are given final design projects of their own. The final projects include following phases:

• Statement of a need, providinga design problem with an architectural counterpart

• Formal analysis phase, including typological categorization

• A design brief developed by selecting a particular category

• Parameterization, resolving the design brief and exploring variations

• Utilization, coding the hypothetical design using the parameters,

• Testing the code, evaluating its expected benefit, performance and usability

• Returning to the parameterization or utilization phase if necessary.

Each group of design project had to develop their own final project. Below depictions are the example of a final project which was a parametric canopy design. (Çolakoğlu, Yazar, 2007)

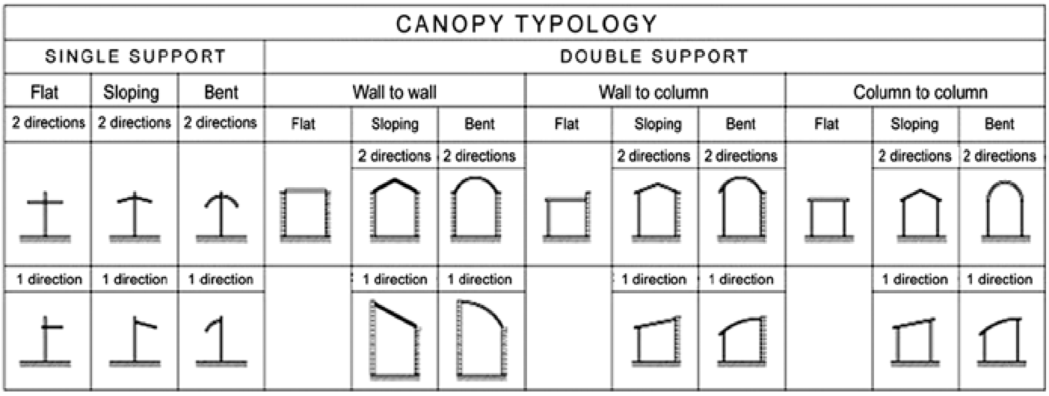


Figure 2.7. Typological analysis
(METU JFA 2007/2, 166)

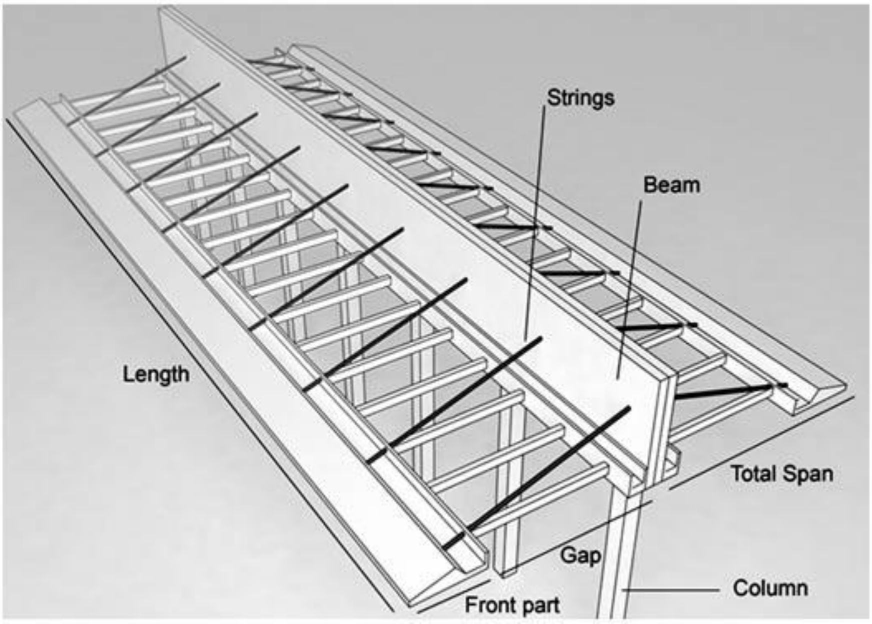


Figure 2.8. The design outline for the final project
(METU JFA 2007/2, 166)

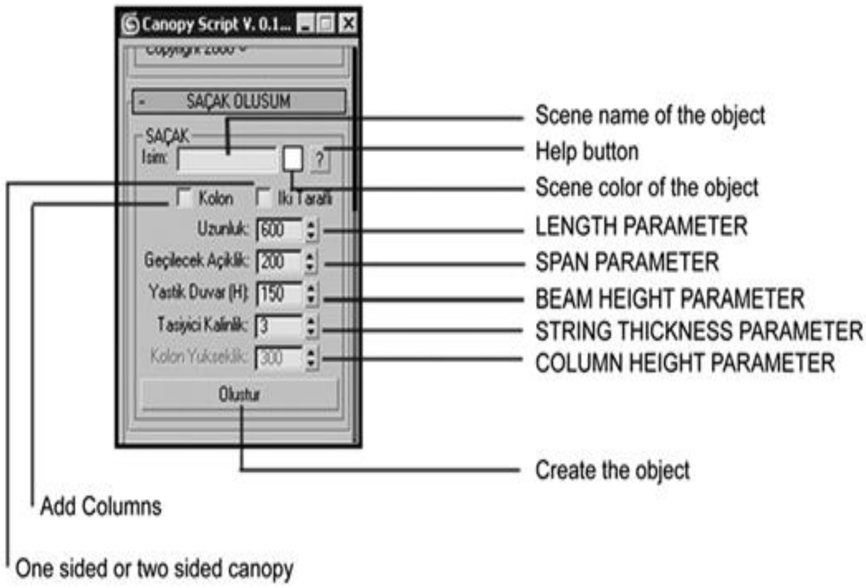


Figure 2.9. Graphical user interface of the student project
(METU JFA 2007/2, 166)

The final project process moves in three stages the first of which is the formal analysis phase, and the latter is the parameterization. The analysis is for the canopy typology research and the parameterization is for the canopy’s support.

The parameterization phase moves in six parameters as depicted in the figure2. And finally the test phase of the project is depicted in figure3. The graphic depicts the evaluation of the usability of the script and the reasonability of its outputs.

In conlusion, ‘’a designer in order to use computational tools in an explorative design context needs to be geometrically aware and computationaly enabled’’ (Aish, 2005). Designing the Design actually introduces a new of computational thinking and mechanism on which these tools operate.

2.2. Design Studio Affected by Computational Design

A comprehensive transformation process named ‘‘Digital Architecture’’ or ‘‘Computational Design’’ is not only a representation of a tool transformation. Beyond that it has a direct impact on the “school of design” appompanied with a cognitive design structure. It is generally accepted that in architectural design, tools and mindscapes go through a transformation parallel to design studios. However, there are still no acceptable pedagogic models which can handle such transformation.

The tools called studio exercises actually represent the teachability frame of this research. Especially exercises used at the early stages of studio education are evaluated as a pedagogic tool because they aim at improving the mindscape structure of students according to the architectural design thinking aspects.

Same approach was also utilized in advanced studio education. However, the potential contribution for new design thinking was quite vague. In order to understand the design studio with studio exercises, there should be constructed definitons which develop relationship between studio exercises and design studios utilizing logical fictions.

2.2.1. Studio Model Changes from "Behaviorist" to "Constructivist"

Before the teachability arguments came to the surface, the changeable and unforeseen situation of design exercise which is an intense intelligence activity, had already presented its learnability as a prerequisite. However, that learnability of design is accepted highly related with what learning activity is and how it is defined. In this manner, to build the pedagogy of the design education, education theories that have been developed recently in the science of education should be examined. These theories have been classified under four basic education models according to Yazar. (Yazar, 2009) Those;

- Behaviorist Learning Model,
- Cognitivist Learning Model,
- Constructivist Learning Model,
- Humanist Learning Model

Watson (1913), who claimed that the dog experiments of Pavlov on alteration of behaviors through conditioning have also similar results on humans, has been accepted as one of the founders of behaviorist learning model. According to the behaviorist approach, learning is the fact that human who comes into the world as mentally unoccupied get the information passively as a result of their developed reactions to their enviroments. This definition of learning is based on the memorization hypothesis which the student records the information in the way that they were given. In this type of education model, transfer of the information is focused on the teacher and the only efficient method for evaluation depends on the fact that the student returns the obtained information in a specific time. The behaviorist model consists of assumptions that there is not a genetic difference between indiviuals and they are able to obtain an ability at the same level.

In the mid of 20th century, with the developments on psychology of true perception and social sciences, behaviorist learning model has lost its place to a new and contrary model. The cognitivist learning model which admits that the human has an active role in learning rather than being passive, is based on evaluation of intelligent processes from an analytical perspective. According to this model, students process the information they are given like a computer and turns them into the information.

Since the mid of 20th century, development in children's psychology and education have provided the introduction of a different learning model based on constructivist approach. This learning model is approved among the present education systems. According to the constructivist learning model that emphasizes the significance of personal experiences, past information and environmental conditionals on learning process, getting knowledge should be based on the idea of intelligently synthesis rather than taking from outside. Bruner's Discovery Learning theory (1967) and Vygotsky's Social Development Theory (1978) are the most known learning theories in the paradigm of constructivism.

Some researchers, who support the approach of which each student has his/her own learning model in a general pattern, have focused on the systematic explanations of learning models which examine and classify these patterns. This kind of researches is called as humanist learning model.

2.2.2. Computer Usage is Transformed from "Presentation" to "Design"

Since the day that algorithmic design emerged, design thinking methods have changed. Even the lectures and classes became obligatory and computational design thinking has been included in many methods. For example, design studios introduced some new exercises compromising algorithmic design to teach the students how to use the computer in a better way or it could be said that in a more proper way so that the use of computers in a design world becomes necessary although in order to make the best of it, one needs to learn to use computer accurately. Therefore, universities and design schools and etc. started to offer new programs that included teaching of algorithmic design which introduces different ways of computer based design process.

Computer based design programs or courses actually came into existence with a clear introduction that would depict the benefits of computational design and the benefits of taking such courses. Computer use in design process actually started with CAD programs. It was basically used for the presentation basis of a design. Of course it has a lot of benefits with its problem solving features. However, some would argue that computational design limits the creativity process in architectural design. Apparently, it is true that computer programs test the design possibilities and structure stability and etc. Similarly, they only focuse on the presentation rather than design. For example computer programs like 3DMax, BIM programs and etc mainly focuse on modelling or 3D modelling of a prepared architectural design solution. And such modelling programs are basically used for presentation like rendering. Nowadays, rendering seems a very popular presentation method in architectural world. It is an obligation to prepare a model, or else a 3D model of one's design and present it in a more realistic way which might materialize with computer modelling programs. And since most of these programs are seen as limitation for creativity, it is obvious that the use of computer should address to the presentation rather than design.

Algorithmic design is actually based on numbers and parameters and most importantly on scripting which shows that design might occur with numbers or design with scripting. As mentioned before some experts argue that computers limit the creativity in the process of design. However, some other experst claim that because this algorithmic design method introduces a new way to architectural students and presents a new age of design, it actually offers a new approach in design process. "Computational design tools do not provide a designerly way of doing as does the intelligence acquired through design experience. However, they spread computational thinking which takes an approach to solving design problems and designing systems based on concepts fundamental to computer science." (Çolakoğlu, Yazar, 2007)

CHAPTER 3

COMPUTATIONAL THINKING AND ARCHITECTURE EDUCATION IN TURKEY

The developments in computer technologies did not go unnoticed by architectural education and the new technologies started to be used for research, analysis and examinations in architectural education. As a result of these researches in the computational thinking model of education, Turkey opened its doors for this new development. However, when compared to the other parts of the world, computer-based thinking started a bit late in Turkey. Therefore, introducing such kind of education was a big move in Turkish educational context. In general, the main concern of computation is to deal with problems on a computational model and to utilize an algorithm in its operation. To make the design problem solvable by the help of computation, it is also achievable to create a conceptual model in which the problem is represented with a set of variables and logical relationships between them. In this way, the computational design has provided that architects can solve complicated problems of the architectural design in a more conscious way using advanced computing capabilities and thus, computation has gained a place in the field of architecture.

There have been a lot of researches conducted about design in architecture, and they are still pursued. However, when it comes to the education of technology and especially the utilization of technological informations with design education, it has never been researched much in Turkey despite the fact that it is usually seen as a very important research area. This part mainly focuses on a kind of education based on computer and technology. However, architectural education has to be considered as a complete concept. As a result, in order to understand this new educational model created for technological education in architecture, a comparison is needed between architectural education in Turkey and architectural education around the world. The history of systematized architectural education in Turkey is not very old. Before the concerned law addressing the universities was accepted in 1944, architecture was a sub discipline of engineering department and students were named engineer- architect. Yet, in the following years, the department of architecture was separated and architectural courses were opened. During this historical process of architectural education, while pioneering architecture departments were trying to create an image of new architectural education, other universities followed them and developed thier educational models based on the models introduced by those first practioners. However, the term “ecole” used in the architectural context would not perfectly cover the creations of the first graduates of those universities. As a result, it was divided into subcategories as the better shipyard worker, the better drawer, the better detailer, and the better governor. This appeared as a big expectation not only in Turkey but in all parts of the world for the diversity and enrichment of architectural education. On the other hand, an equalizing movement has still been processed in terms of architectural education. Equalization in education is important considering the architecture as a profession. RIBA from Great Britain, NAAB from USA, MIAK, from Turkey are the foundations for the equalization. Other than that, there is a research conducted in order to keep the equalization among countries in architectural education.

It can be said that there is an equalisation attempt pursued in Turkey both nationally and internationally. The rising success of architectural end production created a kind of chaos today in the practice of architecture. The theoretical or practical subjects were mostly external in the architectural education in the recent past, but now it created a seperate area of specialization and the actual architect became neglected. So, a connection is needed between them. The discipline of architecture identifies the design as " a form imagined in mind". On the other hand, technology is " a developed tool in order to create, change and develope one's physical surrounding". From these description, it is obvious that design is all about mind while technology is a physical surrounding.

After the development of computer technology, lessons and courses and lectures started to emerge as an introduction to architecture students in Turkey. The research for new models to fit into architectural education considering the effects of computational design started. Çolakoğlu is one of the first researchers for computational design in Turkey. Computer is used as a tool in architectural education. Unlike the view of former researchers, in the educational approach introduced by Çolakoğlu (2007), it is declared that computational architecture education is higly related with computational thinking rather than mere algorithm progresses. But also computational thinking is described as having an algorithmic logic which is used in design as it is rational, consistent and systematized. Based on similar purposes, but covering a limited and a more specified field, this part introduces the distant seeds of computational thinking in the unique context of Turkish art and architecture. Turkey as a different context for not being a center of technological developments for many historical reasons seems to have peculiar stages in terms of its integration with computer culture. For the field of architecture and design, in the first sense, it seems reasonable to accept that the ideas are translated along with the transfer of digital technology. However, a more thorough insight will show that an important accumulation, increasingly in the recent decades, can be revealed highly in academic field as well as it is possible to discover earlier works that contain computational qualities in different forms.

3.1. CAD Based Architectural Design History Before 1990's in Turkey

It is quite obvious that the history of computers and computer based design in the architectural design is not very old. It only dates back a few decades when compared to the development of methods in practical design. (Gero, 1983) All the same, it is said that the development of the user interfaces has been very fast. From the view of architects, these interfaces are critisized for their inflexibility in sketching even though the computers can create drafts and the creation of alternatives in a quicker and more effective way in the final stages of designing.

Almost in all architectural departments in Turkey, there is a technology-based course. These courses are mostly to do with the theoretical knowledge. Therefore, how this theoretical knowledge can be connected with the stages of a design process seems a little bit vague. The concept of technology in Turkey is usually observed in the area of traditional building science.

Considering these approaches, architectural practice came up with some questions to understand this new era better;

With what are we going to create?

How are we going to create?

In what way are we going to create?

In what size are we going to create?

The questions actually have the answers related to technology. Students started using computer as a drawing tool and thus a representation tool. First, it started as a complementary element, a testing tool for drawing considering the beginner CAD software. In Turkey, universities have been using it as a 2D representational tool, for plans, sections and etc. However, the software was mostly to do with the utilization of the approach in the country. METU was one of the universities that integrated technology into its programs in 1993. Computer was used for the fourth graders' final design projects. However, not all the students made the use of it. Some would still prefer traditional ways of expressing a design concept. After the 90's, computer technology became an obligatory course, and it was considered as a tool for design concept process rather than a finalisation element.

CAD was used as a presentation tool in architectural education, rather than a design tool. Nowadays computer is basically preferred to solve a design problem; hence, it has been utilized during the process of architectural design. However, such courses, especially the courses based on CAD, are still in the curriculum of the architectural schools in Turkey. The table below depicts the schools which still conduct CAD –based courses as computational design courses in architectural education.

In addition, besides using computation based design only as an abstract presentation tool, the schools started to use it as a tool in architecture as well. In other words, it started to be used as a teaching and learning tool. AutoCAD became an obligatory course in the curriculum to help the architectural students broaden and revise their way of thinking. For example, ITU is one of the first universities to have introduced mandatory computation based design studios for students. Apparently, it brought about some disagreements among the academicians and professors in the first place mostly because it was a dramatic change and an entirely new perspective in architectural education. There was a constant discussion about the computational education. It was actually a gender discussion of who can absorb it better or learn it easily. There even came some statistical figures showing the eagerness for the computational design between genders. The results would show that male students were slightly more eager to wotk with computers, whereas female students would stick to more traditional ways of designing and presenting. Yet, it was before 90's and obviously technology was not that utilized and implemented in the schools of Turkey. But still, there are some courses and lessons that can exemplify the situation in the architectural schools in Turkey.

Table 3.1. Table depicting current courses in Istanbul Technical University and Middle East Technical University

SCHOOL NAME	COMPULSORY COURSES RELATED WITH DIGITAL		ELECTIVE COURSES RELATED WITH DIGITAL	
	Course Code	Course Name	Course Code	Course Name
Istanbul Technical University (ITU)	MIM 111	Architectural Design I and Rendering Techniques	MIM 318	Bilgisayar ile Yapma Çevrede İklimsel Performans Değerlendirme
			MIM 344	Mimarlıkta Enformasyon Teknolojileri
			MIM 345	Mimarlıkta Enformasyon Teknolojileri
			MIM 426	Günümüz Mimarlık Düşüncesi ve Tasarıma Yansıması
			MIM 439	Mimarlıkta Bilgisayar Uygulamaları
			MIM	Mimarlıkta Temsil ve Sunum
Middle East Technical University (METU)	ARCH203	DIGITAL MEDIA IN ARCHITECTURE I	ARCH 450	Generative Design in Architecture
	ARCH204	DIGITAL MEDIA IN ARCHITECTURE II	ARCH462	Computer Aided Drafting and Design
	ARCH351	BUILDING DETAIL MODELING	ARCH470	Digital Design Studio
			ARCH475	Digital Design Studio II
			BS534	Analytical Modeling and Computer Analysis of Structures
			ARCH477	Architectural Modeling
			ARCH524	Architecture and Different Modes of Representation
			BS566	Computer Graphics for Architectural Drafting Purposes
			BS565	Computer Programming and Introduction to Architectural Applications
			ARCH585	Computational Design Research Lab

Table 3.2. Table depicting current courses in İstanbul Bilgi University and Yıldız Technical University

SCHOOL NAME	COMPULSORY COURSES RELATED WITH DIGITAL		ELECTIVE COURSES RELATED WITH DIGITAL	
	Course Code	Course Name	Course Code	Course Name
Yıldız Teknik Universitesi (YTU)	ENB 0110	TEMEL BİLGİ TEKNOLOJİSİ KULLANIMI	MİM 4296	MİMARLIKTA ANİMASYON
	MİM 2281	ELEKTRONİK ORTAMDA ANLATIM		
	ENB 0120	TEMEL BİLGİSAYAR BİLİMLERİ		
Istanbul Bilgi University	ARCH 114	Tasarı Hesaplama	ARCH 362	Parametrik Modelleme
			ARCH 365	Mimarlık ve Hesaplama: Temalar

The table above shows the courses that are obligatory in ITU, METU, Bilgi University and YTU. Computer based design is compulsively used at those schools. However, before 1990's, this kind of modelling and 3D representing computational design was not popular. The computer use of architecture students was limited with CAD based programs, and it was only for 2D drawings and presentations. However, CAD based programs, especially AutoCAD was not used for 3D presentations, and it was not introduced to make architecture students achieve a new way of thinking according to the design methods. AutoCAD was a tool that had newly emerged as a technological tool and tried to be integrated into the educational world of architecture in order to catch up with changing technologies. The table below depicts the current situation in today's architectural schools and the programs that they use as compulsory and elective courses.

3.2. Computational Design Tecnologies After 1990's

Before 1990's, computer aided design was welcomed by architects just because it was a great opportunity, and it would offer many more practicalities. For that reason, "architects began using computers in ways that imitated the manual typing book keeping and drafting procedures customery to the profession."(Fabricating Architecture) During the 1990's, CAD software underwent many changes. Every architect knows that the CAD was used only for 2 dimensional drawing. It can be easily said that CAD programs changed architects' drawing; in other words, it changed the way they created the construction drawings. However, it did not change the role of these drawings immediately in the production of the buildings.

Previous CAD programs actually reflected many features of the architects using them. They might be ranged as of consisting multiple layers such as; ‘‘systems drafting techniques and eventually computerized drafting. It is an advantage for most of the practicing architects that the hand drafting is added or rather integrated as the substitution of hand drafting techniques for computer based drafting, and it turned out to be a big opportunity for architects and for many other practitioners like industrial designers, mechanical engineers and etc. This change or shift in the production of drafting is unquestionably seen as a huge advantage of the technology, and as a result, the need for productivity has increased. CAD programs were originally used only for two dimensional drawings, and they were regarded as primarily useful tools for construction documentation. During the 1990's, architects, academics and professors mainly focused on the newer and much better ways of representing the buildings and environments. The situation at that time may be defined as virtual reality. Creating realistic virtual environments were the demanded drafting abilities. Faster computers and more developed softwares would allow the realistic visualisation.

Turkey is still at the early stages of high technology, but there are great industrial and commercial demands, so the things are advancing rapidly. The following model is designed to explain the outlines of the corresponding courses intending to develop the scope of the architectural knowledge in the future and to replace design educators. The new developed educational model has three basic parts:

1- Design education

2-Design research

3- Evaluation of education, research and their correspondance to each other.

While planning the objectives of CAD education, the following issues are taken into consideration. Whether CAD was appropriate for the education in ITU was a contoversial issue for a while. Identification of some key and funding resources and the identification of CAD priority areas were not very clear.

The table below is prepared according to the curriculum of all the architectural departments in Turkey. It demonstrates elective and compulsory courses which are related with computational design so that which departments in Turkish universities are involved in computational design logic can be seen clearly.

Table 3.3. Curciculum analaysis of architecture departments in Turkey

SCHOOL NAME	COMPULSORY COURSES RELATED WITH DIGITAL		ELECTIVE COURSES RELATED WITH DIGITAL	
	Course Code	**Course Name**	**Course Code**	**Course Name**
Istanbul Technical University (Itu)	MIM 111	Architectural Design I and Rendering Techniques	MIM 318	Bilgisayar ile Yapma Çevrede İklimsel Performans Değerlendirme
			MIM 344	Mimarlıkta Enformasyon Teknolojileri
			MIM 345	Mimarlıkta Enformasyon Teknolojileri
			MIM 426	Günümüz Mimarlık Düşüncesi ve Tasarıma Yansıması
			MIM 439	Mimarlıkta Bilgisayar Uygulamaları
			MIM	Mimarlıkta Temsil ve Sunum
Middle East Technical University (Metu)	ARCH203	Dıgıtal Medıa In Archıtecture I	ARCH 450	Generative Design in Architecture
	ARCH204	Dıgıtal Medıa In Archıtecture II	ARCH462	Computer Aided Drafting and Design
	ARCH351	Buıldıng Detaıl Modelıng	ARCH470	Digital Design Studio
			ARCH475	Digital Design Studio II
			BS534	Analytical Modeling and Computer Analysis of Structures
			ARCH477	Architectural Modeling
			ARCH524	Architecture and Different Modes of Representation
			BS566	Computer Graphics for Architectural Drafting Purposes
			BS565	Computer Programming and Introduction to Architectural Applications
			ARCH585	Computational Design Research Lab

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Table 3.3. Curciculum Analaysis of Architecture departments in Turkey**(Continues)**

Izmir University Of Economics (IEU)	CE 100	Introduction to Computer and Information Technology	ARCH 322	Introduction to Computational design
	FFD 104	Computer Aided Technical Drawing	ARCH 420	Digital Based Design
	FFD 201	Computer Aided Architectural Graphics	ARCH 326	Architectural Geometry
Yıldız Teknik Universitesi (Ytu)	ENB 0110	Temel Bilgi Teknolojisi Kullanımı	MİM 4296	Mimarlıkta Animasyon
	MİM 2281	Elektronik Ortamda Anlatım		
	ENB 0120	Temel Bilgisayar Bilimleri		
Istanbul Bilgi University	ARCH 114	Tasarı Hesaplama	ARCH 362	Parametrik Modelleme
			ARCH 365	Mimarlık ve Hesaplama: Temalar
Gazi Üniversitesi	ENF101	Temel Bilgi Teknolojisi Kullanımı	M360	3d Stüdyo Uygulamaları
	M215	Bilgisayar Destekli Tasarım I	M471	Yapı Projelerinde Bilgisayar Destekli Tasarım Uyg.
	M214	Bilgisayar Destekli Tasarım II	M459	Mimari Amaçlı Multimedya
			M461	Dijital Ortam .Mod.Ve Bina Tipolojisine Bağlı Algı Sorun.(Öd)(Seç.)
			M482	3d Modelleme Ve Animasyona Giriş
Mimar Sinan Güzel Sanatlar Üniversitesi			MIM 254	Bilgisayar Destekli Modelleme
			ENF 401	Bilgisayar Destekli Çizim Ve Tasarım
			MIM 459	Sanal Ortamda Mimari Sunum
			MIM 862	Maket Teknolojileri
İzmir Yüksek Teknoloji Enstitüsü (İyte)	AR 264	Computer Aided Architectural Modeling	AR 313	Computer Aided Archıtectural Drawıng
			AR 463	Mimari Tasarımda Hızlı Prototipleme
Dokuz Eylül University (Deu)	MİM 1514	Bilgisayar Destekli Çizim	MİM 4624	Bilgisayar Destekli Çizim ve Takdim Teknikleri I
			MİM 4635	Mimarlıkta Bilgisayar Programlama
Yaşar University	ARCH 111	Architectural representations I	ARCH 250	Representational Media in Design
	ARCH 112	Architectural representations II	ARCH 270	Advanced 3D Modeling I
	ARCH 117	Spatial Geometry	ARCH 380	BIM-Building Information Modeling
	ARCH 211	Introduction to Digital Design	ARCH 371	Advanced 3D Modeling II
	ARCH 324	Computational Design	ARCH 450	Computational Intelligence in Building Design
			INAR 450	CAD-CAM and Rapid Prototyping
Tobb Üniversitesi				
İstanbul Arel Üniversitesi			MIMMAS001	Mimarlıkta Web Uygulamaları
Çukurova Üniversitesi	ENF 101	Temel Bilgi Teknolojileri Kullanmı		
	ENF 201	Bilgisayar Programlama		
	MIM 395	Bilgisayar Destekli Tasarıma hazırlık		
	MIM 396	Bilgisayar Destekli Tasarım		
Abant İzzet Baysal Üniversitesi		Temel Bilgisayar Bilgisi		
Anadolu Üniversitesi	MİM135	Mimarlıkta Bilgisayar Uygulamaları I		
	MİM136	Mimarlıkta Bilgisayar Uygulamaları II		
Bahçeşehir University	ARC1042	Mimarlıkta Digital Medya		
Balıkesir Üniversitesi	MBB 2113	Bilgisayar Destekli Mimari Tasarım I	MSD 1159	Temel Bilişim Teknolojileri
	MBB 2214	Bilgisayar Destekli Mimari Tasarım II	MSD 1260	Mimari Bilişim Teknolojileri
			MSD 4262	Bilgisayar Destekli Enerji Performans Analizine Giriş
Beykent University		Bilgi Teknolojileri Kullanımı		
Bozok Üniversitesi				
Cyprus Internatıonal Unıversıty	ARCT 205	Computer Aided Design I	ARCT 421	Visual Design with Comp. Aided Pres
	ARCT 206	Computer Aided Design I		

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Table 3.3. Curciculum Analaysis of Architecture departments in Turkey **(Continues)**

Dicle Üniversitesi	MİM309	COMPUTER AIDED DESIGN 1		
	MİM312	COMPUTER AIDED DESIGN 2		
	MİMS421	IN COMPUTER DESIGN III		
Doğu Akdeniz Üniversitesi (Daü)	FARC142	Tasarım Teknolojisine Giriş		
	ARCH281	Bilgisayar Destekli Tasarım - I		
Doğuş Üniversitesi	MİMA 207	Mimari Tasarımda Bilgisayar I	GS 309	Dijital İllüstrasyon
	MİMA 307	Bilgisayarda 3 Boyutlu Anlatım		
	MİMA 208	Mimari Tasarımda Bilgisayar II		
İstanbul Aydın Üniversitesi	BIL103	Bilişim Teknolojisi		
İstanbul Kültür Üniversitesi	MIM2010	Bilgisayar Ortamında Anlatım Teknikleri	MIM0504	Yapı Bilgi Modelleme
			MIM0503	İleri Modelleme Teknikleri
İzmir Unıversıty	ARC 114	Tasarımcılar İçin Bilgisayar Bilgisi		
	ARC 211	Bilgisayar Destekli Çizim Ve Tasarım I		
	ARC 212	Bilgisayar Destekli Çizim Ve Tasarım II		
Karabük Üniversitesi			MIM229	Tasarımda Bilgisayar I
			MIM234	Tasarımda Bilgisayar II
			MIM377	Tasarımda Bilgisayar III
			MIM388	Tasarımda Bilgisayar IV
			MIM465	Mimaride Bilgisayar Destekli Tasarım Stüdyosu
Kocaeli Üniversitesi	MIM111	Mimarlıkta Bilgisayar Teknolojileri Kullanımı		
	MIM122	Bilgisayar Destekli Tasarım		
	MIM152	Dijital Sunum Teknikleri		
Maltepe Üniversitesi	MİMB 172	Bilgisayar Destekli Sunum		
Mardin Artuklu Üniversitesi	MİM 205	Bilgisayar Dest. Tasarım Ve Temsil		
	MİM 206	Bilgisayar Dest. Tasarım Ve Temsil II		
Selçuk Üniversitesi				
Uludağ Üniversitesi	MIM 2006	Bilgisayar Destekli Tasarım		
Yeditepe Üniversitesi	ARCH 103	Mimarlar için Bilgi Teknolojisi	ARCH 432	Modelleme ve Fotograflama
	ARCH 172	Mimarlar için CAD		
	ARCH 271	Mimarlar için CAD II		
	ARCH 272	Mimarlar için CAD III		
Atılım Üniversitesi	MMR 205	Bilgisayar Destekli Çizim I	GTM 009	Üç Boyutlu Mimari Animasyon
	MMR 206	Bilgisayar Destekli Çizim II	GTM 026	Bilgisayarla İleri Sunum II
			GTM 025	Bilgisayarla İleri Sunum I
Başkent Üniversitesi	MİM 136	Mimari Sunum	MİM 441	Bilgisayar Destekli Modelleme
	MİM 229	Bilgisayar Destekli Tasarım I	MİM 445	Bilgisayar Destekli Animasyon
	MİM 230	Bilgisayar Destekli Tasarım II	MİM 463	Mimarlıkta Kodlama
			MİM 466	Parametrik Tasarım
Çankaya University	ARCH 106	Innovative Digital Applications I		
	ARCH 285	Innovative Digital Applications II		
Erciyes Üniversitesi	MİM 212	Bilgisayar Ortamında Sunum Teknikleri	MİM S03	Mimarlıkta Hesaplamalı (Computatıonal)Tasarım Yaklaşımları
	MİM 315	Mimari Modelleme Teknikleri	MİM S06	Bilgisayar Destekli Mimari Çizim
	MİM 316	Bilgisayar Destekli Tasarım	MİM S26	Mimari Animasyon
			MİM S32	İleri Düzey Photoshop
			MİM S59	Yapı Bilgi Modeli (Bım) Ve Uygulamaları
Eskişehir Osmangazi Üniversitesi	152012201	Temel Bilgisayar Bilimleri		
	152011XXX	Bilgisayar Destekli Tasarım 261		
	152011XXX	Bilgisayar Destekli Tasarım 262		
Gaziantep Üniversitesi				
Hasan Kalyoncu Üniversitesi				
Gebze Yüksek Teknoloji Enstitüsü	MİM 102	Mimarlıkta Bilgisayar Uygulamaları	MİM 216	Mimarlıkta Sayısal Tasarım
			MİM 356	Bio-dijital Mimarlığa Giriş
Haliç Üniversitesi				

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Table 3.3. Curciculum Analysis of Architecture departments in Turkey**(Continues)**

Karadeniz Teknik Üniversitesi				
Mersin Üniversitesi	MIM 263	Bilgisayar Destekli Tasarım-I		
	MIM 264	Bilgisayar Destekli Tasarım-II		
Okan Üniversitesi	ARCH112	Computer Applications in Architecture	ARCH489	Computer Modelling
	ARCH209	Computer Aided Design	ARCH462	Advanced 3D Modelling
Süleyman Demirel Üniversitesi				
Özyeğin Üniversitesi	MİM 203	Bilgisayar Destekli Tasarım I		
	MİM 204	Bilgisayar Destekli Tasarım II		
Ted Üniversitesi	CMPE 101	Introduction to Information Technologies		
Trakya Üniversitesi				
Yüzüncü Yıl Üniversitesi				
Akdeniz Üniversitesi				
Amasya Üniversitesi	MIS 105	Bilgisayar Prog.-1		
	MIS 106	Bilgisayar Prog.-2		
Atatürk Üniversitesi				
Gediz Üniversitesi	AR 141	Tasarımcılar İçin Bilgisayar Uygulamaları I	AR 472	Portfolyo Tasarımı
	AR 142	Tasarımcılar İçin Bilgisayar Uygulamaları I I		
	AR 241	Tasarımcılar İçin Bilgisayar Uygulamaları III		
	AR 242	Dijital Mimari Modelleme		
Avrasya Üniversitesi				
Batman Üniversitesi				
Bilkent Üniversitesi	ADA 134	Sayısal Ortamda Tasarım	ARCH 317	Parametric Design Studio
Bursa Orhangazi Üniversitesi				
Canik Başarı Üniversitesi	MİM108	Mimarlık İçin Bilgisayar Teknikleri	MİMS401	İleri Bilgisayar Destekli Çizim Ve Tasarım
	MİM211	Bilgisayar Destekli Tasarım / Uygulama I	MİMS406	Mimari Animasyon
	MİM212	Bilgisayar Destekli Tasarım / Uygulama II		
Çanakkale 18 Mart Üniversitesi				
Fatih Sultan Mehmet Üniversitesi	MIM182	Bilgi Sistemleri - Bilgisayarlı Tasarıma Giriş		
	MIM281	Bilgisayarlı Tasarım I		
	MIM382	Bilgisayarlı Tasarım II		
Hasan Kalyoncu Üniversitesi				
Gedik Üniversitesi	MİM103	Bilgisayara Giriş	MİM417	Bilgisayarlı Tasarımda 3d Modelleme
	MİM207	Bilgisayar Destekli Tasarım I		
	MİM208	Bilgisayar Destekli Tasarım II		
Girne Amerıkan Unıversıty	ARC211	Dıgıtal Desıgn And Presentatıon 1		
	ARC212	Dıgıtal Desıgn And Presentatıon 2		
İstanbul Gelişim Üniversitesi	TSD241	Bilgisayar Destekli Tasarım I		
	TSD242	Bilgisayar Destekli Tasarım II		
	TSD341	Bilgisayar Destekli Tasarım III		
	TSD342	Bilgisayar Destekli Tasarım IV		
İstanbul Medeniyet Üniversitesi				
İstanbul Kemerburgaz Üniversitesi	ARCH 284	Sayısal Tasarıma Giriş	ARCH 282	Dijital Çizim ve Sunum Teknikleri
			ARCH 382	Mimarlık ve Sayısal Tasarım
İstanbul S.Zaim Üniversitesi	MIM 211	Bilgisayar Destekli Tasarım I - Caad I		
	MIM 212	Bilgisayar Destekli Tasarım II - Caad II		

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Table 3.3. Curciculum Analaysis of Architecture departments in Turkey**(Continues)**

Kadir Has Üniversitesi	ARCH 211	Bilgisayar Destekli Tasarım (CAD)		
	ARCH 212	Sayısal Tasarım Stüdyosu		
Kocaeli Unıversıty	MIM111	Mimarlıkta Bilgisayar Teknolojileri Kullanımı	MIM152	Dijital Sunum Teknikleri
	MIM122	Bilgisayar Destekli Tasarım		
Lefke Avrupa Üniversitesi				
Melihşah Üniversitesi	MIM 104	Bilgisayar Destekli Çizim 1		
	MIM 203	Bilgisayar Destekli Çizim 2		
	MIM 204	Bilgisayar Destekli Tasarım Atölyesi		
Mustafa Kemal Üniversitesi	MIM 2406	Bilgisayar Destekli Tasarım I		
	MIM 2511	Bilgisayar Destekli Tasarım II		
Niğde Üniversitesi	ENF1021	Temel Bilgisayar	MIM3034	Bilgisayar Destekli 3 Boyutlu Çizim
Nuh Naci Yazgan Üniversitesi				
Pamukkale Üniversitesi				
Toros Üniversitesi	ARCH 283	Bilgisayar Destekli Tasarıma Giriş		
	ARCH 284	Bilgisayar Destekli Tasarım		
Uluslararası Kıbrıs Üniversitesi	ARCT 205	Computer Aided Design I	ARCT 421	Visual Design with Comp. Aided Pres
	ARCT 206	Computer Aided Design II		
Van Yüzüncü Yıl Üniversitesi				
Yakın Doğu Üniversitesi	ARCH-203	Bilgisayar Destekli Tasarim I	ARCH-444	Bilgisayarla Sunum Teknikleri
	ARCH-206	Bilgisayar Destekli Tasarim II		
	ARCH-307	İleri Bilgisayar Destekli Tasarim		
Yeni Yüzyıl Üniversitesi	MİM109	Bilgisayar Destekli Tasarım I		
	MİM110	Bilgisayar Destekli Tasarım II		
	MİM211	Bilgisayar Destekli Tasarım III		
	MİM212	Bilgisayar Destekli Tasarım IV		
	MİM310	Mimarlık Teknolojileri IV		
Zirve Üniversitesi	ARC 112	Bilgisayar Destekli Tasarım I		
	ARC 213	Bilgisayar Destekli Tasarım II		

As a result, after the 90's computer based design developed. It was not only AutoCAD to be used for designing but also some new technologies emerged and started to be used and integrated into the educational world of architecture. For example, in studios, especially in the studios of Middle East Technical University, at the second year of architectural education, the course named Digital Design was actually a compulsory course to be completed by students. At the first year of the architectural education, the computer based design is not taught. However, the design studios encourage students to think in a more parametric way and craft in a more computerized way. The computational design part starts during their first year of internship. In order to pass the course, the internship students need to learn and present their drawings in AutoCAD. Not only AutoCAD is taught as a learning tool for students in computational design but also BIM product known as ArchiCAD is taught in order to make students gain knowledge of 3D modelling and representing ways of their projects.

Table 3.4. Table of compulsory courses in YU, AU, and BU

SCHOOL NAME	COMPULSORY COURSES RELATED WITH DIGITAL		ELECTIVE COURSES RELATED WITH DIGITAL	
	Course Code	Course Name	Course Code	Course Name
YEDİTEPE ÜNİVERSİTESİ	ARCH 103	Mimarlar için Bilgi Teknolojisi	ARCH 432	Modelleme ve Fotograflama
	ARCH 172	Mimarlar için CAD		
	ARCH 271	Mimarlar için CAD II		
	ARCH 272	Mimarlar için CAD III		
Atılım Üniversitesi	MMR 205	Bilgisayar Destekli Çizim I	GTM 009	Üç Boyutlu Mimari Animasyon
	MMR 206	Bilgisayar Destekli Çizim II	GTM 026	Bilgisayarla İleri Sunum II
			GTM 025	Bilgisayarla İleri Sunum I
BAŞKENT ÜNİVERSİTESİ	MİM 136	MİMARİ SUNUM	MİM 441	BİLGİSAYAR DESTEKLİ MODELLEME
	MİM 229	BİLGİSAYAR DESTEKLİ TASARIM I	MİM 445	BİLGİSAYAR DESTEKLİ ANİMASYON
	MİM 230	BİLGİSAYAR DESTEKLİ TASARIM II	MİM 463	MİMARLIKTA KODLAMA
			MİM 466	PARAMETRİK TASARIM

The table above shows that, for example, in Yeditepe University 3D modelling is not a compulsory course unlike the case in METU. The compulsory classes are limited with CAD courses only. The 3D modelling and representing is only listed as elective courses. Just like the situation in Atılım University, the compulsory courses for computational design is only limited for drawing for designing but not modelling. However, 3D modelling and advanced presentation of a project is only seen as elective courses. As a result, it can be easily said that since the 90's, education system design studios have changed, and computation based education systems have become more common. The way of thinking has changed with the the computer as well, as in the past it was regarded as a drawing tool rather than a learning or designing tool. The educational systems in METU, ITU and YTU in terms of the computational design are good examples of the change mentioned here.

Thus, it can be said that the educational views of the universities are extremely important because there should be a balance between the disadvantages and advantages of such views. The course analysis above depicts that CAD is used widely all over Turkey, and it is of great use. "Of course, the software cannot intend anything, and certainly the developers did not intend such results, but the effect remains. This phenomenon can also be illustrated with reference to the graphic design". (Lawson, 2002)

CHAPTER 4

EVOLUTION OF COMPUTATIONAL DESIGN EDUCATION IN TURKEY

All universities and targets in Turkey have been examined within the scope of the thesis. It examines lesson mechanism, program content and curriculums of universities. Yıldız Technical University (M.Sc. Programme in Computer Aided Architectural Design), Istanbul Technical University (Architectural Design Computing M.sc Program), Middle East Technical University (MS. Computational Design and Fabrication Technologies), and Bilgi University (Architecture undergraduate program) have been studied for their use of computational design logic. There are no radical changes in these universities, but at least there are initiatives. So only, there is no fundamental change in the curriculum, but the computational design logic is used in the courses. For example, it has also been observed that some experiments have been conducted in universities such as the İzmir University of Economics and Yasar University. The four selected universities are examined with reference to their objectives and contents. It has been found that they have introduced some new methods for the computational design thinking. In this context, the course contents and circiculum of these programs have been analysed in order to understand the newly formed educational models.

4.1. YTU M.Sc. Programme in Computer Aided Architectural Design

Graduate program in Yıldız Technical University, called M.Sc. Programme in Computer Aided Architectural Design which offers master and doctoral degrees, started in 1991. The founder of the programme, Prof. Dr. Necati İnceoğlu, was the academician who introduced the first studies about computational design not only in the university but also in Turkey. According to Prof. Dr. Birgül Çolakoğlu, who is currently the head of Computational Design Graduate Program and also still gives undergraduate and graduate courses in Yıldız Technical University, Inceoğlu was a pioneer in this field. He could foresee which way the architecture would improve through. At the beginning, computer was so unprecedented that there was no experienced staff about computer technologies. But those who constitued the programme were design-aided academic members who did not have detailed knowledge about computer and also cad programming. Their training had started with the help of The Chamber of Architects. Therefore, the first studies were in the matter of how this new tool is used, how it could be integrated with architecture and architectural process and how it could be useful in design process.

In the following years, computer has been integrated to the education very fast and AutoCAD started to be used in courses. In 1994, drawings of a collective housing project in undergraduate studio were generated by using AutoCAD as it included many units and modulations repeating greatly and CAD was beneficial in behalf of gaining time. The project based on arrangement of terraced houses placed on a sloping terrain was finalised with AutoCAD 11 succesfully and hence it was stimulating for that period. Concordantly, these CAD courses were also offered in graduate programmes. The main objectives of the courses were to use the programme as a tool and to fasten the drawing process decreasing the load on architects/students, thus it was predicted that the architect would have more time for designing rather than drawing.

In 1994-1995 academic year, the first 3D modelling and animation courses started in Turkey. An instructor came to Yıldız Technical University and introduced the modelling programme of 3D Studio. This was an innovation for that period as there was no one who was able to use these 3D modelling programmes. With these newly introduced courses, many experts of computational modelling and design started working in the field. By 2000, YTU had become a leading university with a big emphasis on computational design within the university's existing courses.

Starting in 2000s, the question would center around how the computer can be used as an expression of intelligence besides being used as a tool. It was also argued in which way the computer could be used as a producing and manufacturing tool instead of being a mere drawing machine. A thinking method based on mathematics, called parametric design, started to be introduced. In coordination with these developments, Yıldız Technical University also started to revise its educational approach to computational design.

In 2002-2003 academic year, a drastic change that would lead students up to another stage in programming has been made. Çolakoğlu says that according to this new approach, the goal of the architecture faculty should be teaching thinking methods to the students together with some necessary skills. Introducing the methods of research and guiding them onto new channels of thinking should be the objectives of the related programs at universities. In the direction of these objectives, the architecture department got re-structured. In addition to that, with the emergence of internet technologies, the examples from all around the world have become accessible to individuals, and the developments in the field started to be followed easily. Self learning platforms on the internet provided that the individuals can learn the technology and innovations on his/her own. And so the students also started to learn new methods and programmes in the field of computer aided design which were not thought in the architecture faculty. Çolakoğlu says that ‘’ All these developments and the requests coming from the students have forced the architecture schools to change their curriculums and course contents. ‘’

We can conclude that the existing education approach at YTU’s Faculty of Architecture started to be re-shaped after 2003.

4.1.1. Aim of the Program

The new objectives of both the graduate and the undergraduate programs were to improve the students’ thinking skills and teach them also new thinking methods. In accordance with these goals, leading students in innovative and inquisitive thinking process must be the education model of the courses in general rather than teaching how to use ‘the tool’ of computer. The new curriculum of graduate program was arranged according to this model. The transformation and adaptation process to the general curriculum of the university was not tough as the program was formed independently. At the same time, the aim of the program was to construct a new program which has its own editing.

Program Outcomes

1. Critical Thinking: Academic and professional with critical thinking in general subjects interpret, evaluate opposing views, to reach categorical conclusions
2. Analytical Thinking: Test by using scientific methods and technologies, problems and solutions specialists to produce an attitude of thinking and creative
3. Research: The Architecture of obtaining information about processes, assessment, propose a study on the architectural design and computer-aided design, existing information search, access and compiling the results obtained using the new research direction of the guiding
4. Presentation Techniques: national and international arenas, fields of architecture, design theory, computer and communication technologies and presentation effective oral, written and visual products to communicate with supported
5. Design: Architectural design and related design fields, in support of computer-related field of specialization and perform theoretical and practical studies on the academic level, the logic of the research design and method for the coupling of a subject
6. Technological innovations: architecture, computing, communications, and other related issues to be aware of technological innovation, information
7. Sustainable Design and Technology Relations: architectural and urban design decisions, technological inputs concept of sustainability, the sustainable design of these technologies to examine relationships
8. Interdisciplinary Study: relationship of different disciplines in the research, analysis and interpretation, and conduct an interdisciplinary study
9. Scientific Ethical Behavior: Research and publications in the field to use the correct scientific and ethical principles, norms and standards of behavior to develop the necessary knowledge and
10. National and international expansion: expansion of the program to strengthen inter-agency work on all kinds

Figure 4.1. Program outcome of YTU master program
(http://www.bologna.yildiz.edu.tr/index.php?r=program/view&id=242&aid=38)

As a result of this program, students learn critical and analytical thinking, tecnological innovations, research and presentation skills, scientific ethical behavior, and interdisciplinary study. They explore the interdisciplinary platform between architectural design and computer technology. They understand the contributions of art and architecture to the enrichment of electronic media, information access and creativity.

4.1.2. Curriculum and Lessons

Basically, there are 10 elective courses besides the obligatory courses such as graduate workshops, seminar and thesis. The graduate students must complete the all obligatory courses and seven of elective courses to be able to graduate. They are free to decide which courses they would register according to the their own academic objective. In the curriculum of the program, 10 program outcomes are catalogued and a matrix that shows the relation between the courses and outcomes is presented. According to the interview that I made with Çolakoğlu, now I will explain the contents of some courses. One of them is the ‘Computational Design Theory’.

Course & Program Outcomes Matrix

		Program Outcomes									
Code	Title	1	2	3	4	5	6	7	8	9	10
MIM5125	Graduate Workshop 1	5	5	4	4	5	3	5	3	5	-
MIM5126	Graduate Workshop 2	5	5	4	4	5	3	5	3	5	-
MIM5102	Introduction to 3D Modelling and Animation	5	5	5	5	5	5	5	5	3	-
MIM5101	3D Studio Practices	5	5	5	5	5	5	5	5	3	-
MIM5103	Interface Design	5	5	5	5	5	5	5	5	3	-
MIM5106	Shape Grammars	4	5	4	4	4	5	2	5	4	-
MIM5107	Techniques of Computer Aided Architectural Representation	4	4	5	5	3	3	3	5	5	-
MIM5108	Concepts of Informatics	4	3	5	3	-	5	-	4	-	-
MIM5109	Computer Programming for Graphics	5	5	-	5	5	5	5	5	3	-
MIM5115	Computational Design Theory	-	5	5	4	4	5	1	3	5	-
MIM5116	Basic Concepts of Computational Design	5	4	5	5	5	4	-	-	-	-
MIM5132	Computational Design Technologies	5	3	3	4	3	5	-	-	-	-
MIM5001	Seminar	4	5	5	4	4	3	-	4	-	5
MIM5000	M.Sc. Thesis	5	5	5	3	2	5	5	5	5	-

Figure 4.2. Program outcome matrix of YTU master program
(http://www.bologna.yildiz.edu.tr/index.php?r=program/view&id=242&aid=38)

The main objective of the course ‘Computational Design Theory’, lectured by Çolakoğlu for 8 years, is to emphasize the different methods of thinking and answering the questions such as what is algorithmic thinking and what is the relation with design process. The brief conclusion of the researches and discussions that are made in the class can be stated as:

‘’Actually the designer/architect thinks algorithmically and the language of this algorithmic design process is an abstract language. But the formal background of this language is also geometry in conclusion.’’

She says that the architects should have a comprehensive knowledge of geometry to make some geometrical compositions and the abstract compositions in design. But generally, the architects use geometry intuitinally without being aware of this situation. They use plenty of geometrical rules that do not go beyond some limited geometry knowledge. As she teaches in the lectures, Çolakoğlu thinks that the architects should have more than this limited knowledge of geometry. This is because the tools in the programs that have been created for designers and architects have a geometrical and mathematical logic and work based on defined rules depending on the cause and effect relation. Due to all these reasons, in the ‘Computational Design Theory’ course, it is clearly seen that the computational language, designer language and the language that is used in tools can overlap in some point and the designer is not far away from this point.

As parallel to that course, Çolakoğlu also give the Shape Grammars course in the master program. She expresses that the Shape Grammars are the first formal methodologies of computational design. They can be thought as mathematical based approaches at creating different form compositions and a logical bridge between the real world and the computational world as shape grammars deal with geometry and form which are well-known concepts by designer or architect.

Another course that is offered in the master program is 'Graduate Workshop'. This is the course in which the knowledge given in other theoretical lectures turns into practice. With this course, it is underlined that first it is necessary to reach the parameters to create a form and then to define such parameters in a network of relations. According to the process of finding out parameters and linking them, outcome of the exercise emerges as a form. The main point of this course is that in generating form, parametric information and the cause-effect relationsbehind them should be studied together, and hence, judging by the sythensis of all this information, designer will be able to create the form that is needed.

In the master program of 'Computer Aided Architectural Design' in Yıldız Technical University, the main project course is not like a studio course as Çolakoğlu claims. Mentioned in the previous title, Graduate Workshop may be understood as a workshop designed for 3 hours a week. However, the coordinator of the course, Çolakoğlu, says that students have to take it as a project course because of the time time-limit.

In this project course, initially, a design problem is defined and it is expected that the problem is solved with the utilization of all digital tools. The whole process including the design and manufacturing is important for the project. It is highly emphasized that anything that could not be transferred to the manufacturing is not generated. It means that nothing should remain on the paper as a theory because the ultimate goal is to teach by practising. There are also supportive courses that improve the programming skills in advanced levels. They go parallel to the thinking method. These courses don't intend to teach softwares such as script, rhino or grasshopper. In the introductory stage, intense rhino lectures are given, and they last for three weeks. Students are expected to learn the logic of the program during this short term. After the introduction, the student should improve his/her own on digital programs as it is necessary for them to develop their own methods while using the tools. It is also fundamental that how the scripts or codes are established is defined with a prestudy.

After constituting the geometrical logic and defining the relations of parameters, one can start to use the tool successfully.

At the end of all this process, students meet the language of script that is intermediary language providing designer’s geometric language translation into the digital program. In this way, they can experience the richness of variation and the broadness of the design world. For example, just changing some parameters, they can obtain 30 different alternatives.

4.1.3. Evaulation

As a conclusion, Çolakoğlu states her vision of the curriculum of architecture schools. She thinks that the supreme disadvantage of current architecture faculties is not doing industry-oriented researches. The field of computational architectural design is capable of hosting research and development studies that can contribute to the industry especially to the construction industry with the innovation of construction systems and materials. According to her, the fact that the computational logic and the data processing in architectural design contribute to the research and development integrating with the architectural design will be crucial for the new structuring of curriculum in architecture schools. It is seen in the scope of these evaluations that material, construction and practice knowledge has taken an important place in architectural education.

4.2. ITU Architectural Design Computing M.sc Program

A graduate program in Istanbul Technical University is called M.sc programme. This is a graduate program under the Department of Informatics which provides training in master and doctorate level. The coordinator of this programme is Prof. Dr. Mine Özkar Kabakçıoğlu. Prof. Dr. Gulen Cagdas is the president of the branch of the main science or ' The Institude of Science and Technology' department in precise. Prof. Dr. Gülen Caglan who is currently the head of Computational design in architecture is also a member of executive commitee.

The history of the master and Phd programs starts as a need in higher education. The first doctoral admission in the faculty of architecture was in 1955, and the first doctoral award was given in 1960. The Institude of Science and Technology was established by the Rectorate in 1982 for for the establishment of master's and doctoral programmes under the new higher education law. As a major institute providing graduate studies at the university with seventy master's programs and 45 doctoral programmes, it awards around 700 master's degrees and 100 doctorates yearly and has so far awarded more than six thousand master's degrees and doctorates. The doctoral programmes in the field of architecture provided by the institude of Science and Technology are; Architectural Design, Building Sciences, and History of Architecture and Restoration. A recent addition to these is a doctoral programme under the department of Informatics. It is named as "Architectural Design Computing."

4.2.1. Aim of the Program

Architectural Design Computing is a new approach in the architectural design area. The program can be seen as an integrated study that confronts the basic architectural design process and provides an alternative. There are many research areas that the architectural design computing actually focuses on. They are;

Research on the Tools, Products and Media as well as Modeling Approaches and Paradigms that Enhance and Facilitate Theoretical and Applied Studies in the Intersection of Architecture and Information Technologies

• Concepts Emerging in Parallel with the Developments in the Intersection of IT and Design Disciplines: Cyberspace, Virtual Reality, Interaction Design, Communication, Interface Design, Embedded or Pervasive Environment.

. Computer Aided Design Paradigms

• Computational Design Methods

. The Phenomenology of Computational Thinking

. The Pedagogy of Computational Design

• Generative Approaches, Shape Grammars and Fractals in Architectural Design

• Genetic, Nanotechnological, Evolutionary and Generative Approaches in Architectural Design

• Design and Representation in Multimedia and Web Environments

. Visualization of Design Data

• Remote Sensing and Spatial Data Processing

• Data Mining in Architecture

• Theory of Space with regards to Information Technologies

• Cognitive Processes, Their Extensions and Related Tools in Architectural Design

• Building Information Models

• Interdisciplinary Studies and Architecture

The aim of the program is to use and develop architectural creativity as integrated with information and communication technologies; scientific, technological, intellectual and social developments, to produce original solutions by using various approaches, methods and techniques with a researcher and an expertise and a creative thinking system to the problems; research, application and training in the fields of success can take the task to train graduates.

4.2.2. Curriculum and Lessons

Apparently, the program is not exclusively designed for only architecture strudents. Interior designers, industrial product designers, urban and regional planners, landscape architects and computer engineers are also allowed to apply to the program.

The program aims to provide students with innovative and inquisitive thinking process. In addition, it intends to improve the thinking skills and create new designing methods. Thus, some additional courses appeasered. For example there is a Digital Architectural Design studio;

ITU
Graduate Course Catalogue Form
(The Course Of Digital Architectural Design Studio)

Name	Digital Architectural Design Studio (Dijital Mimari Tasarım Stüdyosu)
Code and Level	MBL514E - Master
Program	Architectural Design Computing
Language and Term	English - Spring
Type	Compulsory*
Credit	3
ECTS Credit	7.5

* The type of course is valid for only its program, it may be different for other programs.

Course Infos

Course Description To research, propos
develop and use a series of tools, method
and approaches for solving an architectur
design problem by means of computation
methods, To discuss and evaluate th
reflection of computational architectur
design approaches on the field
architectural design.

Figure 4.3. ITU graduate course catalogue form
(http://mimarliktabilisim.wixsite.com/adcomputing/msc)

This is a course of architectural design studio and it aims to solve the architectural design problems using computational methods. The objective of this course is to generate innovative, creative, and original architectural design solutions by using computational design methods. In addition, the second aim is to acknowledge, evaluate and use architectural design computing processes, tools, methods and approaches. The outcomes of this course might be defined as: It is a helpful tool for a student, and if she or he wants to come up with the creative solutions for architectural design problems, she or he will be able to use the computational methods in order to create them. Another outcome is to provide the students with the understanding of the interdisciplinary character of architectural design related computational methods and to be able to use this knowledge for proposing new design tools, methods and solutions. And finally the third outcome of this course is to be able to execute critical analysis, synthesis, and evaluation of new architectural design approaches brought by computational methods.

There are some activities that reinforce the outcomes mentioned above. And computer programs used for the course are; drafting, 3D modelling and scripting software and tools such As Autocad,3dmax, Rhıno, Maxscrıpt, Rhinoscript, Grasshopper, Processing.

ITU
Graduate Course Catalogue Form
(The Course Of Generative Systems in Architectural Design)

Name	Generative Systems in Architectural Design (Mimari Tasarımda Üretken Sistemler)
Code and Level	MBL512 - Master
Program	Architectural Design Computing
Language and Term	Turkish - Spring
Type	Compulsory*
Credit	3
ECTS Credit	7.5

* The type of course is valid for only its program, it may be different for other programs.

The objectives of this course;

#	Objectives
1	To be informed about the role and application of generative processes in architectural design
2	Analysis of architectural design in the context of the current design paradigms
3	To analyze the grammar of architectural styles, to develop new design grammars and to be able to use grammar approaches in the creative design process.
4	To be able to use fractals and patterns as a tool for aiding design
5	Designing and implementing a generative design model

Course learning outcomes of this course;

Course Infos

Course Description Computational architecture; Algorithmic and parametric architectural design; Generative systems in architectural design; Models that constitute fundamentals of generative architectural design systems: architectural languages and typologies; Architectural design knowledge and representation and interpretation of generative knowledge; Different generative design approaches and models; Components regarding architectural design product and design process, design elements, relationships between design elements and operators used in computer aided design process; Shape grammar and design grammar approaches; Design grammar types and structures; Defining the rule-sets of architectural languages and generation process of designs; Fractal geometry and its role in architectural design; Approaches regarding generation of fractal designs and patterns within computing environment; Parametric generative system application in architecture; Development of a generative model by using a computer programming language.

Figure 4.4. ITU graduate course information form
(http://mimarliktabilisim.wixsite.com/adcomputing/msc)

The course title is Generative Systems in Architectural Design. It is a compulsory course by the program architectural design computing. The primary objectives of the course are to get familiar with the role and application of generative processes in architectural design besides analysis of architectural design in the context of the current design paradigms. Other aims can be explained as: to analyze the grammar of architectural styles, to develop new design grammars, to be able to use grammar approaches in the creative design process, To be able to use fractals and patterns as a tool for aiding design, and finally, to design and implement a generative design model. On the other hand, the expected outcomes of the listed objectives above can be listed as developing and intensifying knowledge in the architectural design computing area based upon the competency in the undergraduate level. Additionally, there is an the inter-disciplinary interaction related to the architectural design computing area which can be seen as interpreting and forming new types of knowledge by combining the knowledge from the architectural design computing area and knowledge from various other disciplines. The third outcome of the course is the ability to use the expert-level theoretical and practical knowledge acquired in architectural design computing area. The fourth outcome is solving the problems faced in the area by making use of the research methods. The fifth outcome is the ability to carry out a specialistic study related to architectural design computing area independently. The sixth one is using the computer software together with the information and communication technologies efficiently and according to the needs of the architectural design computing area. The seventh one is being sensitive to social, scientific, cultural and ethical values during the collecting, interpreting, practicing and announcing processes of the architectural design computing area related data and the ability to teach these values to others. And the final one is using the knowledge and the skills for problem solving and/or application (which are processed within the area) in inter-disciplinary studies.

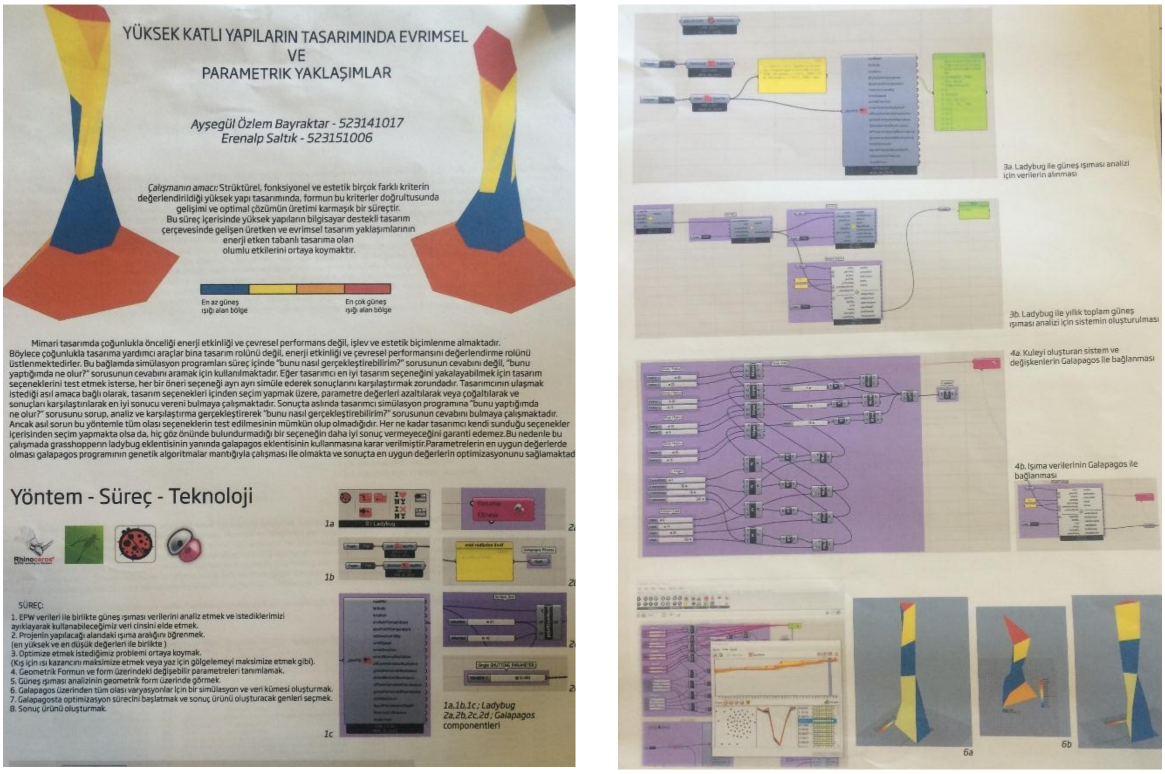

Figure 4.5. ITU MBL 511 Course examples
(Photo by the author, ITU, 2016)

In this ITU MBL 511 Course, the use of computational and paremetric thinking approach in the design of a high-rise building has been investigated. Many complex criteria such as aesthetic, functional and structural have been tried to be simplified in the study.

4.2.3. Evaulation

To conclude, the courses that are mentioned and exemplified above use activities to reinforce the improvement in thinking and solving architectural design problems. The activities include homework assignments such as; article readings, presentations, and forcing students for model presentations. Computer programs are also used for 3D modelling, scripting and scanning literature. Besides, modeling an architectural form with a generative approach is expected from students.

As a result of this program, students use their architectural knowledge as integrated with technology and can produce original solutions with scientific, technological and intellectual structure.

4.3. METU MS. Computational Design and Fabrication Technologies

The name of the master program in the Middle East Technical University (METU) is MS. Computational Design and Fabrication Technologies. It is a joint master of science program established by Faculty of Architecture of TU Delft and the Department of Architecture of METU. The objective of the program is to settle a well-structured collaboration between universities in the graduate program providing a double Master of Science degree.

4.3.1. Aim of the Program

Prof. Dr. Arzu Gönenç Sorguç, The Head of Computational Design Studio, states that the initial purpose of the joint master program was to provide students with a good deal of information. Firstly, this program was a part of Scientific Research Project (BAP) designed by Arzu Gönenç Sorguç and Şebnem Yalınay, and then the program was decided to be designed and developed as a master program. The students who participate in the program visit the universities abroad as exchange students for two semesters and prepare a few projects while taking some courses related to their master programs. Then for the following two semesters, they come back to their own university and write a thesis about the projects that they take part in the universities abroad. It is important that neither university in the exchange program gets priority over the other and the study load and participation is equally shared between institutions. Sorguç states that TU Delft and METU had already had their own graduate program on computer-aided architectural design before the program was established. To create a joint master program, the existing courses were examined again and a decision was made about the methods of unifying the studies on a common base. Then, the outcomes and objectives of the courses were defined. According to the objectives, the curriculum design and the content specification was finalised.

‘To be able to be a good designer and deeply use all types of technology together while being a designer.’

The expectations from the joint master program of Computational Design and Fabrication Technologies are identified simply by Sorguç in that way. She sees technology as a production tool and also a presentation tool and hence the program are arranged as being able to provide this interdisciplinary environment that is necessary. It is highly valued that the students are interdisciplinary user of technology and also the interdisciplinary designer. For this reason, the program aims to give such projects that the students are forced to use a plenty of different media tools. This is because that the architecture is an interdisciplinary field and the digital media should be seen as a tool that improve the capacity of architecture not as a separate tool.

4.3.2. Curriculum and Lessons

In the curriculum of the joint master program, basically there are four obligatory courses including the computational design studio, thesis, research in computational design and the seminar in thesis research. The graduate program does not offer a list of electives courses that the students should choose from to graduate. It is possible to take elective lessons from any of the departments such as biology, material, computer engineering or phsyics. Students have the chance of getting the knowledge of the subjects that could be beneficial in their design project. Moreover, the design problem is created to encourage the students to research and make the use of other scientific areas as one of the main objectives of the program is to create an interdisciplinary research atmosphere. In the first year of the program, there are different courses like physics, statics, material performances, production and epistemology that are offered by architecture department of TU Delft. Besides these courses, students get involved in two projects that will be used as the subject of the thesis in the next stage. When they come back to METU, they start to write up their thesis synthesizing the ideas from their projects and their accumulated knowledge in the area of study. Therefore, the elective courses and the research are very essential fort the completion of the graduate program with a good thesis paper.

Course Code	Course Name	METU Credit	Contact (h/w)	Lab (h/w)	ECTS
ARCD500	M.SC. THESIS IN COMPUTATIONAL DESIGN AND FABRICATION TECHNOLOGIES	0	0	0	50.0
ARCD501	COMPUTATIONAL DESIGN STUDIO	6	6	3	8.0
ARCD511	RESEARCH IN COMPUTATIONAL DESIGN	3	3	0	4.0
ARCD590	SEMINAR IN THESIS RESEARCH	0	0	0	10.0

Figure 4.6. METU graduate course information (https://archweb.metu.edu.tr/msc-computational-design-and-fabrication-technologies-architecture)

Sorguç states that in the graduate program, there is not a concept that seperates the main course and the supportive courses. In the other universities, generally the design studio is the core of the program and the other courses are dependant courses. However, in METU, this concept was changed and evolved. According to the new concept, It is more sensible that the design studio and all other courses are conducted together and valued equally. The reason that the new approach is achieved is that the concept of computational thinking is taught in undergraduate program starting with the first year. Therefore, the students are able to adapt easily to process in the graduate program. In this manner, we can say that there is a reorganization in both undergraduate and graduate programs. Sorguç says that the education in the first year is based on the computational thinking, and all exercises in the basic design studio are created within this approach. After the first year, in the summer intern, the students get the knowledge of all types of technology as an introduction and learn the CAD technology mostly. In the second year, there are two compulsory courses called ‘Introduction to Digital Technologies 1 and 2’ whose subjects are computational design and construction management. With these courses, it is expected from students to learn the digital modelling very well. These all changes can be thought as a transformation from conventional methods to digital methods. As a basic example, even in the first year, students start to create their physical models with the help of laser-cutting machines. The important point here is that the laser cutting needs the use of computer for modelling the project and the potentials of digital modelling can carry too far the complexity of the project. Student can be aware of this situation and pass the limit. It shows that students deal and get familiar with the computational right from the beginning.

Besides the compulsory courses in the first and second year, there is a great number of elective courses that are offered by Digital Design Studio (DDS). DDS is simply the core of computational design education in department of architecture. It is also a good platform for a number of workshops, and public seminars which can be seen as an ideal venue for international interactions.

Offered Courses

Arch 333 Mathematics in Architecture
Arch 361 Integration of Buildings Systems in Architectural Design for Environmental Control
Arch 470 Digital Design Studio
Arch 475 Advanced Digital Design Studio
Arcd 501 Architectural Research Studio
Arcd 511 Research in Computational Design

Figure 4.7. METU graduate offered courses (https://archweb.metu.edu.tr/msc-computational-design-and-fabrication-technologies-architecture)

As the general curriculum of the master program, the studio course does not have a usual process. It contains the theoretical and practical aspects of the study, and it is an important part in that it controls the tools. It is necessary for students to have a good deal of knowledge of digital medium including the programming and the use of tools. In that manner, as Sorguç points out the studio is an experimental venue whose philosophy is ‘reseach by doing’. It means that from the beginning of the project, students should define, develop and implement their unique algorithms and parameters for the project. Only with this step, learning starts properly. Students have to read, model and simplify them.

At the beginning of studio, design problem is defined with a simple, open ended phrase. The design project does not have a defined subject. The student specifies his/her own subject, process and scenario. Therefore, each of the projects that originate from the same phrase has quite different compositions in the end. For example, one of the design topics from the past years is ‘breaking the box’. It does not mean anything at the begininnig or means too many things that the project can become a product of urban design or a building. This uncertainty in the studio sometimes can be tough for students. Sorguç states that for one semester, just four tutorials about the digital program are given in the studio. After that, the student should explore the tools that are necessary for their projects. As the way of each project is distict from each other, the tools that they should use also be different from each other. After the tutorials, students should decide how the design problem is represented, what is designed and how it is transformed into a mathematical problem. They can find the necessary support in this process at the studio. Sorguc defines that approach in digital design studio as ‘learning by doing’, and again for Sorguç it means the genuine learning.

4.3.3. Evaulation

At last, this master program focuses on teaching advanced design technologies and new design tools and new design paradigms. It is anticipated that students will have a history of exploring and the research areas where they can practice in the past-oriented vision.

4.4. Bilgi University Architecture Undergraduate Program

In undergraduate program, Şebnem Yalınay Çinici and Onur Yüce Gün together have conducted a study together on processability of the topics and they had experiments on different issues. According to their systematic scheme; from the begining of the first semester, all three departments; architecture, interior architecture and industrial design, start to process initial pieces of computational design area.

4.4.1. Aim of the Program

Design operations are carried out by simple practices. It is a primitive version of some common practices observed in pioneering universities of Turkey such as İstanbul Technical University, Yıldız Technical University and Middle East Technical University.

The educational system established by Şebnem Yalınay Çinici and Onur Yüce Gün offers a complete computational design based course schedule. The courses are seperated according to the effect of computational design. Parallel to the basic design studio course, architectural geometry is offered as a course. Additionally, there is an architectural drawing course as well. It seems that basic infromation of computational basic design is provided by other courses related.

In common architectural ecoles, supporting courses of basic design are generally autocad and similar two dimensional drawing programmes. In Bilgi University, two dimensional vector based programmes are not thought in the first year.

According to Assistant Professor Doctor Tuğrul Yazar, a distinctive approach of Bilgi University in this field of study brough about some changes that no other programs in the country were able to offer. He emphasizes the intrumental analogues of the courses. For instance, boolean command and solid void relationships topics are learned in the same week. Therefore, on the one hand, students learn about computational tools, and on the other hand they are forced to use the computational tools in traditional ways.

As a result, while the architectural geometry course deals with generating forms, basic design goes beyond that. Knowledge of architectural geometry turns into basic design products, which means the objective of the system is achieved.

Another goal of the Bilgi University curriculum is to eliminate the restrictions in the stage of presentation. Basic design is settled on material knowledge. The

producibility, joint details, variations of materials, geometric relationships, product strategies, drawing strategies are important principles of the course. Before passing architectural notion, common forms of three departments; architecture, interior architecture and industrial design, should easily produce and reproduce.

As a different approach to algortithmic computational design, Bilgi University prefers to form using natural material properties, instead of deterministic forms restricted by numbers and rules. Educational system of Bilgi University comes and goes between the computational design and geometric exploration by material properties. To illustrate, it is prefered to create geodesic formes by material itself instead of making geodesic dome. The purpose is to catch irregularities. In this way, students become able to present changable, adaptable forms on the basis of material knowledge. Geometric equivalent of this is regular deformations. Pattern deformations and how to deform them gradually stay in the architectural geometry course, whereas in basic design studio, it transforms into an open-ended topic.

In the second and third year studios, there is no computational disciplines. There are several attempts in the graduate program for computational design. However, there is no direct computational design programme in the graduate program. Graduate students participate in design studios as well but there is not a master program requiring a dissertation. Academically promising graduate programmes don’t seem to be functioning yet. Although, there have been some demands for such courses, they have not been activated yet due to someorganizational problems and the tight schedules of the professors.

Assistant Professor Doctor Tuğrul Yazar says that undergraduate and graduate programmes should not be judged differently in this respect. Undergraduate programs could work better than graduate programs in terms of stimulating and developable products. For example, in the second semester studio of the first year, students prepare pavilions. The final products could be more than students could present. The main topic is not forms but it is rather how materials come together. Professor Yazar compares this with the pavilion displays of Achim Menges. Yet, designs of students are very basic compared to the advanced works of Achim Menges. But still, Yazar believes that graduate students could reach the standards of Achim Menges displays if they are encouraged and supported by the educational system.

In short, the method conducted at Bilgi University is an exploration for both students and instructors. It is a platform where the question of computational design is discussed. However, there are no clear answers. According to Assistant Professor Doctor Tuğrul Yazar, there is still no unity in the practice. Every year, different methods and approaches are tested.

A proper basis for computational design is essential. In order to establish a durable, dependable basis, a kind of determination and enthusiasm should be expressed by instructors. Şebnem Yalınay Çinici manages her team in an unusual way. She leads the people in terms of what they can contribute. Salih Küçüktuna, Deniz Manisalı and İnanç Eray joined the educational team this way. The studies are conducted and participants are led with this positive energy of Şebnem Yalınay Çinici, and it definitely motivates the students.

The system highlights the pedagogical side of the computational design. Strecthing the rules for design is an issue in the system. Some practices are to do with normlessness and formation of a fractel structure. The quality of design works are not argued. Progressivism has become prominent.

Another issue of computational design is supporting courses. It is observed that the other courses are out of the topic, and some instrumental issues appear. Communication between students and instructors can be lost in the second year, third year and the fourth year studios because of computational based basic design. The reason for this might be while students think with three dimentional elements and tools, instructors expect traditional plan based architecture. Computational design stands on a critical point. Introduction to design could be done with other methods. Joining parts together is key to adjust the situations.

On the other hand, computational design as a thinking tool is a very controversial and contradictory matter. Human mind carries the creativity beyond the tools. However, besides the unpredictable forms, stability and producability of the designs became unknown without handcraft experience. In this regard, students are liberated under some rules and regulations in design. Randomness takes no place in design.

4.4.2. Curriculum and Lessons

The studio exercises and course plan are directly in relationship with computational design. Basic design course was re-arranged in this sense. Exercises and studio lessons are overhauled and became computational based basic design studio.

Students who have not taken design classes before face pedagogical challenges. On the other hand, they are not well prepared to take design courses in that way. Thinking in terms of rules, structuring relations among forms make students use geometry and generate variable and reproducable forms.

Producing, reproducing, integrity, components, forms and setting rules for a design product are discussed in basic design studio. At the same time, in the architectural geometry course, exercises aim to solve some geometrical problems, understand forms and how to design them geometrically using rhinoceros progragramme.

Primary objective of the architectural geometry is not to teach the three dimensional programmme tools. The main purpose is to provide the students with geometrical knowledge and help them develop design products using the acknowledged three dimensional rules. Three dimensional programmes such as rhinoceros help with the emergence of a direct platform on which better design results can be achieved.

In the first semester courses, basic forms and geometry is instructed. Pyramids and cubes and other geometrical elements are taught. Complex forms are covered in the first semester. As a result, in the second semester studio, students are able to achieve the expected capabilitity of coming with presentations, drawings and designs to be preformed in the computer platforms like autocad and rhinoceros. They also experiment with real materials and come with some inconventional design results which could not be achieved by computer, which creates a shift in architectural education. Computational design area is restricted by presentation techniques. It contains algoritmic, drawing and product tools.

Material performance plays an important role in design process. It is because the real world consists of un-geometrical, tangable elements. The approach at Bilgi University is more to do with the expression of real world in geometry.

In the first semester, students build stick bridge structures. It is discussed in a geometrical relationship. Forms and integrity of forms, generation and regeneration of them, juxtaposition and adjacency are projected to design. Instead of singular elements, variations and regenerated forms are essential in projects.

Permissiveness of material choice end up as inconventional and unique basic design products. It brings about some very useful results for second semester courses. Projects are structurally weak in this early stage but the next conventional steps usually come better as as a result of the basic knowledge the students are provided with initially, which is a big advantage in deed.

Architectural geometry course teaches the students rhinoceros programme. The advantage of rhino is that it is basic and offers smooth geometrical results. Three dimensional proccesing and cnc cut are experienced in the first year design studio. Rhino is suitable for these processes. Also, it is fast in terms of generating forms. Basic formal concepts become comprehendable using rhino. Another advantage of rhino is its similarities with other conventional programmes and autocad. After the fundamental collective first year design learning, departments are seperated. Industrial design programs remain loyal to rhino. Unlike the industrial design programme, arhictecture and interior architecture programmes encourage students to use autocad. Contradiction between the basic education and the common architectural notion appears to be resulting from the tendency towards using rhino and three dimentional platforms. Instructor-student relationship gets difficult as a consequence. On the one hand, instructors expect conventional and two dimentional design Works from students, but on the other hand, students seem to favor a three dimentional discipline in their projects.

Despite the difficulties, experiments and production based on material are still the main method in the first year studio. In the recent years, an attemp to use local materials started. Crucial part is to take out the design just from drawings. In this context, innovative material production techniques gain popularity in the stage of design. Architects are welcomed again in the production stage and they free themselves from intangible geometric fields.

Production process requires communication with the engineering faculties. Engineering discipline aims production in principal. Unpredictable qualities of obligatory and elective courses contribute to the orientation and advancement of the design and production techniques.

Figure 4.8. Bilgi University AR 101 lesson example
(Photo by the author, İstanbul, 2015)

Figure 4.9. Bilgi University AR 101 lesson example
(Photo by the author, İstanbul, 2015)

Figure 4.10. Bilgi University AR 101 lesson example
(Photo by the author, İstanbul, 2015)

4.4.3. Evaluation

The main stream at Bilgi University is to excell the drawing and modeling strategies over the mere memorization of programme commands. Teaching programme instructing is believed to be a waste of time. There are nine sections in the basic design studio in which the instructors prepare exercises and design problems in coordination and in a flexible manner.

Target is the final product. Nevertheless, the method is identified by students. Richness of the procedures is the objective. Feedbacks and final products determine the failures and acquisitions. It surely encourages the instructors to develop new methods.

CHAPTER 5

CONCLUSION

In architectural education, a better understanding of teaching and seeking for new ways to teach better has been in progress for many years. Along with the rapid progress of computer technology, the number of new learning tools and methods has also increased. Initially, it appeared as implementing "the architectural computer" into the existing courses. Yet, computer technology based on newly- designed tools has been more useful than traditional techniques. Thus, it is obvious that a need to create a brand new educational model aiming at the integration of architectural education with the computer technology has emerged.

The aim of this thesis is to introduce an innovative approach of design education to analyse the new intellectual and theoretical tendencies in today's designing practises. Traditional educational system of architecture in the form of studio exercises seem to be temporary and open ended design events that actually end up limiting the subject titles. However, the education of the architectural design should be depending more on a problem solving approach addressing to a particular problem in the design process. This educational approach focusing on the process, student and the creativity and explained in the previous chapters introduces a constructive learning model which puts a big emphasis on the learning - teaching process rather than a program based on mere teaching.

The thesis analyses the expected changes of an educational program with reasons because design technology and the needs of the environment have a continuous influence on the gap between traditional education and the kind of education proposed in this paper, and the gap is getting bigger and harder to deal with. The urban environment is a living organism which gets moulded, shaped and changed by the feelings and emotions of people living there and by the way the same people comprehend and define that particular area. Consequently, the situation described creates continuous movements which lead to be recognised as differences.

Computation based design seems to be in high demand. The reason for this is apparently being the most applicable solution for the problem created in the process of design creation. In fact, in better words, computational design has been created in order to find applicable solutions for the problems that have been created in the design process. Computational based design systems generally utilize algorithms to create the form of design. In order to keep up with the rapid change of the urban environment, several courses and introductions have emerged. More and more universities are introducing obligatory courses of computational design. However, computation basis has gone a long way since the publication of the first materials in this field. On the other hand, it has been able to keep the original intention to create a learning-teaching and problem solving approach.

The first experiments on computer based design and education were practiced in the late 60's and 70's. Papert came up with his first attempts on computational design in the year of 1980 at the MIT Media Lab. The examination was about teaching programming language to the students of architecture and showing them how to use it and operate it on a design basis. The computer based programming was a special language called, Logo. Papert thought that teaching was the most appropriate way of learning while teaching others about design, and that would help emphasize learning about something. In order to learn how to operate a computer properly, all the information needs to be organized intelligently and program needs to be designed and planned as a whole. Moreover, problems must be disintegrated into simpler and solvable sub problems.

Later, in 1987, a book on computational design was published. It was the first introduction to the computational design approach in education. It was introduced by William J. Mitchell, who is one of the most influential authors in the field of computational design theory. The book was titled as *The Art of Computer Graphics Programming*. The purpose of this book was to create a relationship between architecture and computer science. However, the book has never been republished and it was almost forgotten since the codes in the book were written in Pascal. The book presents information on hardware and software. In addition to that, the book discusses the graphic packages of 2D and 3D modelling, and apparently the final part of the book is very technical. Main computational concepts are presented in the book.

Consequently, Harel and Papert in 1991 established the Epistemology and Learning Research Group with a developed constructionism. Harel and Papert described new learning tools via utilizing computers. They depicted computer as a convivial tool instead of a teaching tool. They thought that if computers are used more in an active way, they would allow much more embellishment. Hence, to be able to use it in a more active way, a user needs to create his or her own software tools. ‘Their pedagogically successful experiments led to what became known as Papert´s principle: some of the most crucial steps in mental growth are based not simply on acquiring new skills, but on acquiring new administrative ways to use what one already knows". (Minski, 1988)

The publication of the book titled *The Art of Computer Graphics Programming* in 1987, led to a kind of inspiration for a brand new research area which would allow to examine computer based design teaching models. New courses which also aims to explore and investigate the process and theories of computational design teaching models began to be introduced. The very first courses were by Nagakura in 1998. Later, in 2002, Terzidis and in 2004, Celani and finally Duarte in 2007 came with similar courses. Courses were basically about introduction of programming by using Autolisp in AutoCAD. The courses came with the titles of ‘‘Formal Design Knowledge and Programmed Constructs", "Algorithmic Architecture Course" by Terzidis,CAD Creativo by Terzidis and CAD II: Programming and Digital Fabrication by Duarte. The basic contexts of the courses are described in detail in the previous chapters.

Consequently, a course titled as " *Designing the Design*" has thus been developed for current architectural students. Computational design is an algorithmic approach. It is basically related to algorithmic thinking because an algorithmic tool is more rational and deterministic and current architecture students prefer to use those tools rather than the existing tools of their own. In order to do this, architects and architecture students need to have some explicit knowledge or information about how to use this design system.

Designing the Design has been established in order to create a relationship among computational design thinking, design computing, and digital design. The purpose of this is to help the students develop a new way of thinking for the use of the tools in order to create new methods of designing. A more detailed explanation is given in previous chapters. However, it has to be said that this particular course differs from the other four pioneering courses. It has two modules to describe. They are both based on algorithms and scripting but needs to be utilized through exercises. Consequently, several practices are carried out in design studios. First, it began with CAD programming and thus with the based courses accordingly. The practices are based on CAD systems with 3D scripting. The practices follow the stages like; first, students are introduced with the logic of computation, in other words, with the principles of programming logic. After students gain enough experience and information about scripting and programming, practices start.

To conclude, in the recent practice, digital design tools have been changed, and they began to provide a programmatic way of visualising building geometry. Computer based design is concerned with complex geometry. A designer using these tools in an explorative design context needs to be ‘geometrically aware’ and ‘computationally enabled’. (Aish, 2005)

The gap between traditional architecture and digital design is getting bigger and harder to deal with. Thus, " *Designing the Design"* is a course that is introduced to fill that gap which is related to the architectural education, the architect's prospective and his/her design tool. In order to do that the logic and mechanism on which tools operate has to be introduced. Just like the course titled *Designing the Design*, there have been many attempts to fill that gap since the 80’s. (Çolakoğlu, Yazar, 2007) The same attempts intend to catch up with the rapid change, and several courses have been introduced to do so. Although computational design tools are obligatory for students, they do not provide a pre-designed way of doing things. They just provide a way of thinking that might help to solve the problems and design systems. Mainly, it can be said that the system is based on a problem solving and learning -teaching approach.

As a result of the researches carried out, a development in architectural education in Turkey has been witnessed easily. Chapter 4 also supports that it is not possible to create a new educational model without some crucial changes like the ones explained in this paper in all universities around the world.

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