MODEL MAKING AS A VALUE-ADDED TOOL IN PUBLIC, EDUCATIONAL AND PROFESSIONAL DOMAINS

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ABSTRACT

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PUBLIC, EDUCATIONAL AND PROFESSIONAL DOMAINS

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Models are one of the oldest mediums used for creating, communicating and representing ideas throughout the ages, whether these ideas are based on dogmatic, intellectual, ideological, or architectural thought (belief). Whatever their purpose, models, embody a value that reflects their worth to their makers/owners; but this value is not easy to quantify as it may be based on implicit considerations that are difficult to define and measure. On the other hand, it is possible to add measurable value to human endeavors by the use of models. The purpose of this study is, therefore, to investigate the impacts and importance of models in the relevant domains, i.e. public, education, and professional; and to determine the value added to a project by model-making.

Data in these three domains was gathered from interviews, questionnaire surveys, course performance grades, modeling skills' evaluations, universities, local officials, and from an experimental studio course. In the public domain, the value added due to the impact of architectural models was measured by conducting a survey amongst the visitors to the Miniaturk Park in Istanbul. In the educational domain, the premise was that a design idea evolves as a 3-dimensional object in the designer's mind, which is transferred to 2-dimensional sketches and drawings and then re-transferred into the final 3D object; hence, design should start with a 3D model of the project. This study, therefore, proposed a new methodological approach based on the use of model-making as a design tool, to improve and strengthen the students’ performance and creativity. To this end an experimental design course was conducted in two international universities in the 3rd, 4th and 5th year studios. By observing and evaluating the students’ performance in these courses it became possible to define the impacts of physical models in the learning environment as a measurable value. The evaluation criteria too were defined to formulate a uniform and transparent assessment system for the students’ projects. In the professional domain, the study investigated the impacts of both modeling mediums (physical and digital modeling) on the design and production of buildings, through a survey of various architects.

It was determined that model making can be used as a tool to add value to architectural projects and edifices. It was also seen that the value-added impact of architectural models in the public, educational and professional domains can be accurately measured.

Keywords:

Architectural design; Architectural education; Model-making, Physical models, Digital models; Impacts of models; Value-added.

ÖZ

KAMU, EĞİTİM VE MESLEKİ ALANLARDA MODEL YAPIMININ KATMA DEĞER ARACI OLARAK KULLANILMASI

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Modeller, Dogmatik, entellektüel, ideolojik veya mimari düşüceler (inançlar) içeren fikirleri oluşturan, ileten ve temsil eden en eski kurgular olmuşlardır.. Amaçları ne olursa olsun, modeller, yapımcıları/sahipleri için kendi değerlerini yansıtmaktadır. Ancak değerlerin, ölçülmesi ve tanımlanması, üstü kapalı tanımlamalara dayalı olabilmelerinden dolayı, bu değerlerin miktarlarını belirtmek kolay bir işlem değildir. Diğer yandan, insanların çabalarına ölçülebilir değerlerin eklenmesi modeller kullanarak olanaklı olabilmektedir. Böylece bu çalışmanın amacı modellerin ilgili (kamu, eğitim ve mesleki) alanlardaki etkilerini ve önemlerini araştırıken, model oluşturmanın bir proje için ekleyebileceği değeri belirlemek olmuştur.

Bu üç alandaki veriler görüşmelerden, anket araştırmalarından, ders performans notlarından, modelleme becerilerinin değerlendirilmelerinden, üniversitelerden, yerel yetkililerden ve deneysel stüdyo dersinden toplanmıştır. Kamu alanında mimari modellerin etkileri ile eklenen değerler, İstanbul'da MiniaTurk Parkının ziyaretcilerine yapılan anket çalışması ile ölçülmüştür. Eğitim alanındaki öncül düşüncemiz ise tasarım fikri tasarımcının aklında 3 boyutlu nesnenin olarak geliştiğini ve sonradan bunun eskizler ve çizimler haline döndüğü ve en son 3 boyutlu nesnenin oluştuğudur. Sonuç olarak bir tasarımın, projenin 3 boyutlu modeli olarak başlaması gerekmektedir. Bu çalışma böylece öğrencilerin performans ve

yaratıcıklarını geliştirebilmek için, model yapımının tasarım aracı olarak kullanılmasını ve bunun yeni bir yöntemsel yaklaşım olmasını önermektedir. Bu amaçla deneysel tasarım dersi iki uluslar arası üniversitede öğrenim yılının üçüncü, dördüncü ve beşinci sınıflarında yapılmıştır. Bu derslerdeki öğrencilerin performanslarını değerlendirerek, fiziksel modellerin eğitim ve öğretim süresinde kullanılmasının etkileri, ölçülebilir bir değer olarak tanımlanabilmiştir. Değerlendirme ölçütleri de öğrencilerin projelerini değerlendiren bütünleşik ve belirgin sistem oluşturmak için tanımlanmıştır. Profesyonel alanda, çalışmamız her iki modelleme ortamının (fiziksel ve dijital modelleme) binaların tasarımı ve üretimi üzerindeki etkilerini araştırmıştır. Bu araştırma bir dizi mimarla yapılan söyleşilerle gerçekleşmiştir. Model yapımının mimari projelere ve yapılara değer kazandıran bir araç olarak kullanılabildiği sonucu ortaya çıkarken verilmiştir, mimari modellerin toplumsal, bilimsel ve profesyonel alanlarda katma değer etkileri doğru olarak ölçülebilmektedir.

Anahtar Kelimeler:

Mimari tasarım; Mimarlık eğitimi; Model yapımı, Fiziksel modeller, Dijital modeller; Modellerin etkileri; Katma değer.

To the memory of my late Mother and Father

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2D	Two Dimensional
3D	Three Dimensional
CAD	Computer-aided Design
CAM	Computer-aided Manufacturing
CAAD	Computer-aided Architectural Design
eCAADe	Education and research in Computer Aided Architectural Design in Europe
VE	Virtual Environment
CIC	Construction Industry Council
CABE	Commission for Architecture and the Built Environment
DQI	Design Quality Indicator
METU	Middle East Technical University
Arch101	Basic Design (Courses initiated by "Arch" code are belong to METU)
AC111	Bases of Design I (Courses initiated by "AC" code are belong to Benghazi University
AR111	Basic of Design I (Courses initiated by "AR" code are belong to Elmergib University
GPA	Grade Point Average
CGPA	Cumulative Grade Point Average
ST	Student number
INST-A1	Instructor A1
AR-1	Interviewed Architect sample 1
AR-2	Interviewed Architect sample 2
AR-3	Interviewed Architect sample 3
AR-4	Interviewed Architect sample 4
AR-5	Interviewed Architect sample 5
AR-6	Interviewed Architect sample 6

R	Value of linear correlation
R^2	Value of the Correlation coefficient

CHAPTER 1

INTRODUCTION

Modeling during the design process is one of the most important ways by which any architectural composition can be tangibly perceived. The model, which may be produced in reality or virtual reality, is a powerful medium through which a designer can fine tune his design ideas and also present them. Hence models not only help creation but also creativity in design by virtue of their embodied characteristics.

When the matter is concerned with the invention and creativity of idea (bringing the unseen to reality); it is crucial to investigate the role played by the models and the making of models when designing. Thus, the issue is to consider the term "designing" as a verb, not as a noun "design", which is an activity concerned with the processing of ideas. Creativity, innovation and inspiration, are among the most important criteria that any individual designer must acquire in general, and the architect in particular. It is argued that the performance and level of creativity in designing have been affected by the toolbars limitation brought by 3D software and digital technology. This has been a debatable issue since the emergence of the digital technology and virtual reality, as many experimental, empirical and extensive studies are being conducted to overcome this problematic issue. According to the eCAADe (Education and research in Computer Aided Architectural Design in Europe), toolbar restrictions and spatial interactions are still a critical dilemma that is difficult to overcome, despite the remarkable progress in the research findings of the recent studies.

With regards to spatial interactions and tangibility, the direct interaction between the designer and the model has been missed when dealing with digital models on the 2D projection screen (objects are still viewed in 2D), whereas with physical models sculptured objects inhabit the real space of the viewer. Therefore, to enforce such an interaction between the designer and the objects, advanced modeling techniques have been recently developed in VR (virtual reality) modeling. Additionally, the need for better interaction between the designer and his idea has led to the invention of a new technology of “haptic devices” that can compensate the lack of 3D software in designing. These devices provide the tactile ability to control and manipulate the objects in virtual environment during the modeling process. Tactile interactions such as orientation, pressure strength, bending, twisting, lofting and kinesthetic and so on, which occur naturally through the body responses are the most difficult to simulate digitally, and thus need further explorations. Therefore, handmade models are still the best way of experiencing the spatial characteristics of design tangibly.

The premise of the study is that the design idea is essentially generated within the human brain three-dimensionally. Besides, it is well-known that the traditional concept of the design processing is also about the transformation of the idea from being a three-dimensional concept already generated in the brain, into a two-dimensional one through sketching and preliminary diagrams on a piece of paper. Then, the designer starts developing and generating his idea to become a three-dimensional object all over again. Models are not usually considered to be tools for the creation of an idea in the first place, instead they are treated as a modification, regeneration, representation and analysis tool that is applied only after the essence of an idea has already been created. Based on this premise, the proposed methodology is to transform the design idea directly as a three-dimensional concept from the mind to a 3D reality, by relying mainly on making of models from the very beginning of the design process, rather than converting it into a two-dimensional concept on paper.

The focus of this study will be to investigate the issue of model-making as a means of creativity in architectural design and education. As both models and model making play a significant role in the design process, they need to come to the forefront and take the place they rightly deserve. With the claim that students of architecture should be encouraged to be more creative and skilled, it is therefore, crucial to achieve and develop a new methodological approach in design teaching to improve the performance and quality of the students in designing. In this way it will be possible to assess and evaluate the value added by model-making. This approach is expected to enforce and improve the learning and creativity criteria in architectural education and propose a means of measuring the students' performance as value-added design through the making of models.

1.1. Statement of the Problem

The measurement of the value of design is a problematic matter involving complex subjective judgments. Therefore, the study addresses the question within the context of designing rather than design itself; it focuses on the process of design activities. Because the process of calibration and measurement of the actual value of design is rather fuzzy, this study discusses how to establish a standardized method that can be relied upon to assess the actual value of the design (the value that could be obtained by the making of models). As there are several criteria that can play an important role in determining the actual value of the design, the focus will be on the standards underlying the essence of the idea of design and creativity in thinking and learning. Design value has always been assessed and measured subjectively, and hence could not be quantified; this study seeks to develop a clear methodology that can objectively assess and measure design value as well as the value added through model-making.

Unfortunately, the role of modeling and the model-making process have not been considered at all in terms of their relationship to the design process as a thinking and innovative tool. Instead, the making of models has mostly been considered as a means of representation and analyzing of the finished or already created product in its physical state after being transformed from the conception stage. This issue, in spite of its great importance and impact on the core of the design process, is still neglected by many researchers and scientific studies. Therefore, this study is going to addresses the model-making issue as the core of designing progress by establishing new methodological approach based on experimental studies to find out the significant role played by model-making in the creation of architectural ideas. This methodological approach was proposed to be implemented in architectural education for improving the performance abilities of the students as well as in design practice. In addition, it is critical not to neglect the fundamental impacts of physical models on public domain. But still the question that should be answered is how to address and evaluate these factors as a value that can be measured and quantified for the design processing.

1.2. Objectives

The major and minor objectives of this study, were formulated in the three domains, where architectural models have a significant impact; namely Public, Educational and Professional. These objectives are listed below separately for the three domains:

- **In public domain**: to investigate the impacts of architectural models (in public places) on increasing public awareness and the desire for knowledge regarding historical heritage and identity of communities, as well as for promoting the tourism industry,

- **In educational domain:** To investigate the impacts of models:

a) In architectural studios as a creative design tool.

b) In evaluating students performance and grades in design.

c) As a means of understanding design parameters.

d) To propose an evaluation strategy for measuring value in design studio.

e) To employ a new teaching and learning approach based on making models in design studio.

f) Determining the value of peer learning in the model-making environment.

- **In professional domain:** Analyzing the nature and characteristics of the two modeling techniques in design (digital versus handmade modeling) to establish:

a) The degree of tangibility in model making as opposed to conventional and computational design approach.

b) The iconic limitation of both types of modeling in design.

1.3. Procedure

The foundation of the study was built upon theoretical discussion related to cognitive assumptions in the historical development of architectural models and how they were employed. Also, the practical aspects of employing models in architecture and their role in understanding the design process were studied. Thus, the literature review of the study included the following issues:

- A chronological approach on how architectural models have been used and implemented in the designing and construction of buildings since they first appeared and then went through several stages of transitions.
- The epistemological approach of model making either as a thinking mechanism, means of creativity, or a way of learning in education (design studio).
- The changes brought about by the emergence of new technologies and their impact on the design process.
- Finally, since the measurement of the value of design is a major problematic matter of the study, the study contributed to the debate regarding how the value of design can be articulated and measured, particularly in the context of architectural education and practices. Therefore, various sort of research material were proposed and discussed in details (concerning each domain namely; public, educational and professional domain).

To tie the theoretical background with the aims and objectives of the study, an investigation was conducted through interviews, questionnaire surveys, and data collection. The feedback was then analyzed and the outcome variables and parameters tested.

Hypotheses

1. Whether they are digital (rapid prototyping) or hand-made, models have significant impacts on designing buildings. Although these impacts are implicit and based on the individual's considerations, they can be identified as measurable values.
2. The interplay and integration between the model-making mechanism and the

essence of design creativity opens up many paths to reformulate more efficient designing methodology within the framework of both increasing design efficiency and the value of the product (buildings) itself.

3. Physical models have significant impacts on public when they are used to represent actual buildings/projects to increase exposure (history, architecture, culture).

1.4. Disposition

This, the 1st Chapter presents the background, objectives and methodology of the research.

The 2nd Chapter presents a literature survey on topics related to the area of study.

The 3rd Chapter presents the results of the face-to-face interviews and on-line questionnaire; and also discusses the results of analyses of the data thus obtained.

Chapter 5 gives details on the experimental studio course; i.e. its objectives, content and conduct in 4 design studios in two Libyan universities. Also presented are the results of the survey conducted amongst the students regarding the evaluation of this course.

Finally, Chapter 6 wraps up the study with the conclusions and recommendations for further studies.

CHAPTER 2

LITERATURE REVIEW

The research starts by establishing a chronological approach on how architectural models have been used and implemented in the designing and construction of buildings since they first appeared and then went through several stages of transitions. It also considers the epistemological approach of model making either as a thinking mechanism, means of creativity, or a way of learning in education (design studio). Thereafter, the changes brought about by the emergence of new technologies and their impact on the design process is also investigated. Finally, since the measurement of the value of design is a problematic matter that involves subjective judgments, the study contributes to the debate on how the value of design can be articulated and measured, particularly in the context of architectural education and practices

2.1. Models Through History

Modeling has an evolving history since ancient times. In his book titled "Designing with Models", Mills (2005) went over a brief introduction about "model history". He tried to highlight the importance of models in general, through the historical narrative summary by addressing the role of models in ancient civilizations to the present day. Accordingly, models were made primarily as symbols during Egyptian and Greco-Roman times, whereas builders during the Middles Ages "with the advent of cathedrals" were carrying and presenting their individual expertise through the making of mock-up models, such as arches for buildings. Additionally, models during the Renaissance were used as "a means to attract the support of patrons", as mentioned by Mills (2005) and Dunn (2010) in the case of the "*duomo* in Florence", Italy. After the domination of architectural education by Beaux Arts training, models were replaced almost completely by drawings (elevation & plans studies). However, by the late 1800s, the use of models as an explorative tool began to be implemented in architectural design, as seen in the work of Antonio Gaudi, to explore structural ideas and developing an architectural language, for example in his design of *the Sagrada Família* (Figure 2.1 & 2.2). After that period, a shift to modern architecture had begun to be noticed, where the role of "orthographic and perspective" drawings had a limited usage as a method of exploration, giving priority to the model as "a design tool" (Mills, C, 2005 & Dunn, N. 2010).

Figure 2.1: Antonio Gaudi, reproduced model of "La Sagrada Familia", **1983-1926**. Up side down structural analysis made from strings and weighted sacks.
(Source: https://www.flickr.com/photos/tillnm/3209875667/in/photostream/)

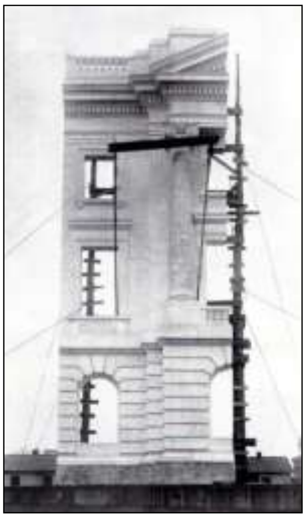
(a)  (b) 

Figure 2.2: (a) Department of Agriculture Building, 1905. Modelled by James Parrington for full-size mock-up (Moon, k. 2005). and (b) Vladimir Tatlin's assistant building model made from wood and metal plate connectors was one of several models made in 1920 for testing the design. (Dunn, N. 2010)

Between the 1920s-1930s, during the Bauhaus period, the use of model making took the core of architectural education and practice. Criss Mills pointed out that during the period of modernity, i.e. the 1950s; the 'role of modeling in architecture began to decline due to the embodiment of platonic solids (cube, cylinder, etc.) as a reductive and unsophisticated design approach'. Until the late 1970s when the modernism thought was weakened, the 'model regained its position again as a powerful tool' for design exploration (Figure 2.3) (Mills, C, 2005).

Figure 2.3: Wooden Concept model of Sydney Opera House by Danish architect Jørn Utzon, 1958**.** This model represents the geometrical solution for the pre-cast concrete shells. (Dunn, N. 2010)

During the 1990s, there was a challenge between the "model's role and the shift in technology" that was seen in the substitution of CAD and modeling programs as digital simulations for all experiences. Even though, the emergence and implementation of new technologies and "digital media" proved to offer positive benefits, the "immediacy and direct relationship" that can be offered by the making of physical models still play a crucial role in design process. According to Criss Mills, this claim was approved by Ben Damon, an architect with Morphosis (a pioneering office in rapid prototyping), when he stated that "Physical models will never go away" (Mills, C. 2005). Likewise, James Glymph who works for Frank Gehry Partners, has pointed out that it is misleading to think that digital modeling could entirely replace the role of drawing and physical models. Therefore with this realization, incorporating both techniques each in its right place during the design progress would help out to 'reduce the gap between design and production'/crafting by interconnecting physical design (traditional) and digital modeling methods (Figure 2.4 & 2.5) (Moon, k. 2005).

Figure 2.4: (left picture) Morphosis Experimental media and performing Arts centre, 2002-03. 3D printed resin. (Right picture) Gehry Partners, Düsseldorf's Media Harbour. 1996. CNC milled design-process, layered paper and resin. (Moon, k. 2005)

Figure 2.5: Final design model for Marques de Riscal Winery, 2000 Spain, being digitized by a Gehry partners. (Moon, k. 2005)

For comprehending the importance of ‘scale models’ to the design process, Albert Smith offered a chronological narrative for the development and the roles of models in architecture since the Egyptian scale models. Accordingly, the relationship between architecture and the scale model had been depicted in the sense that Smith (2004) demonstrated the most effective progression amongst concept and 'machine', and between the ideas with the final building. In view of that the nature of the ‘scale model' as well as the vast potential of this design tool (i.e. model-making) was revealed as a thinking and communicative medium. His chronological transitions shifted from Egypt and Rome to the relationship between the Greek historical masterpiece models, Medieval and Renaissance models and then up to the role of scale models in the present day through the work of well known architects. Smith significantly questioned the use of 'scale model' for projects that let designers to comprehend the effectiveness of communicating their ideas through the model as a tool. (Smith, A. 2004)

Smith points out to the importance of models a basic tool for the coexistence and adaptation of mankind to their environment, by going back to almost the very beginnings of human life, even before the appearance of housing. Here, he tried to focus on this phenomenon because of its active role in the lives of human beings in general. It should be mentioned that many researchers might ignore this role, while it is considered the core of the exploration, discovery, and communication processes in design creativity. Smith takes up the idea of a "stick" and its appearance in ancient human life, where it was the tool that could be used in all kinds of activities, such as: walking, hunting, and exploring, and also as a "scaling" tool (Figure 2.6). For instance, when this tool was stuck into the ground to know the time, and then later was dedicated for building his shelter for protection. Thus, it can be seen that despite the simplicity of the idea behind the "stick", it should be regarded as a very important point, as Smith mentioned:

> *"The stick took on a life of its own; it represented a better way of understanding the sun, creating questions about a vast chaotic universe. It changed from a tool into a scaling machine….encourage the possibility of understanding the measure of things".* (Smith. A, 2004)

Figure 2.6: The idea of “stick” represented the appearance of models as a tool in ancient human life. (Smith, A. 2004)

Therefore, the value and importance of “the stick” is that it offered the ancient people the ability to begin formulating an understandable measurement for defining the “invisible unknown”. Consequently, the author tried to link several similarities between the stick and the architectural model in terms of their primary use, asserting that architectural models should be used typically as “thinking mechanisms”, not only as a means to represent or design. Thus, architectural models served as “measuring mechanisms expanding the architect’s intellectual capacity” to understand, create and express the complexity of the unknown or the undefined things.

In short, it can be inferred that the models, since ancient times were not just a tool for representation or simulation, but also a tool for thinking and creating in order to cope with the environmental conditions of all constraints (Smith, A. 2004).

2.2. Epistemological Approach of Model Making

Design, has been widely considered the essence and the core of most of the engineering activities (Simon, 1996). It has also been said that in academic domains universities should accommodate their students to provide effective design solutions to meet the needs of society. (Evans, McNeill, & Beakley, 1990). Similar to "problem solving", design has been considered as a natural and everyday activity. "Needs and dissatisfaction" in most everyday transactions with the need to develop satisfactory solutions is the starting phase for any design process. Based on this belief, many "scientists have been designing and acting as designers throughout their careers, in spite of not being aware of or recognizing that they are performing in a design process" (Braha & Maimon, 1997). Therefore, this section highlights the nature of design thinking and investigates the necessity of understanding this phenomenon.

2.2.1. Nature of design and thinking mechanism

In several areas, "knowledge is generated and accumulated through actions" (i.e., doing something and evaluating the results). In other words, knowledge is generally employed to produce work, and work is evaluated obtain and produce knowledge. It is argued that creative people have a propensity to work in two different ways: "either as finders or as makers" (Owen, 2007). Finders, accordingly, express their creativeness through innovation. They are tend to understand and to find explanations for ambiguous phenomena. Makers, on the contrary, are likewise creative, but they are driven to recombine what they know in new arrangements and ideations. By differentiating between both 'finders and makers' on the way how they think and work, other factors might similarly reveal differences among professional fields and hence help to identify the nature of "design thinking" (Owen, 2007).

Razzouk and Shute (2012) discussed the design thinking conceptual diagram proposed by Owen, (2007). They mentioned the four quadrants (Synthetic/ Symbolic; Synthetic/Real; Analytic/Real and Analytic/ Symbolic) in Owen's conceptual diagram and the importance quadrant in education (Figure 2.7). This was attributed to the need for improving the students' thinking skills, capability to investigate, manage, create and willingly cope with real-world problems. Despite the importance of its impacts on education and practice, the nature of design thinking is still vague and cannot be generalized. Hatchuel and Weil (2009) argue that design is a way of thinking – an activity that initiates with a concept about "unknown object" that expands in a sequential progress into other concepts and/or new knowledge. At its core, 'design thinking' is attributed to the way designers observe and how they consequently 'think" (Liu, 1996). Accordingly, Liu (1996) distinguished the interrelationship between the so-called "iterative and interactive" as a process where designers observe and distinguish (any unexpected problems that may come out of ideation), to outline any relations among ideas to solve the problem, and analyze what could have been drawn "as informing further design efforts" (Do & Gross, 2001; Lloyd & Scott, 1995). Accordingly, too often designing starts with an illustrative depiction that is progressively transformed into more complex and detailed graphic representations. This sequential progress in design assists the designer to reflect, communicate, and even be self-critical, and thus serves to settle the representation and testing the designer's goals. In other words, diagramming in design serves as a "primary vehicle for thinking and solving problems" (Do & Gross, 2001; Nagai & Noguchi, 2003). Lawson, B (1980) states that: "Design involves a highly organized mental process capable of manipulating many kinds of information, blending them all into a coherent set of ideas and finally generating some realization of those ideas" (Lawson, B. 1980).

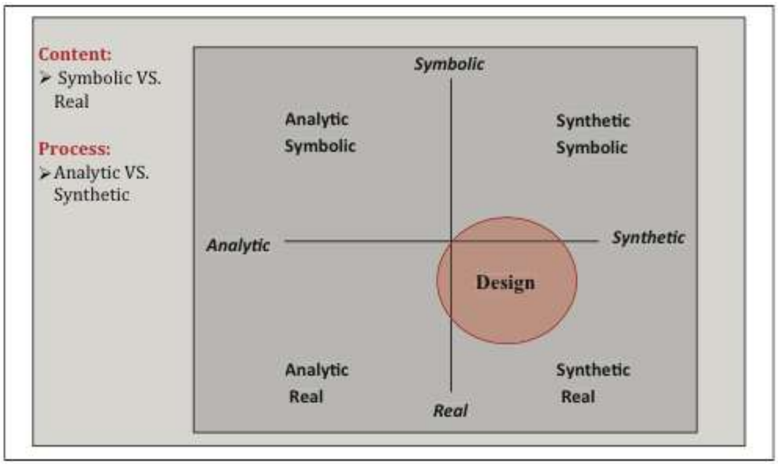


Figure 2.7: Owen's design thinking conceptual diagram. (Razzouk and Shute, 2012)

In practice, it is argued that "designing is a situated act, which means that designers invent design issues or requirements in a way that is situated in the environment in which they design" (Suwa, Gero and Purcell, 2000). Accordingly, a strong correlation has been realized between "unexpected discoveries" and the invention of issues and requirements. Unexpected discoveries are those instances when a designer perceives something new in a previously drawn element of a solution concept. Not only do unexpected discoveries become the driving force for the invention of issues or requirements, but also the "occurrence of invention" tends to cause new unexpected discoveries. This clarifies the nature of design as a phenomenal activity that emphasizes the importance of instant and momentary transitions between various modes of activity during the design process. e.g., drawing sketches and conceiving of design issues that are dynamically related to one another (Razzouk and Shute, 2012).

Design has always been considered as a complex activity that takes many forms of consecutive progressions and ends up with a final product. Based on this idea, Dorner (1999) observed various forms of thinking in designing. Accordingly, design starts as a floating idea(s) on how the final or desired product should be created and tested. These design ideas are formed and developed based on the designer's observation, experience and foreknowledge about the product. The author mentioned another form of thinking that involves the sketches and models for bringing the cloudy idea to a more concrete form. Accordingly, "sketches" and models are supposed to simplify the "characteristics of the product" helping to form a specific line of thought that facilitates the development process and forms the basis for the design thinking process" (Dorner, D. 1999). However, thinking in design may take various forms, although all of these forms demonstrate and end up with specific creations/ outcomes.

Design thinking has always been attributed to the discipline of architecture as it involves multidisciplinary interactions. In architecture, "design requires a balance between art and science. In architectural design, the idea should be subject to certain rules and requirements to make an efficient and standing product/building and students must acquire this knowledge in architectural schools. Based on this belief, Schön (1988) states that while the architectural design studio is believed to be an exceptional learning environment in universities, it actually represents an opportunity, a model of "learning-by-doing" which makes it a unique learning environment compared to other disciplines (Schön, D. A. 1988). Eagen *et al* (2010) mention that experimental tasks and practical progress in conventional design studios enables the understanding and comprehension of the boundary conditions for various creative issues. Teaching architecture relies heavily on action learning, an approach, which offers a way of responding to increased demands for outcome-based action learning in other fields (Eagen et al. 2010).

Accordingly, Donald Schön (1988) examined how professionals really go about problem solving and concluded that "reflection-in-action" was an iterative, collaborative process, combining both art and science. He maintained that the fundamental of ideation in "designing" could only be reinforced through experience, "reflection in action" and "Knowing in action", which formulates the basis of any design process (Schön, D. A. 1988). This emphasizes and postulates that "learning by doing" is a natural approach that cannot be learnt from a book, and this kind of tacit knowledge should be inherited in designing and could only be learnt in the unique environment of the studio (Schön, D. A. 1988).

The design thinking model presented by Kembel (2009) is notably different for its explicit treatment of empathy. His five-step cyclic model consists of "empathy, problem definition, ideation, prototyping, and testing" (Kembel, G. 2009). When considering the context of design thinking in architectural design and education, the thinking mechanism of designing might be viewed in a number of ways. According to Rowe (1991) and what has been discussed so far, these ways can be investigated in various aspects. Designing in architecture can be attributed to the historical record of production (the lines, shapes and masses of past buildings and urban artifacts) interpreting them according to various "aesthetic canons, social circumstances, and technical opportunities" (Rowe, P. 1991). Peter Rowe asserted that "designing could be examined for conformity with theoretical prescriptions of what constitutes proper architecture and good design" (Rowe. P, 1991). Therefore, designing is believed to be a practical form of inquiry to the extent that it is concerned with making and achieving the satisfactory and useful for the occupants and their needs. Based on Peter Rowe's and other empirical studies and investigations, designing in architecture must be engaged within the normative realm of discourse about architecture based on practical evaluation rather than just analyzing and identifying the aspects of design activity. Therefore, designing is a sort of making mechanism that can only be evaluated and achieved through practice and coming into existence.

2.2.2. Creativity and architectural design

"Real thinking is formed precisely when the work of language is indissolubly joined to the work of hands". (Ilyenkov 1974: 1)

Creativity is becoming increasingly important in architecture and industrial design. In today's competitive business world, it is extremely important for companies to create new and useful products. Harris (2009), the author of one of the guiding books on creativity, says that "creativity should become a core part of a competitive company's culture". The word "creativity" is defined as "the ability to create". "To create" means to turn new and imaginative ideas into reality". Hence, "If you have ideas, but don't act on them, you are imaginative but not creative" (Naiman, 2013). Accordingly, Patrick Harris mentioned two processes that are involved in creativity: "thinking and producing". Creativity is introducing something new and original, not like anything seen before, whereas a product is becomes creative when it novel, unusual and appropriate. Although Harris highlights the reality that everybody is creative contrary to beliefs that only special, talented people are creative, a study at Exeter University titled "What is Creativity" concludes that excellence in creativity is determined by "encouragement, motivation, opportunities, training, and practice" (Sternberg, R. 1999). It is not possible to reach high levels of success in any field without devoting thousands of hours to serious practice. Therefore, "creativity" is not "linear progress"; it is "iterative activity and progression" (Harris, 2009).

A study conducted by Murat Sönmez (2012) discussed the importance and role of "Creativity and solid modeling" both in product design and education. It has been found that excellence in creativity is determined by encouragement, motivation, opportunities, training, and practice. The author points out to the extent of threats facing the economy and industrial production in most parts of the world because of the absence of motivation in creativity and the entering of the digital realm into design. Therefore, many of the recent studies focused on the necessity and importance of need for the integration between conventional creativity and technology so that both can strengthen each other instead of one being replaced by the other. This debatable issue of creativity has taken the attention of many scientific researches since the implementation of drawing instruments before 1970s, along with the development of a computer-based drafting tool by Ivan Sutherland in 1963, up to the domination of solid modeling and virtual reality in today's design and production. Despite the obvious impacts of these advanced technologies on design and construction, there are still many studies looking for solutions on how to find compatibility between the employment of these techniques with the human ability and skill to maintain the essence of creativity as essential means for the design processing and application. Therefore, in education systems concerning the matter of designing and creativity, many studies have recommended that education system should be able to feed creative minds by offering some courses and facilities for developing the students' creativity in art, design and production. (Sönmez. M, 2012)

There are great expectations for innovation and creativity in our world. According to Ritter *et al* (2012), in their study titled "Creativity: The role of unconscious processes in idea generation and idea selection. Thinking Skills and Creativity", it is mentioned that the impacts of human experience and skills on developing creativity in design has become crucial, as being creative is a quality that is more and more sought in our society. However, generating and developing new ideas might not be as easy as it seems, and people often struggle in creative settings. In view of that, "creativity is not an innate quality and requires developing sophisticated reasoning skills". Processes that support idea generation still need to be defined; especially "conscious and unconscious processes" (Ritter, vanBaaren, & Dijksterhuis, 2012).

Another study discusses the issue of creativity as an interrelationship between "physical and expressive thinking". In defining this relationship, Andrew Macklin (2010) states that physical thinking occurs "silently" in the body where meaning develops from experiences that are "idiosyncratic and intuitive". Expressive thinking, on the other hand, such as language, is a collective socio-cultural system of words, terms, signs and symbols that brings linguistic intelligibility to experiences, but also mediates the truth of those experiences with conventional and embodied meanings or analysis based on a given causal logic. It is also stated that experiential design pedagogies value physical thinking through hands-on making where ideas emerge “sensually and discursively”. Accordingly, it is premised that expression and the body are not separate cognitive worlds but intertwined and mutually elaborate each other in the event of being. Therefore, with his experiential design thinking, the author states that architecture design occurs through “physical experiences”, where the shape, form, space, planning, scale, materials and textures of architecture evolve from designer’s bodily encounter with tools and making techniques, exploring materials, creating sculptures and building models (Macklin; A. 2010).

Therefore, many studies have shown that creativity is “a process of sequential mental expressionistic occurs inseparably at certain moments and develops with practical experience”, which is known as “thinking-making”. In short, interrelationship between physical and expressive thinking in identifying creativity have been addressed in many questions to formulate the essence of creativity in designing and learning. That is; “What is the relationship between language (verbal, non-verbal or written) and physical making (e.g. model making or material studies) in terms of the creative process of design in architecture? Accordingly, Macklin; A, (2010) discussed the interrelationship between experience and acting in design education. He investigated how we use “language to stimulate making or how does the “experience of making transform language? How does language orient body movement, direct the use of tools or change perspectives on reality? Where is the expressive or creative power of language and how can it inform experiential teaching and learning?” Accordingly, Andrew Macklin concluded that “creativity is an activity that can take the form of “making-thinking-realization” (Macklin; A, 2010). In addition, Hargreaves (2001) mentioned that ‘you can have creativity without innovation, but you cannot have innovation without creativity’. In this context, it has been found that creativity formulates an important element in the production of new knowledge, concepts, and innovation, that it can be developed and practiced, especially in architecture studio learning environment (Hargreaves, D, 2001).

2.2.3. Perceptions and tangibility through physical modeling

A key ethical dilemma that impacts on most forms of design is perception. Perception that lies at the core of many design briefs, specially the one based on practices and production, seeks to create "desirability and generate motivation" in designing. As the issues of perception affect the essence of the design process, especially for linking the real and virtual worlds, it has been found that many philosophical and scientific studies are based on extensive research that will interpret the importance of perception in our daily lives. According to Alva Noe (2005), "Perception is not something that happens to us, or in us, It is something we do" (Noe, A 2005). He further argues that:

> *"Perception and perceptual consciousness depend on capacities for action and thought -- that perception is a kind of thoughtful activity. Touch, not vision, should be our model for perception. Perception is not a process in the brain, but a kind of skillful activity of the body as a whole. We enact our perceptual experience".*

Mainly, to perceive is to do, it is then "a way of acting". It is argued that all perception is touch-like in that "what we perceive is determined by what we do (or what we know how to do); and determined by what we are ready to do. Therefore, the author points out to the importance experiments demonstrating "change-blindness" to illustrate that we do not see everything that is there, only what we expect, want, and need to see. Noe (2005) offers several concepts that rely on the foundations of perception in general and differentiates between ordinary and blind people in the way they perceive their contextual environment., He believes that both ordinary and blind people perceive the environment around them using their skills (knowledgeable activity) not just touch, motion, smell and so on, as a whole in the "environment that must be treated as the site of perception" (Noe. A, 2005). Thus, doing any sort of work/task depends on the environment, skills, and on the way we are embedded in that environment.

In task performing and making the issue of perception has more to do with how the performer is interacting with the physical environment and objects beside his skill-based activities. Many empirical studies have discussed this complex issue aiming to decode the relationship between perception, tangibility and designing, particularly in the context of 3D modeling and visualization. Tangibility and intangibility play an important role in the making of models whether physically or virtually. Eva Hornecker (2007) discussed the role of tangible physicality in terms of interacting with different representations such as “sketches, drawings, diagrams, physical models, prototypes, and gesture as representational Forms” (Hornecker, E. 2007). She criticized the variations and lack of feedbacks on interaction between various means of representation (manual and digital). Accordingly, it has been found that the sense of tangibility (particularly in terms of how objects are materialized) between the various forms of representation is still problematic. The precision of perceiving and controlling the object properties using digital devices brought unsatisfied feedbacks, particularly in the context of defining the surface properties. In their experiment, Zaman,. *et al*. (2011) observe different hand movements using four different materials of different surface qualities and of different hardness to detect various hands/fingers controls during the making (of models) process. They highlighted several significant issues such as materials/textures perception and constraints, scale and size, etc. The authors tried to capture an accurate translation of the human hand movements in the physical environment that could greatly improve the quality of the designer’s relationship with the digital environment. Even by the aid of haptic devices, it has been found that grip forces, human hand’s imitation, and simulating the properties of deformable objects are still hard to detect (Zaman,. *et al*, 2011).

The concept of tangible interaction and physicality has seen a shift from its literal meaning in terms of physical objects and their manipulation towards a holistic interaction approach that also incorporates body movements, human behavior and social communication by means of tangible artifacts. So far, current studies are being conducted in-depth on the issue of tangibility, particularly in the domain of architectural design and 3D modeling. In the past, tangibility was not debatable because the relationship between the designer and the model (idea) were considered directly-related. By entering the digital era, an increase in demands to strengthen the connection between the designer and his/her idea in the virtual environment led to the conduction of many experiments to make this relationship more realistic in terms of object tangibility and physicality during ideation processing. Consequently, while there are still many unanswered questions that remain, the outlook on virtual reality as a creativity support tool remains positive, particularly if their features can easily be manipulated to better suit the domain and the users. At this time there are still many benefits to using more traditional sketches or physical models in some circumstances, as they still offer strong advantages in terms of convenience, orientation, scale factor, feeling of presence, constructability and materiality, but the popularity of new haptic devices may be an indication of things to come.

According to Johann Habakuk (2007), Eva Hornecker. 2007, McKnight. L, 2007 and Ramduny-Ellis, D. et al. 2007. In the proceeding of the second workshop on physicality (2007) to reduce the gap between the user (designer) and the task manipulation in virtual environment there is a need to incorporate the best aspects of both mental and physical environments, which does not necessarily mean it should aim to mimic the physical world perfectly. It is stated that the new system of virtual environment as well as the use of haptic devices may not be the perfect tool for all types of creativity, but it does offer the possibility of prototyping creativity to support environments using its physic-based and scripting features, and making it available for testing among a large number of people, so that perhaps the most creative outcome of these abilities is a novel way for supporting creativity itself. However, any final tests for any further experiments should and will always be how to produce more efficient and reliable products.

2.2.4. Model-making in architectural design and education

Designing, which is giving form to new objects or environments, is largely a question of anticipating the workings of spatial and material environments, which can become 'reality' only by being built. Until realized, a 'design is essentially a figment of the designer's imagination', although his or her ideas may be laid down and conveyed to others via specialized design media (Collopy, F. 2004). Contrary to the architectural drawing, which is essentially a two-dimensional interpretation or representation of (aspects of) a design, the architectural model is a powerful design tool that is used not only for representation purposes but is also dedicated to generate multiple design ideas. Like buildings the model is a three-dimensional object that can be perceived dynamically, even though it is usually ‘scaled down’ to a manageable size. Fred Collopy (2004) in his study titled ‘Managing as designing’ pointed to the typical aspect of ‘classic-physical-model’ making in that the ‘construction’ (making the model) of the model is to a large extent a building process in its own right (Collopy, F. (2004). Based on that, Fred Collopy (2004), investigated the distinctive design approach of Frank Gehry by the use of multiple models and perspectives on various scales and using both hand-sketches and physical models simultaneously, as well as his implementation of digital techniques for the final production (Figures 2.8 & 2.9). It is a reflection on how models were used as a creative, generative and communication tool during the design process.

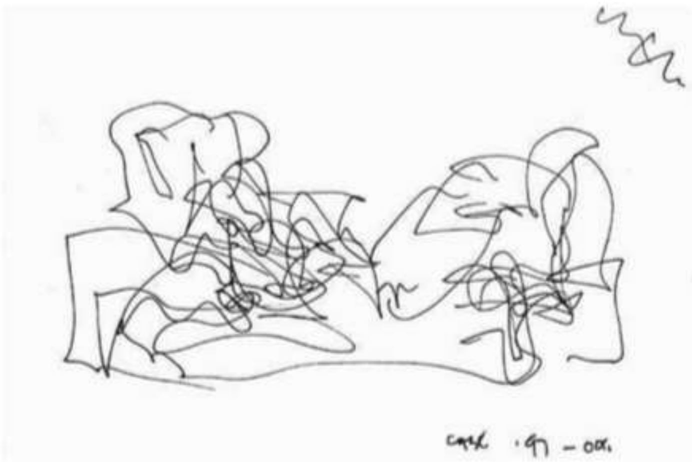


Figure 2.8: An early Frank Gehry sketch of the Peter B. Lewis Building. (Collopy, F. 2004)

Figure 2.9: Gehry, in the stages of early planning, known for constructing at least two early models out of blocks with various scales and materials. (**Sources:** http://www.theguardian.com/artanddesign/architecture-design-blog/2014/may/08/the-competition-film-shows-how-starchitects-really-work & https://kurtwootton.wordpress.com/

The design approach for Gehry works from both the "inside out", as in the massing models, and from the "outside in" based on freehand sketches of the building (Collopy, F. 2004). Accordingly, it is mentioned that the importance of such an approach in that process is the totality and tangibility when a designer work his hands. Ghery's officemakes models of the exterior and interior elements out of paper, metal, plastic, waxed cloth, or any available material that gives them both the form and feeling that they are seeking. It is a way of investigating the relationship between modeling materials and real ones. i.e. which material is representative of which one and why?. Furthermore, the design tools that were dedicated for thinking, interaction and tactile materials, models are another, relatively unexplored possibility. Edwin Hutchins in Cognition in the Wild demonstrated the nature and importance of thinking phenomena. He stated "thinking is not something done exclusively inside the head, but is often accomplished in interaction with other people and with our tools" (Hutchins, E. 1995). This means that thinking does not just occurred mentally; it is a coherent process interrelated with several phenomena and elements, including the tools of expression to reach the final (outcome) product. Collopy (2004) observed such interaction in Ghery's design process. It is noticed that the digitized models "steps" were only to purify the final design and prepare for further details of how the structure is to be built by relying mainly on a satisfied and convinced physical production of their design. Significantly, it is believed that keeping the connection between the initial sketches and the physical models as close as possible, with both being close, tactile form of work in which "mind, hand, heart, and materials" are a closely integrated instruments of cognition and creativity, and is the best way to maintain the desired feeling in the work of Gehry's teamwork from start to finish (Collopy, F. 2004).

The models, according to Gehry's partners, were treated as a physical tool for thinking, not a representation of the building they were designing. Besides, Fred Collopy (2004) discussed the "design vocabulary" brought by the implementation of such a process to engage the diversity of the innovative experience of designing, and the criteria for making design assessments. Other studies have engaged the role of models in design evaluation criteria. The concepts of "sense-making" addressed by Robert Irwin (1977) and Karl E. Weick's (2004) "decisive grounding" bring to mind the question of how models encourage different judgments of the object. It is believed that the focus in Ghery's work was on designing that runs from more formalized and formal, back towards forms and concepts and perceptions.

Fred Collopy (2004) with his study titled "I Think with My Hands" (On Balancing the Analytical and Intuitive in Designing) discusses the roles of sketches, models, and the effects of scale, in designing and production. The author investigated the idea of "thinking with hands" that it is the use of hands in design thinking. Similarly, the use of human hands in learning and practice was also a convincing matter for Joseph A. Paradiso (2002). He asserted that human hands have a significant role in learning and design manipulation that offers a deeper understanding and stimulation for the designer Paradiso, J (2002) and also supports this idea and states that "We learn with our hands although one can study and understand a concept through literature and diagrams, physically engaging with an actual object produces a deeper understanding; it stimulates the kind of intuition that is often critical to a designer". Dorta, T (2008) also supported the claim that the ideation process in design is still done with "traditional manual analogue tools" since the current advanced computer "interfaces are inconsistent with the needs of designers", and this created somehow a gap between the designer and the origin of his idea(Dorta, T. 2008). This may well prove to be one of the most valuable contributions of model making in design thinking. Accordingly, here, it is seen that the concept of 'learning with hands' appraising and learning from each piece was evidently captured in the study of Fred Collopy that every step (in the process) has its own impact on the one following it (Collopy, F. 2004). Thus, this concept should be focused upon in depth when considering the role of models as initially thinking tool during the design process.

In Ansgar Oswald's treatise entitled "Exploring the Nature of Architectural Models in the Twenty-first Century", the idea that whether the use of computer tools can compensate for a lack of hand skills was discussed. He asserted that "The drawing is the language of the architect" and the "sketch" is basically the germ cell of the design that "reveals the creative skills of its author" (Oswald, A. 2001). Thus, transferring these principles from hand drawing to model-making, one may assume that the ability to convert a design into a preliminary construction/working model made of physical materials is necessary for the development of unbiased clarity of vision which enables the architect to visualize the projected building.

On the other hand, it is pointed out that ‘virtual reality’ blurs the relationship between design and matter and visibly interferes with sensory perception. This interference into virtual environment tempts the observer to view the graphical image as the material representation of an idea (Oswald, A. 2001). Hand drawing and manual model-making, are considered to be similar to writing in that they rely on the use of ‘typographical writing systems’ that lacks a feeling for the shape of the letters which forms words and sentences to strengthen a sense of their meaning. By applying this principle to architecture, it is stated that model-making can only be learnt by making models, it is a practical activity that falls within the assumption of ‘learning by doing’ as addressed by Schön, D. A. (1988) . Therefore, learning the skills of model-making in schools and improving it in practical life are very significant. When there is a lack of such skills many wonderful ideas could not be put into practice because the construction of model exposed the idea as illusory. Conversely, many ideas are never put into practice because they were never taken to the stage of the model. For instance, Ansgar Oswald, (2001) criticized the work of Leonardo da Vinci in that he created countless sketches and construction drawings for devices and machines from “lathes and cranes to vehicles and mechanical flying machines” (Figure 2.10). However, because no models were ever made to determine whether Leonardo’s construction ideas would actually work in practice, his “drawings remained what they were at their inception” (Oswald. A, 2001). Based on this belief, it can be inferred that only by constructing a model a design idea could be put into practice, and so the use of computer tools cannot compensate the lack of hand skills.

In architectural education, extensive studies and experiments have been conducted in determining the impacts of architectural models as a methodological approach in learning. Among these studies, the one conducted by Nick Dunn (2007) is very significant and it concerns the significant role of architectural models in the creation of learning spaces (environments) between students and tutors.

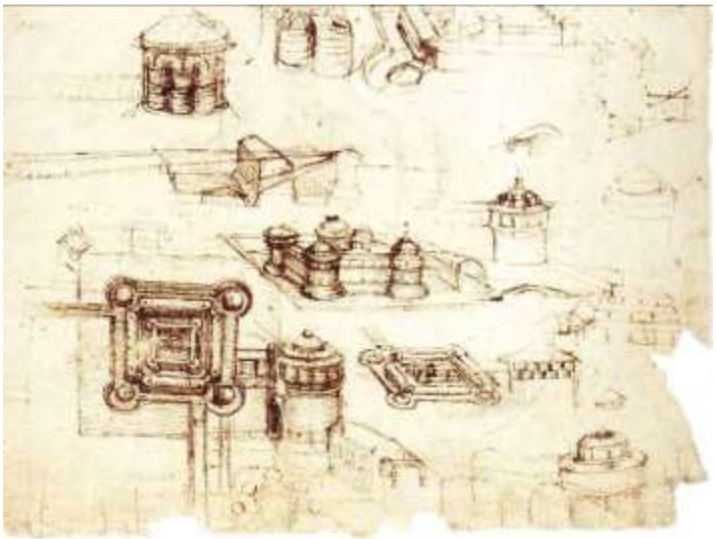


Figure 2.10: Leonardo da Vinci: Study for a fort with square ground plan, Pen and ink sketches.
(Source : Oswald, A. 2001)

The author demonstrated also the roles and impacts of physical models in education environments that were attributed to the physical tangibility of the model. It is argued that when we fabricate, touch, or simply observe the miniature, we have entered a private domain where the sense of closeness and intimacy is implicit. A physical model not only enables a more effective method of communication, but also defines and identifies the relationships between elements within a certain environment. Dunn identified the importance of architecture models in both learning and practical environments, where he practiced the effectiveness of physical models on tutors, students, clients and architects. The modeling of an architectural design has significant implications for the design process of a student; and Porter (1979, p.61) summarizes this process as follows;

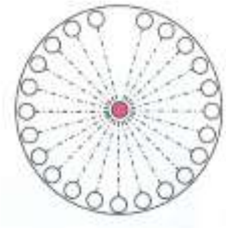
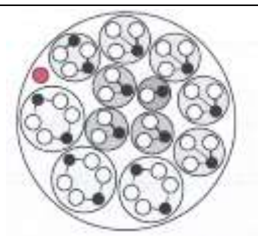
> *"… The idea has to pass through space and be translated into two or three dimensions, as a descriptive model, which allows the designer to experience the nature of his idea and develop its conception. This perceived experience, newly-represented, of a form- space acts as a basis for further development inspiring his creative imagination on to other representational form for personal or group evaluation. This two-way language of design is a continuous dialogue between concept and mode*

of expression - alternating until the creative process is exhausted".

We know that architecture models can assist in determining the interactive relationship of communication, such as between tutors or clients who are identified as "the receiver" of information, and student or an architect who is "the transmitter" of information (Dunn. N, 2007). To illustrate, in educational environment a model allows the tutor to understand a student's design in three-dimensions more readily than when represented in two- dimensional drawings. It is argued that drawings can clearly help designers generate concepts, but they may not necessarily be the most effective method of communication. The two-dimensional picture of a three-dimensional object (space) requires great skill of the viewer in order to interpret and imagine the space described (Sommers. V, 1984). In fact, whether in education or in professional practices the progress of transferring and communicating someone's idea to others has been an issue of debate and may not be an easy task to handle. Thus, Nick Dunn practiced such an interaction and means of communication within educational environment to facilitate the complexity of ideation in design and education. To do so, the following table explains how the physical and virtual models were implemented in educational environment in various learning circumstances, and how it impacted the relationship between students and tutors as well as the learning outcomes (Table 2.1). This table was prepared by gathering information from Dunn's study.

Many experiments have demonstrated that creating such spaces facilitates and enforces the process of training and error detection, so that through the presence in these spaces it provides opportunities for the students to learn from each other, in addition to the ease of communication with tutors. This is a significant issue concerning the learning processing, particularly in the design studio. Thus, creating an interactive learning environment in architectural education has been considered extremely important. It is noted that such environments have been accidently formed only by the coexistence of physical models, as the matter of presence is almost absent when dealing with digital models (Dunn, N. 2007).

Table 2.1: A summary of the impacts of models on various learning scenarios

Activity description	Graphical representation	Discussion
Layout of learning environment during lecture using physical model. In this occasion the tutor is the "transmitter" and the students are the "receiver" of information.		The model used here as an explanatory tool by the tutor. Physical interaction only occurred between the tutor and the model, while students interact visually.
Layout of learning environment during lecture without using physical model. In this occasion the tutor is also the "transmitter" and the students are the "receiver".		In typical learning environment where no models exist, only verbal (intangible) interaction can be occurred.
Layout of environment during workshop. In this occasion the models offered to create multiple learning environments, where the students become the "transmitter" and the tutor becomes the "receiver" of information		In practical courses the necessity of using physical models (objects) created multiple learning environment with different interactions within a single space.
Private learning environment is created between the students and the tutor. In this occasion, the model is used as an exploratory tool by the student to clarify his design idea. However, the tutor and other students became the "receiver" of information		Visual, verbal and physical interaction between tutors and students. In this case the tutor is the "*receiver"* of information and the student holding the model is the "*transmitter*" of information.
In learning environment where the digital applications are mainly used (digital design studio), the "receiver" and "transmitter" of information remain the same. The different can only be identified in the interactions between the users of that environment.		The use of models in digital design studio environment. In such occasion no physical interactions occurred between the students, tutors and the model. Only visual interaction is occurs between the "transmitter", "receiver" and the virtual model throw 2D screen image.
This event is typically shows the type of dialogue and interaction between students, tutor and the "virtual" model		In this occasion although the student control the model using computer mouse, the dialog and interaction between the "transmitter" and the "receiver" occurs intangibly.

Many other studies have focused on the role of architectural models in education as a means of communication and representation rather than a way of thinking about and generating ideas. Often the problem that is facing many students during their design studio is how to externalize the idea of their design for facilitating the understanding of the relationship between the idea and contextual circumstances (the site).

Models have also an active and prominent role in creating multiple interactive environments between different disciplines (knowledge sharing) (Figure 2.11).

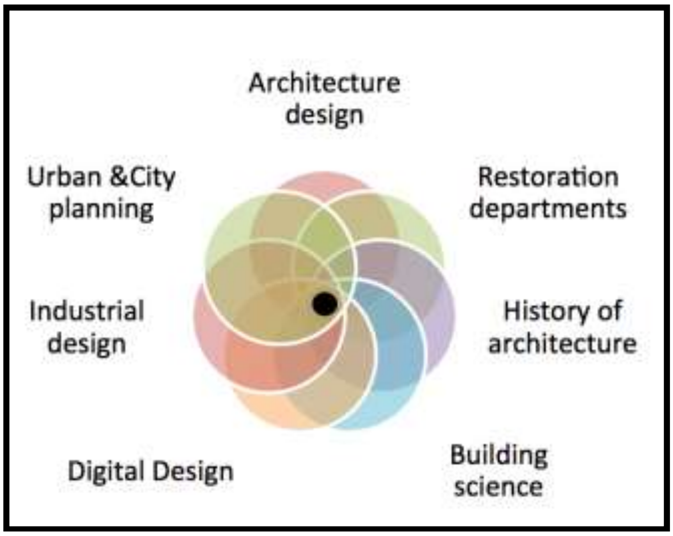


Figure 2.11: Models assisted to create interactive learning environments between multiple disciplines.

The impacts of models on learning environment are very significant and can be summarized as follows (Dunn, 2007):

- Visual appreciation of three-dimensional properties.
- Provide tactile interactions (in physical modeling only) (tangibility).
- Facilitate various design/tasks Manipulations.
- Passing around (mobility).
- Flexibility through dismantling and rebuilding.
- Rearrangement and editing of components.

- Varying degrees of information to be communicated from basic formal inquiries to highly detailed models.
- Testing the build-ability of the design.
- A design development process to be recorded.

2.3. Practical Approach to Model Making

Physical models are used in order to compensate the lack of clarity found in the two-dimensional representations of design, while digital models have provided a more effective way of visualizing objects with greater accuracy. In fact, the fundamental differences of these two approaches play a significant role in today's architecture design practices. The questions that arise are: "Where do the fundamental differences between the use of physical models and that of the new computer technology lie?"; "What can digital models offer that the physical ones can NOT?"; and "if digital models can compensate for the role played by the hand-made models, then why are we still engaged in making hand-made models? For answering such questions the main differences and types between these two techniques (physical models & digital models) should be clarified. In this section, the different categories of models are going to be classified, and then the above mentioned questions will be tackled by investigating the two techniques in terms of their major roles and impacts on the design process.

2.3.1. Categorization of models

Before discussing different classifications of models made by various scholars, it is important to remind that the word model wherever mentioned here refers both to physical and digital models unless a distinction is made. However it should be clarified that the main focus of the study is "architectural model-making" rather than "architectural model", with physical model-making process having a particular priority. Therefore, the focus of the study chooses to adopt a taxonomy for models that is done regarding the operational values of models, which are mostly related to the process of model-making rather than representational values. In order to provide a wider understanding about models and model-making, different classifications and categorizations were reviewed and are presented in the following paragraphs.

In his study, Criss Mills (2005) used the term "architectural model" as a means of discovery, and considered it as an integral part of the design process. The author outlined the most commonly used types of "models" in terms of how they are made (practically). Accordingly, the author initially concerned with the types of models that are used within the design process for enhancing the designer's ability to understand the spatial components of the design. All the model types that Mills discussed were considered as "study models", so that their purpose was to generate design ideas and serve as a transitional step for refinement. Additionally, the author addressed several changes that have taken place in design industry, concerning the use of digital information for the development of design and communication (Mills, C. (2005). The different types of models mentioned in literature are listed below:

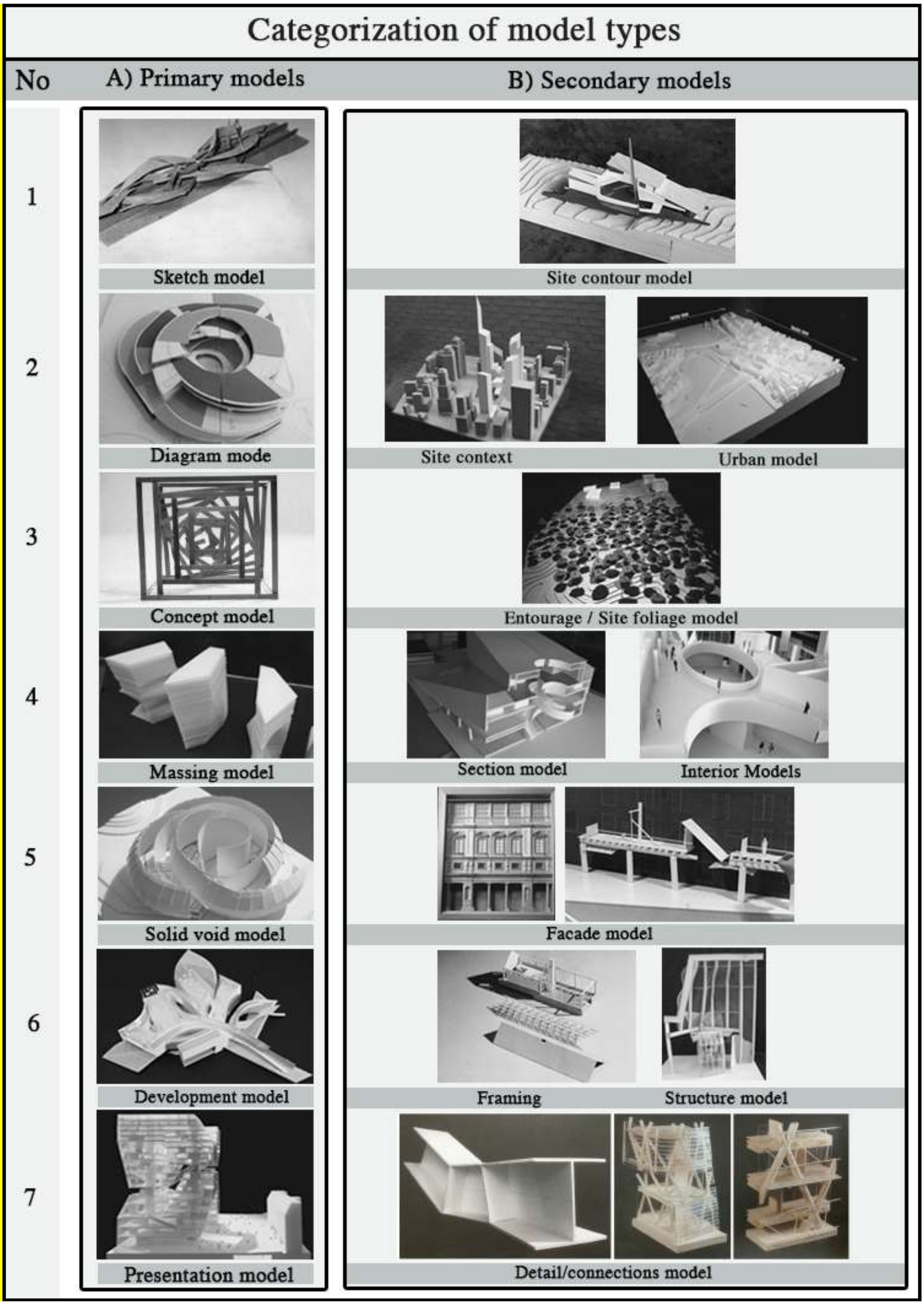
- **Sketch model**: Small alternative sketches can be made early in the design phase to explore basic building organizations and reflect general relationships of program circulation and architectural concerns
- **Diagram model**: - A small model used to map out abstract site relationships and establish initial tectonic elements such as the circular element.
- **Concept model**: a model made to explore ideas about shade, light, and shadow, or to make interpretations of compartments and empty space.
- **Mass model**: massing models are typical of the building representations used for site plans
- **Solid/void model**: a model representing the central void and linear nature of wall and roof planes, this model type is somewhere between a development model and a refined sketch model
- **Development model:** They imply that some initial decisions have been made and a second or third level of exploration is being conducted. Presentation/finish model: model made for design presentation
- **Site contour model**: This model represents topography and building relationship to the site. Typically, they reproduce the slope by employing series of scaled layers, representing landscape levels.
- **Site context model**: shows the surrounding buildings, built to study

building’s relationship to the mass and character of existing architecture.

- **Entourage/site foliage model**: Representing the modeling of people, trees and site furnishings, this is to give a sense of the scale of the building and surroundings without interfering with the perception of the building
- **Section model**: enables to explore the relationships between internal spaces and external skin of a building, also it may be used to demonstrate an effective method of communicating the variety of structural ideas within a design without representing the entire building.
- **Façade models**: these types of models are built when isolated elevations are needed for study and refinement
- **Framing/Structure model**: this type is related to a detail model in that its primary use is in visualizing the relationship between framing and structural system in space. It may represent the exact location of beams, load transfers, and other technical conditions
- **Detail/connections model**: represents some parts details and inter-relation, it can be used for later tests or mock-up of part of a structure aiming for further investigations progress

Thus, various information concerning digital modeling programs, techniques and methods were updated along with the interference between modeling programs and the growing use of rapid prototyping process. According to Mills (2005), "study models" are classified into two main groups: primary models and secondary models. Primary models “are abstract in concept and are employed to explore different stages of focus". On the other hands, secondary models “are used to look at particular building or site components." Both types are differentiated and represented in Table 2.2.

Table 2.2. Categorization of model types based on information gathered from Criss B. Mill's study.
[Source of figures: Mills, C. (2005)]



In another study, the types and models categories were investigated in a slightly different way. In his study titled *"The ecology of the architectural model",* Nick Dunn (2007) explored the role that a scale model can play in architectural education environment. It discussed how a model interacts with its user or contributes to the understanding of the use of a model as part of an educational process. Besides, the author also introduced some general definitions and established different properties of architectural models. Dunn refers to the relationship of a model with what is being represented and the process of its design and development i.e. *why* and *how* it exists. Accordingly, taxonomy of different types of models was attempted by looking at existing classification with their relationship. Then, the study concluded by describing the potential constraints for the use of models. Based on the definition by Echenique (1970) that a model is "a representation of reality where representation is the expression of certain relevant characteristics of the observed reality and where reality consists of the objects or systems that exist, have existed, or may exist" , the author suggests considering the potential relevant characteristics of reality that Echenique refers to and look at how they may be represented.

By the same token, it is assumed that the relevant characteristics of a model are determined by the questions that the model is designed to answer. However, such an assumption relies on the model-maker's ability to focus on these characteristics as the intention(s) for the model. Basically, it is stated that the ambiguity of the word 'model' and its potential set of definitions led to consider different types of models. For addressing the ambiguity of the term 'model' and its potential whether a theory, a law, a hypothesis, a structural idea, a role, a relation, an equation or a synthesis of data, it is demonstrated that; as a noun the "model means representation"; as an adjective it means "degree of perfection"; and as a Verb it means "to demonstrate" (Echenique, M. 1970). Thus, to overcome this multi-definitional term, Nick Dunn identifies three principle types of models (Dunn, N. 2007):

- "Material analogue models: these are both strongly predictive and justified by choice criteria.
- Conceptual models: these are strongly predictive but are not justified by choice criteria.

- Mathematical models: these are a type of formal theory and are weakly predictive in the sense that all the relationships are supposedly known so that new properties of the observable facts cannot be predicted."

Material analogue models are based on the assumption that, by using certain observable facts, a theory that explains some of the phenomena of the real world can be used to predict new properties or explain some other phenomena in the field of investigation. Whereas, the conceptual model is one in which the prediction of new properties in the field of investigation is entirely imaginative and not derived from any casual theory. Accordingly, it is stated that "such models would rather be regarded as imaginative devices to be modified and fitted ad hoc to data. Although, it may be considered arbitrary in the early stages of development, a conceptual model has a very important role since it can give new interpretations of theoretical terms by transforming them into observable 'things' that are non-arbitrary as they are determined by the model itself. Hence, when neither material analogue nor conceptual models are used; and phenomena are explained directly, the explanation becomes a formal theory or mathematical model that is a hypothesis designed to fit experimental data. Accordingly, it is stated that within the environment of the architectural design studio it is the first two categories of models that are principally relevant. Besides investigating the types of models, the study intended to provide various functions that a model can offer; these are presented in Figure 2.12 which is based on information gathered from Mills (2005), Dunn, (2007) and Dunn (2010).

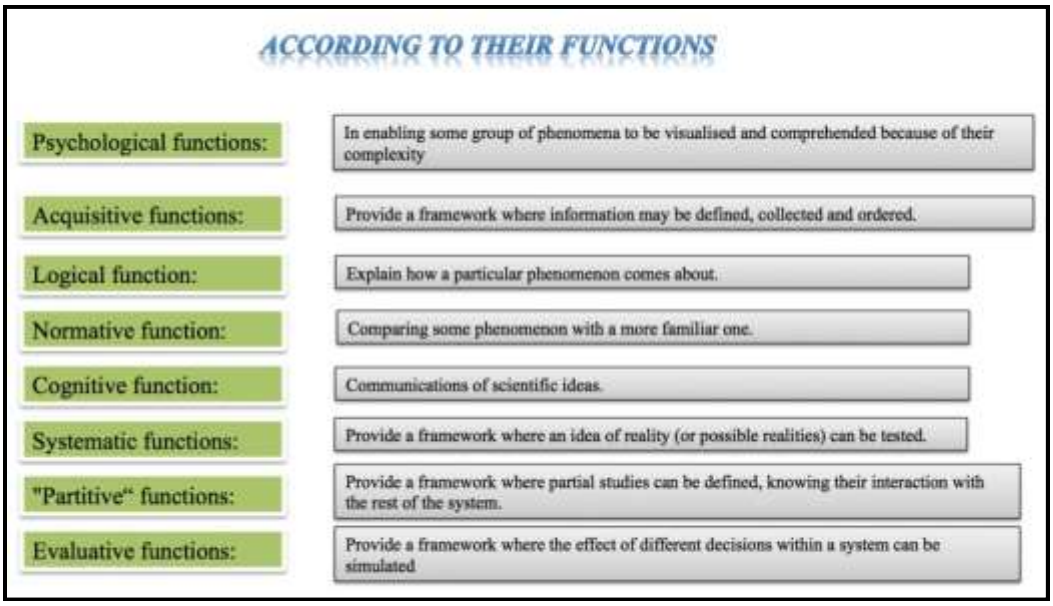


Figure 2.12: Categorization of models according to their functions.

Janke (1978) also identified another five principle types of architectural models namely:

- Town-planning models
- Building models
- Construction and detail models
- Interior models
- Special models

These general categories were further expanded by Porter & Neale (2000) to provide a more comprehensive list of architectural model types as follows:

- Conceptual models
- Site models
- Design development models
- Block models
- Space models
- Structural models
- Interior architecture models

- Lighting models
- Wind tunnel models
- Presentation models
- Exhibition models
- City models
- Full-sized prototypes

Furthermore, four main subsets of model were proposed to find out the properties of the model, that is, a categorization based on the purpose of the model: descriptive model, evaluative model, predictive model, and explorative model. The "descriptive model" is used to assist the understanding of reality by establishing the emergence of a particular phenomenon and describing relationships between the relevant factors.

The "evaluative model" is used to explore or describe something (for example, properties or an experience) that isn't necessarily manifest in the model itself but is related to it. The evaluative model differs from the other types of model since with these it is the model in itself that attempts to assist the understanding of reality or a particular phenomenon, whereas the evaluative model seeks to assist such understanding by its use and relies upon information and actions external to it. The function of evaluative models is to provide data of a qualitative nature i.e. those properties whose variable effects can be "perceived" rather than measured.

The third type is the "predictive model", which is by its very nature is used to forecast the future. It can be further subdivided into two classes: extrapolative, where the continuation of present trends is stated, and conditional, where the mechanisms of cause and affect governing the variables are specified. Predictive models are based on the assumption that the situation is an established rather than an emergent one. An important distinction between predictive models and evaluative models is the type of data generated through their use. The function of predictive models is to produce quantitative data i.e. those variables that can be measured.

The last one in this category is the "explorative model", which is mainly to discover other realities by speculation. This speculative process involves systematically varying the parameters used in the descriptive model to identify those alternatives that are logically possible. Its objective is not only to explore new possibilities but also to refer back to reality and check for the existence of theoretically determined possibilities (Mills, C. 2005 & Dunn, N. 2010).

Hence, as it can be seen that the classification of models may take various forms depending on the nature and the stage of a certain project or design. Therefore, it is better to crystallize all of these categories into other subdivided classes that all the previously mentioned types can be attributed to. Accordingly, Nick Dunn in his study titled "The ecology of the architectural model" stated that any sort of architectural model should be attributed to the following main stages: 1) Conceptual, 2) Physical 3) Iconic, 3) Analogue, 4) Static, 5) Dynamic, and 6) Virtual. All of these should embody the following; scale, time, properties, proportion, logic and efficiency as a design factor (Dunn, N. 2007).

Both Dunn, N, (2010) and Mills, C, (2011) provided a slightly different attitude to the categorization of models. While Dunn suggested that models could be categorized according to their role and function, Mills, on the other hands, maintains that architectural models should be classified according to the projects progress and techniques of construction (see Figure 2.13 & 2.14). As it can be seen architectural models have various types of classifications and usage, so based on what has been stated so far models can be classified into several groups which have been listed and sorted under four main categories in Figure 2.15 to 2.17, which are based on information gathered from Mills (2005), Dunn, (2007) and Dunn (2010).

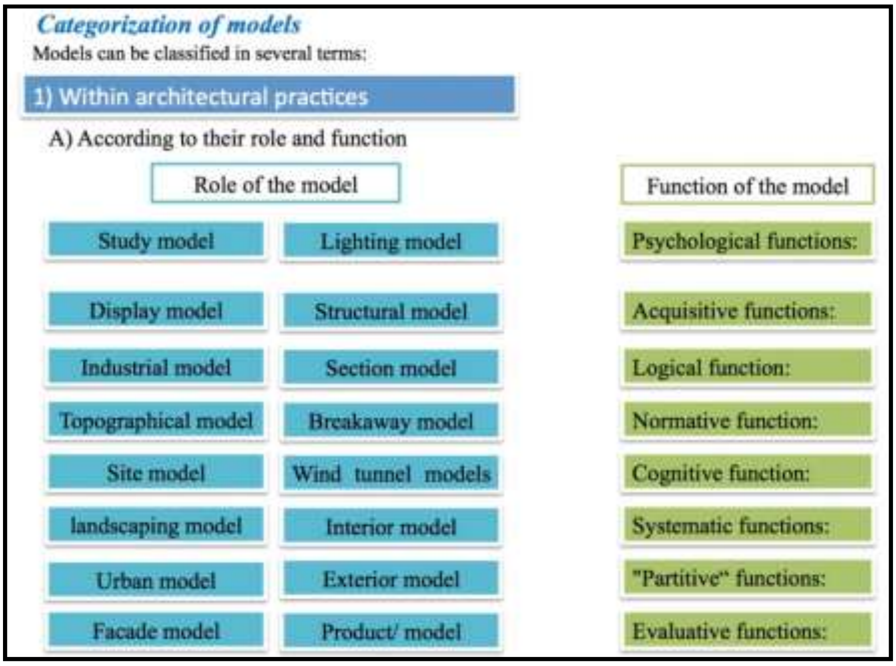


Figure 2.13: Categorization of Architectural models.

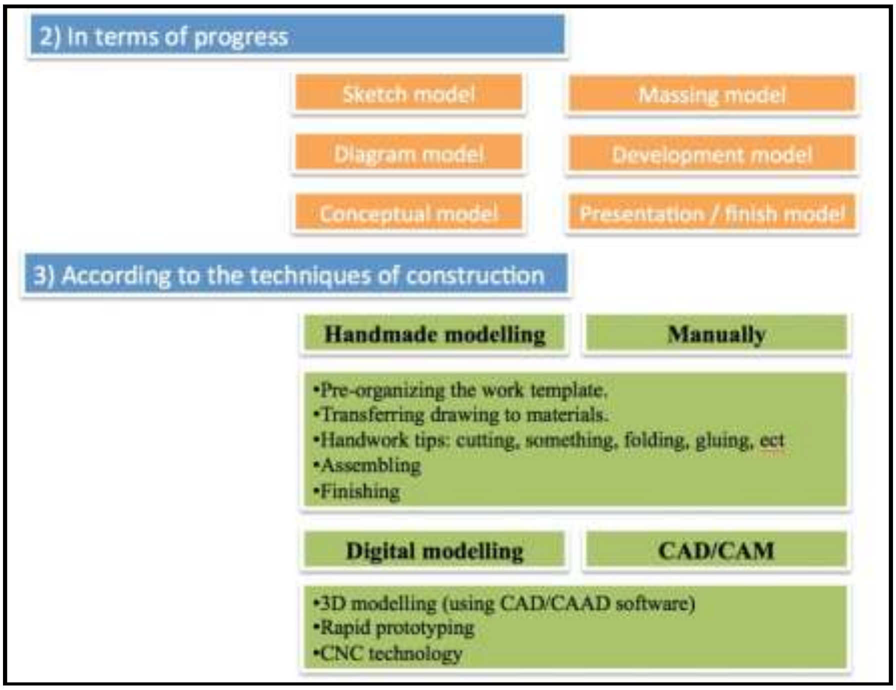


Figure 2.14: Classification of models in terms of progress & techniques of construction. (Sources: Mills, C. 2005 & 2011)

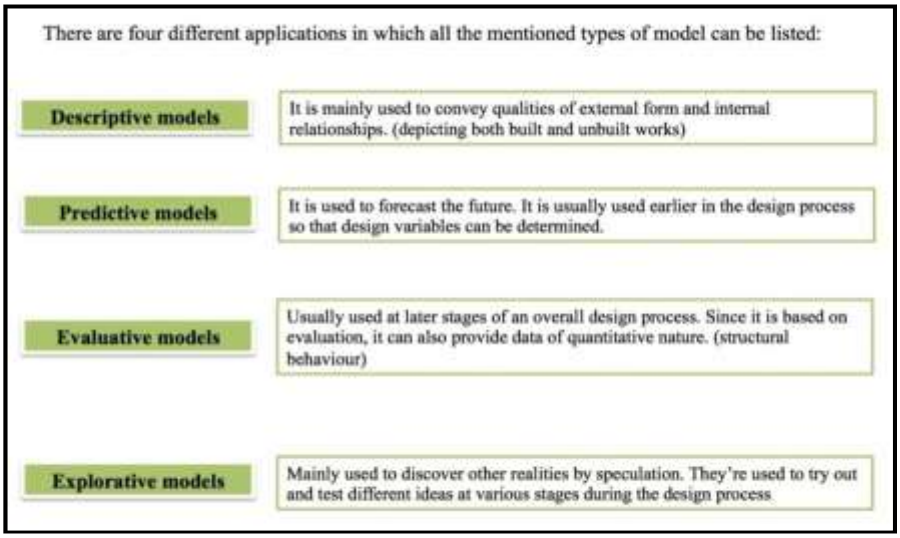


Figure 2.15: Categorization of models according to their application. (Sources: Dunn, N. 2010 & Mills, C. 2011)

2.3.2. Digital modeling versus handmade modeling methods

When studied closely, it is essential to observe the various types of modeling techniques and how they impact the way we approach designing an object/building. As Morris (2006) mentions that, “model types are used strategically, depending on the stage of development and the problem being addressed.” In fact, the fast speed brought about by the invention of digital technology has changed the interaction between the designer and his idea. Unlike handmade models, digital modeling techniques have changed and added many new variables and challenges to the design process.

Back to the previously addressed questions: “what can digital models offer that the physical ones can NOT?” Cheng-Yuan Lin (1999) attempted to answer some pertinent questions by conducting experimental studies. It is argued that despite the gradual increase of digital technology and its role in architectural design, relying on the combination of both physical models and digital analytical methods still dominates current design processes. It is the problem of coordinating these two approaches that plays the most significant role in contemporary design practices. Another problem is the limitation of use that is offered by most software, as architects mostly do not write their codes lacking a complete set of designing tools that is required by the designers/architects. Defining the complexities of architectural space (spatiality) was another concern that is still problematic in the use of computer, whereas it is effectively present by the use of physical modeling. However, with respect to architectural forms, computers have proved to be a more effective way of designing free flowing curvatures and are able to provide a greater degree of accuracy. On the other hand, the use of physical models has proved to be an effective way in correcting the deficiencies of two-dimensional design.

The implementation of modeling techniques in schools has also been noted as a problematic issue. Commenting on this, Cheng-Yuan Lin (1999) argues that "…we don't want them teaching people 1001 features of AutoCAD, we don't want universities to become vocational training schools. We would like to see students who know how to think in 3D".

The two types of modeling, digital modeling and physical modeling, have been investigated and compared among various studies in terms of their differences and value-added features in design. It has been found that unlike physical modeling, users of digital models tend to lose a sense of measurement and space. The scale factor is another issue that is detected as problematic through digital modeling. Accordingly, Lin, C. Y. (1999) investigates the representation capacities of both physical and digital models. He notes that the matter of scale in digital modeling requires a certain level of 'reduction' of the total design information, The disadvantage to this "quality" is the reduced ability to visualize the details in design ; the 'zoom in & out' feature leads to a serious loss of visual information (Lin, C. Y. (1999). In addition, models as seen on the computer screen are still considered to be two-dimensional representations and the situation is still treated as looking at 2D projection or representative image on a screen. Just as what can be visualize by having a 2D sketch on paper, it is essentially a two-dimensional projection of a three-dimensional model which has no depth. Another drawback of the restricted use of digital models is that the outcomes are often perceived as being 'too perfect, too clean, lacking individual expression and the charm of a handmade' artifact (Breen, J. *et al*. 2003).

Wu (2003) mentions four major characteristics of physical models that are different from digital models; i.e., “the vision depth effect”, “real-time shadow”, “quality and quantity effect” and “palpability” (tangibility) (Wu, Y. L. 2003). Therefore, the physical model has some unique characteristics that a digital one does not, that is physically processed, controlled, oriented, and tangibly experienced. This is what necessitates many studies to focus on the development of tangibility and spatiality in design via the virtual world, and thus dedicating more experimental work to establish them. The two types of modeling techniques were also investigated by Huang (2007) by making a comparison between the traditional and digital design progress while tracing the state of physical modeling during both processes. Furthermore, the combination between various digital tools with the design process was further studied through the work of many leading architects such as Frank Gehry and Greg Lynn who successfully implemented various digital tools in their design process. Accordingly, the author preferred to use a methodology consisting of three main parts: Case studies, observations and interviews with designers. The case study sought to analyze the design process of Frank Gehry and Greg Lynn for initial understanding. Besides what was learnt by the case studies, it was necessary to obtain further understanding by practical observation made in architecture design studio with some students.

Huang (2007) conducted an experimental studio focused on the role of physical models in digital design process. Accordingly, two types of design process were investigated. The experiment studio was to define two groups of students who were asked to use different modeling techniques in the initial stages of their design process. To illustrate, one group started their design project using physical model, whereas other group started their design project using digital model. As a result, based on the comparison made between analytical results from the projects of the two groups and case studies, the physical models were very essential and necessary in the digital design process. The design process that mainly relied on the application of digital model during the initial design stage was operated in the virtual environment (VE); hence the designer was unable to control the real feeling of space clearly. Consequently, more outputs and operations on physical models were required at later stages of the design process. Although the use of physical models at the initial stages required the students to spend more time on fine-tuning the physical model, the students were more capable of controlling the overall feeling of space. Therefore, during the design process using computers at a later stage, output and operation of physical model was less needed. Hence, it was found that when a designer uses digital media for designing, the role of the physical model is still more important and more complex than it was in the traditional designing process (Huang, C.Y., 2007).

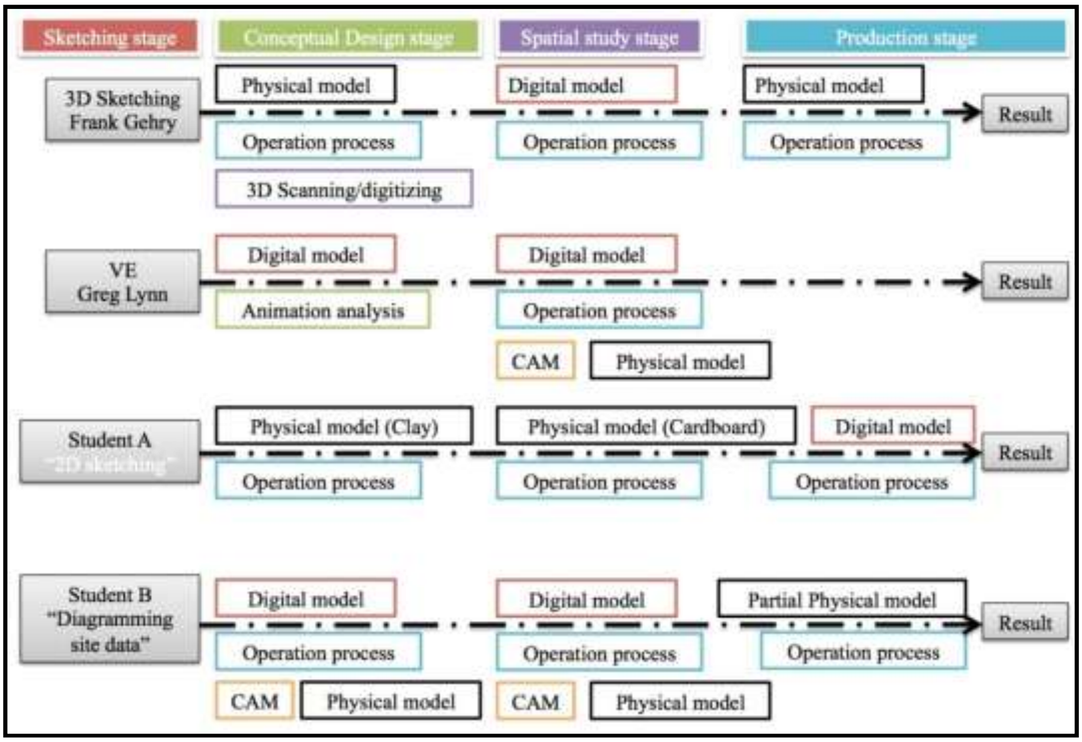


Figure 2.16: Diagram of a case study made to trace the role of physical and digital modeling during the design process (adapted from a study by Huang (2007).

Because of its critical impact on the design process; architecture-modeling techniques have been investigated and developed to facilitate the understanding the mysterious in design ideation process. Many studies discussed the situation of handmade models/model-making in the presence of CAD/CAM technologies. Lim, C. K. (2006), Bettum and Schillig (2006) conduced empirical studies to clarify the significant impacts of both techniques on the design and production of buildings.

Lim (2006) in his study *"From concept to realization"* aimed to provide a deeper understanding of the distinctive features of CAD/CAM tools and their applications. Moreover, the study analyzed the role of the CAD/CAM capability in the production of physical models and the added benefits they offer comparing those offered by traditional handmade (physical) models. The author reminds us that "Filippo Brunelleschi, at the time of the Renaissance, introduced perspective and the three-dimensional physical model to assist designers and artists in their thinking process because of the inadequacy of two-dimensional drawing". Since then, in addition to two-dimensional drawings, physical models have been widely used for presenting the mass, details, interior space, and structural relationships of a design. Therefore, the complicated of spatiality in design became easy to comprehend. In addition to drawings, it is stated that twentieth century architects depended heavily on physical models of various scales when designing with very complicated forms, especially non-geometric forms. As a result, it is believed that the digital design technologies and tools have taken the priority of design applications which aid to reduce the great deal of time and man-hours involved in producing traditional, two-dimensional hand-crafted drawings and handmade models (Lim, C. K, 2006).

Moreover, a physical model offers a "stereoscopic vision", something that is tactile, with mass and measurement. These features allow the designer to better foresee and control any space being worked on. Thus, it is believed that by the use of advanced digital technology in the design process, the way to process the design, configure and even to reach the final required result has become much more easily accessible. Furthermore, with the CAD/CAM digital operation process it becomes possible to fabricate and construct complicated designs that formerly only existed in the designer's imagination. We cannot deny that the use of the new digital medium of CAD/CAM in the design process has changed the design concept, the design process, and even the design result (Lim, C. K, 2006).

Lim (2006) also investigated the assisting role that CAD/CAM plays in the fabrication of physical models and to analyze the changed methods and procedures in the design process. The methodology of the study was to conduct a media tool experiment to understand better the uniqueness of the new design tools and how they can better supplement the digital design process. This experiment was subdivided into two stages:

1. Physical model making by using different media tools: CAD/CAM and handmade;
2. A restrictive use of media tools: laser cutter and rapid prototyping.

This experiment on the use of different media tools in physical model making yielded the following results:

- Difficulty: It was more difficult to make complicated and free form models using the handmade process than using CAD/CAM.
- Time: CAD/CAM was quicker in making free form models.
- Accuracy: CAD/CAM produced more accurate free form models.
- Materials: The handmade process used up more materials than CAD/ CAM fabrication.
- Scale: The CAD/CAM fabrication process produced models with more accurate scale and dimension.
- Design abstraction: The handmade process produced more abstract design thinking when the designers tested and modified the models by hand. While, the CAD/CAM fabrication process had less abstraction.
- Structure: The handmade process provided more choices of structural methods and materials. However, the structural methods were not realistic when compared to the CAD/CAM fabrication process because the designers had to use glue to integrate all the different materials.
- Spatiality: Spatiality representation in the handmade process is from a 2D material sheet (cardboard, etc.) to a 3D assembly model. However, in the CAD/CAM fabrication process, especially when using a laser cutter, the 3D CAD model is decomposed into 2D elements (digital file), and, after the physical elements are output by the CAD/CAM media, a 3D model is assembled.
- Tangibility: during the handmade modeling process a full tactile control was seen during the modeling progress, whereas by the use of CAD/CAM technologies tactile control did not exist, except for the final stages.

On the other hands, Lim, C. K, (2006) identified the characteristics of using laser cutter and rapid prototyping in aiding the design process and creating free-form objects as follows:

- Laser cutter: The production process of creating a physical model relied on a 2D cutting process. A free form of 3D CAD model is ‘decomposed to a 2D skin and structural elements’, which can be fabricated with a laser cutter. Then, the resulting physical elements are assembled to form a complete model. The process is digitalized, accurate, and more realistic than the real-life construction method.
- Rapid prototyping: The fabrication of a physical model is based on a 3D manufacture process. A free form 3D CAD model is projected directly based on ‘layer-by-layer’ 3D printing (additive). Similar to what can Laser cutter offer that the process is digitalized and accurate. However, the designer need not worry about the difficulty of making complicated forms; so can be more liberal and free.

Briefly, this study identified the appropriate applications and supplementary uses of various CAD/CAM tools within the design process. Although the study stated that both "Laser cutter" and "Rapid prototyping" are among the techniques that able to facilitate the production of design, the impacts of modeling (handmade & digital) on design process were not investigated. In other words, the role of modeling as a thinking tool rather than a tool for fabrication was not identified (Lim, C. K, 2006).

Bettum and Schillig (2007) in their study titled “The time and space of physical modeling” discuss the place of handmade models/model-making in the presence of CAD/CAM technologies and argue that “physical models belong to a threatened species of architectural models and are in danger of extinction”. The authors investigated the changes in the production of architecture brought about by the transition from the machine era to the digital era; and point out to the danger of the machine (the use of computer) with its capability to draw and make, taking over the role of a designer and maker to produce the final results. Additionally, certain drawbacks are recognized in that the digital design process leads in a certain sense to a kind of “alienation” of the architect from the context of the process itself. Furthermore, it involves a danger of a “reductive formalism” through which the architect may become distanced from his or her work and its consequences (Bettum, J. and Schillig, G. 2007).

The authors discussed the impacts of "making" in education and design practice, as a process of learning and doing through which an immediate experience becomes possible.. In other words, while constructing physical models, the ‘intimate, imaginary and sensuous making in the production process becomes an important means of gaining creative control’ (Bettum, J. and Schillig, G. 2007). Furthermore, physical modeling allows the designer to investigate the nature of materials as well as constructability of the project; therefore, the complexity of physical production of models offers the ability to discover new types of innovative structures and systems. Accordingly, creatively crafted physical models are “organizational systems, derived through diagrammatic thinking, capable of condensing processed data, including strategic and tactical information”. Such models are believed to contain certain “logic” and are therefore based upon “operative mechanisms”, systems that are capable of fostering "combinatorial developments" (Bettum, J., and Schillig. G, 2007).

Bettum and Schillig (2007) consider learning to be a creative process where information is received in the brain that stores, translates and redirects it. In answer to the question “What can we learn from the model?" three aspects are identified; observing, judging and inventing. Additionally, the direct interaction with materiality in designing through making is another important issue that concerned the authors who criticized the absence of this interaction in the use of CAD/CAM technologies. The authors believed that making architecture has to be considered as "a conscious endeavor in order for us to imagine and investigate the physical, tacit and time-based aspects of space".

Figures 2.17 to 2.19 present diagrams based on the above mentioned empirical studies conducted by Lim (2006) and Bettum and Schillig, (2007). In these diagrams the procedures of both, handmade modeling and digital modeling has been externalized as a step-by-step process to trace and detect the weaknesses and strength of both techniques (digital technique & manual technique) in the design and production of building/objects.

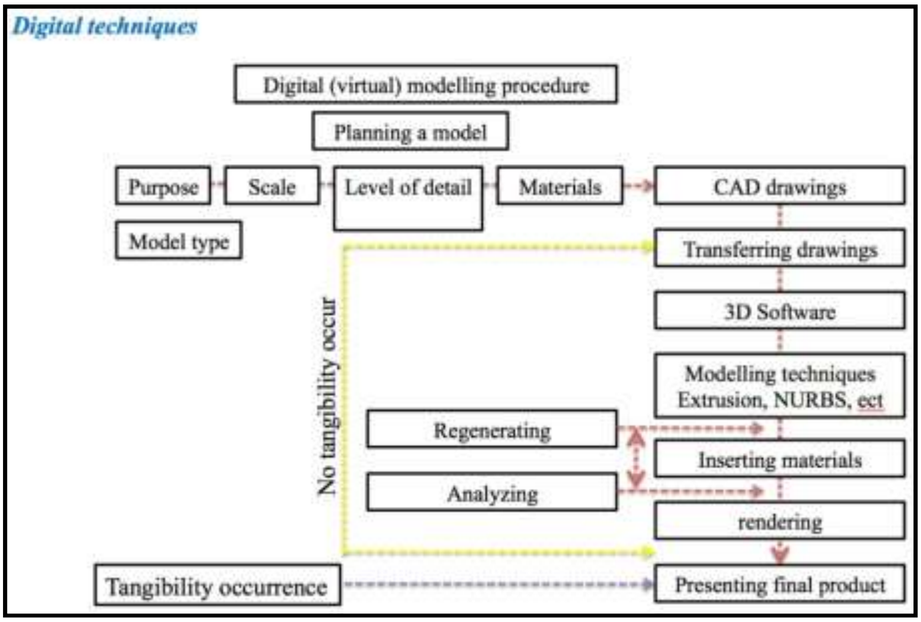


Figure 2.17: Digital (virtual) modeling procedure.

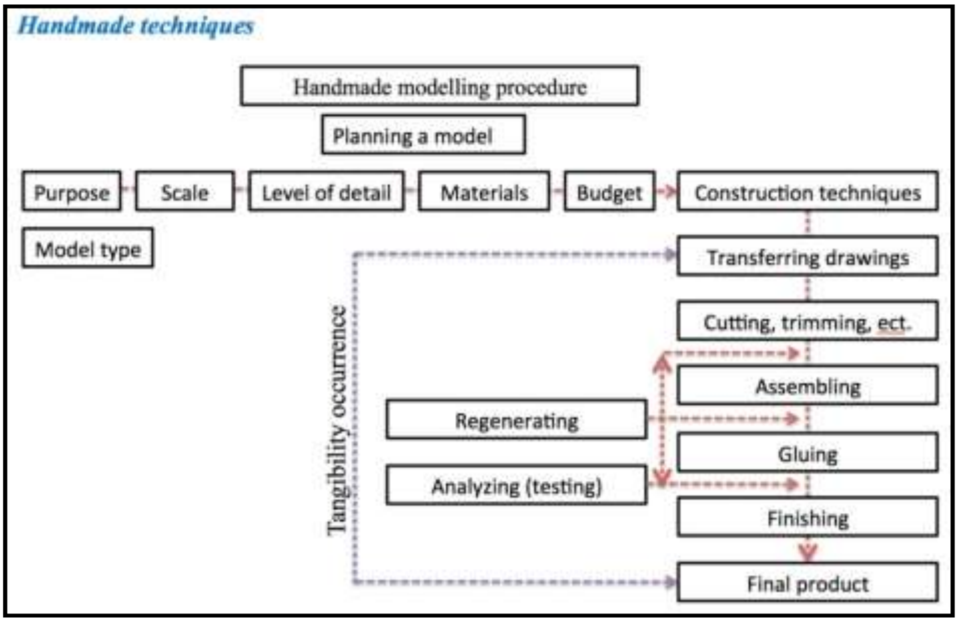


Figure 2.18: Handmade modeling procedure

Table 2.3: Comparison of findings between handmade modeling versus digital & CAM modeling in terms of user & model interactions.

Handmade modelling versus Digital & CAM modelling

Factor	Handmade modelling	Digital modelling	CAM modelling RP & CNC	Notes
Modelling stages	2D-3D	2D-3D	3D	(RP) directly produce from the 3D file data (layer by layer printing)
Time consumption	slow	slow	fast	Except when using laser cutting
Accuracy	less	High	High	
Materials	More option	More option	Limited	Unrealistic in 3D modelling
Structural analysis	manually	Computerized	Computerized	Deriving diagrammatic thinking
Constructability	Direct interaction	No interaction	No interaction	An immediate experience becomes possible
Tangibility	Occurred from start to end	Not occurred	Only after production	only exist during HM modelling
Spatiality	Occurred during the whole process	Not occurred	May occurred during assembling	In HM outside-in & inside-out

2.4. Value Through Design

"Whether we build high or low, with steel and glass, tells us nothing about the value of the building (Mies van der Rohe, 1930)

It might be difficult to discuss what a good design is and how it should be in various contexts, but it is an accepted fact that designs of our physical environment has had a major impact on the way we live and work. The measurement of the value of design is a problematic matter involving complex subjective judgments. Therefore, this study addresses the question within the context of designing process rather than design itself; it focuses on the process of design activities. Because of the process of calibration and measurement of the actual value of design is one of the most complex issues, so this study discusses how to establish a standardized method that can be relied upon to assess the actual value of the design (the value that could be obtained by the making of models). As there are several criteria that can play an important role in determining the actual value of the design, the focus will be on the standards underlying the essence of the idea of design and creativity in thinking and learning. The reason is that design value has been always assessed and measured on the basis of individual considerations. This is a problematic and a complex matter within which subjective judgments are often predominating. Because of the subjectivity in evaluating such issues, this study seeks to develop a clear methodology that can be built upon to assess and measure design value, in addition to the value that could be added by model-making to the design process.

2.4.1. Definitions

Value has many different definitions, which may not be relevant to the subject of study, and therefore just a few of these definitions are listed below. According to Oxford Dictionary the term value and its derivatives can be defined as:

- 'The worth desirability or utility of a thing, or the quality on which these depend (the value of regular exercise).
- The worth of something compared to the price paid or asked for it.
- Principles or standards of behavior; one's judgment of what is important in life.
- The numerical amount denoted by an algebraic term; a magnitude, quantity, or number.
- Value judgment: an assessment of something as good or bad in terms of one's standards or priorities.
- Value-added: the addition of features to a basic line or model for which the buyer is prepared to pay extra.
- Valuable: as (noun) extremely useful or important OR as (adjective) a thing that is of great worth, especially a small item of personal property'.

Rescher (1969) argues that value can be defined as: benefit oriented, subjective, or rational"; it was classified as: cost value, use value or esteem value. As it can be seen, the term value with its classifications may cause confusion in determining which one would fit best in dealing with the undertaken inquiry. Since this study is concerned with whether value in its absolute sense can be measured and defined so that initially the focus should be on the "numeric value" judgment that can be made in a rational scientific manner.

Bunnin, N., and Yu, J. (2004) in their work "The blackwell dictionary of western philosophy" discussed and defined the term "value" in detail. Accordingly, the term value as derived from philosophy of social science, ethics, and aesthetics might be defined as (from Latin valere) "to have worth, to be strong". It is stated that "the conception of value can be traced to the idea of the Good in Socrates and Plato" (Bunnin, N., and Yu, J. 2004). The use of value is generally associated with the distinctions between "fact and value" and between "is and ought" in modern philosophy. However, in ethics, it is stated that something has value if it is good or worthwhile, even though negative values are also possible. Accordingly, the authors tried to state various examples for clarifying the notion of value. "Intrinsic value", for example, was considered as the value of a thing that most people have in normal circumstances, in contrast to the value that the same thing has for special persons in special circumstances. Another form of value is the "sentimental value". For instance, something (a gift for example) might have little intrinsic value in itself, but is of great sentimental value to whom it was given. In another sense, it is said that intrinsic value is objective value, that is, "the value a thing has independent of anything else", so that it would have its value even if it were the only thing that existed.Hence, value can be categorized in two ways; intrinsic and extrinsic or instrumental value (Figure 2.20). Finally, in Philosophy of language & ethics the term value was defined and used to:

> *"…express taste and preferences, to express decisions and choices, to criticize and evaluate, to advise, warn, persuade, praise, and encourage. Their function is to guide our own choices and those of other people by commending or prescribing. Typical examples as mentioned are good, right, and ought, but any word, if used evaluatively, might count as a value word. The value words can be negative or positive, so judgments that contain value words are value judgments".*
> (Bunnin, N., & Yu, J, 2004)

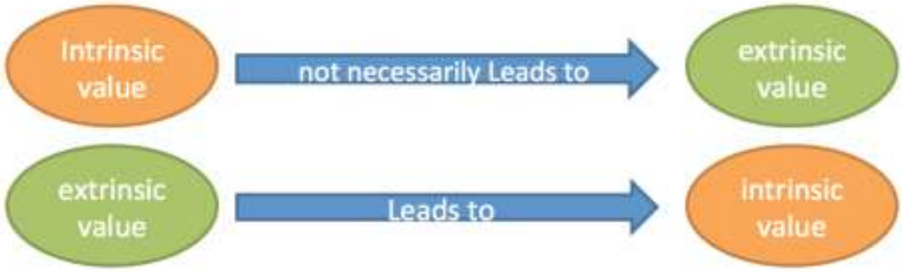


Figure 2.19: Categorization of value in Philosophy of social science. (Based on definitions by Bunnin, N., and Yu, J, (2004))

2.4.2. Quality and value in design

Pursuit of quality is a widespread implicit aim in building design but defining their value in design may vary according to various considerations. It is argued that a well-designed project will impact upon the satisfaction, comfort and well being of its occupants, in addition to the value of its cost and consumption (cost-in-use). In relation to buildings, apart from the definition of value, how the value in design is appreciated and how to measure it, Broadbent et al (1980) argue that "… meaning of buildings are all those things which relate to buildings beyond the face value of their physical properties, to all those things in life which people attach significance and value, including purposes, conceptions, ideas and beliefs".

Allinson (1993) points out the "value-laden" character of the quality concept, while Atkin and Pothecary (1994) highlight the ambiguity of its definition and the difficulty to measure it. Others also agreed with Atkin and Pothecary, like Burt (1978) and Seymour (1990) who recognize the difficulty in quantifying the attributes of quality due its subjectivity. Basically, quality and the evaluation of value have been classified into two main factors, "conformance to requirements" and a "subjective quality" that is based on the individual estimation and judgment, which is difficult to quantify.

Noori, (2012) also conducted a study titled "*Transvaluation of Architecture: A Perspective on Performative value in Architecture*" which was built on the view that acknowledges the significance of value and evaluation in architecture. Accordingly, this study revealed the connection between values and architecture and identified different types of design values that drive architecture. Based on that, the relation between changes in architecture and changes in design values was discussed and the role of design in shaping architecture was highlighted. Therefore, for recognizing the vast influence of values and changes in values on architecture, the author tried to examine a concept from the philosophy of Friedrich Nietzsche, called "transvaluation of all values", in architecture "… which was primarily an attempt to break through the traditional understanding of the boundaries that limit our moral and intellectual life", and to establish in its place a new set of higher values. (Noori, 2012).

According to the author, a detailed examination of the history of architecture showed that values have not only driven architectural design process but also shaped the history of architecture. Accordingly, the different architectural styles found in different eras were significantly shaped by the variations found in the design values embedded in the design process. In that sense, changes in architecture are created by the change in design values. However, technological advancements and paradigm shifts have not been reflected in architecture, as they should have been throughout the history and theory of architecture.

Noori's study, gives a general overview of the types of values, the nature and role of values in human decision-making and the state of values in humanities and natural sciences. He then discusses the nature of value in architecture and its role in shaping it and its schools, movements, and styles. In doing so, various schools of thought and styles from the history of architecture were analyzed. Historically, the conflict among architecture's most well known three values described by Vitruvius in his book "De Architectura", which was written around 25BC, such as "***Firmness, Commodity, and Delight"*** was further discussed. Other values that concerned architecture, and worth to be mentioned, were the materialist values, which emphasized on economic and physical security, and the post-materialist values that emphasized on individuals self-expression and quality life concerns. Besides, aesthetic value was also examined, as it was among the important design values that shaped modern architecture style that could best depicted in the famous statement "less is more" by Poet Robert Browning. By the same token, function was another important value that concerned the modern era. Accordingly, depicting value in architecture has always continued throughout the history of architecture until today. (Noori, 2012).

Two different types of values that influence architecture were distinguished through the definition of two different approaches, that is, “**subjective”** and “**objective”**. The former refers to values as something projected onto objects by a subject, thus values are considered as an internal to a person and depend on the personal stance. Whereas, the latter which is the “objective” understanding of values considers objects as "an independent of subjective of a person, thus, values exist in an object in itself or can be imposed by some other entities such as, rationality, human nature, or other authority with an independent standpoint". Accordingly, values associated with architecture can be categorized into two main types: 1) values in architectural design (the values that affect design decisions), 2) and values of architecture (after creation) as a physical product.

In clarifying these types, it is stated that during the architectural design process an architect evaluates different alternatives and makes decisions about different design aspects when proposing design solutions. Therefore, the study mentioned different values that are believed to have an effect on the design process, whether they are “individual design values of architects or societal-based design values”. For example, aesthetic, functional, environment, economic, socio-cultural, traditional design values, and many others that drive architectural design decisions. On the other hand, concerning values of architecture after creation can be clarified on the large (finished) scale architecture that has many impacts on a society as well as the built environment. Consequently, architecture like any other product gains a number of values such social, cultural, economic values which represents the implication values and values imposed on architecture by public, users, and others who may not be directly involved in an actual design decision-making process but rather are affected by it; e.g. Frank Ghery's Guggenheim museum in Bilbao. Such a project is believed to serve as a good example to showcase values of architecture as a physical product because in addition to its function as a museum, it has a strong economic value: ever since it was built the Guggenheim transformed Bilbao from an inactive industrial city to a touristic center by attracting large numbers of tourists and visitors both nationally and internationally. Architecture can add other values also such as "cultural identity" of a given society; for example the Sydney Opera House by Jorn Utzon which has become more than a waterfront sculpture and a famous building but also a cultural symbol and Australian icon. Thus, this and many other architecture works affirm how architecture can be valued differently based on its impacts enables on its surrounding; especially when the architects designed for these values and predicted the impact and values of their design early during the design stage.

Dorothy Evans (2010) discussed how the issue of value and quality in architecture are judged. In her Ph.D. dissertation entitled "Value Added in Design: Perception Versus Reality" she presents a comparison between things, objects or any activities and how we judge between them in terms of "valuableness". Defining design and is the value of design the author asserts that "… good design is much more than just making something look nice". It's about taking a considered approach to a design problem in order to find the best solution even though some designersoperate with the sole objective of creating something that looks nice. (Evans. D, 2010)

This is a flawed approach and calls for change in people's perception of design value to understand what a good design is. The absence of ability to evaluate and make effective design has been an important issue for many designers and in order to resolve it various significant factors through which the concept of value-added design should be evaluated were studied. Consequently, "descriptive, qualitative and quantitative" responses of designer's and manufacturers' were evaluated and the main factors that should take the priority of any undertaken design were identified as: "efficiency and durability; symbolic or stylistic value; organizational issues; workmanship; materials value and safety". (Evans. D, 2010)

2.4.3. Measuring value in design

Most studies have addressed the issue of the value in several aspects (theoretical and purely philosophical), while rarely it has been addressed in terms of scientifically valid measure or as a standard absolute value with regard to the design process. This increases the motivation for addressing the issue in order to know how is it possible to calculate and assess value through the design of buildings as an absolute value.

Through what has been revised so far, the focus of the study will be on the issue of value only in terms of viability of measurement. In achieving the measurability of value in design, a questionnaire survey was conducted by Bartolo. H. M. G. (2002) considering the following questions:

- How to define quality in design?
- How to choose between the ranges of possible building design solutions and arrive at the best one?
- How to achieve at an optimum compromise between quality and costs?
- In terms of quality and costs, is it possible to produce a quality work with a reasonable cost (not expensive)
- How to predict that a design will be high quality and low cost?
- How to measure quality and economy of a design?

The questionnaire results and answers involved some characteristics like “creativity, good form, composition and proportion”, “attention to detail”, “simple and elegant use of space”, “integration of services” and “fulfillment of user requirements within a stimulating environment”. Quality in design was described as “the achievement of a totality that is more than the sum of the parts”. Besides, the designers’ ability in integrating and transforming the mentioned requirements into a unified whole, is also appreciated. Thus, skilled and experienced designers seem to be a key factor asset in the achievement of quality in design.

Finally, it can be concluded that values in design are relative and can only be measured subjectively. The best that has been achieved in measuring such value is that a **“satisfied”** position is reached (Boon, J. 2002). Therefore, the nature of such value is treated as a design that maximizes the users’ satisfaction from the engagement with the product in terms of their “practical, intellectual, emotional and social involvement, within the context of their preferences relative to other things” (Paul, J.J, 2000). It is known that adding value to a design means to create balanced solutions reflecting a total understanding of the project and user’s needs. On the contrary, neglecting of other essential considerations such as the thinking and creativity mechanism, that is the core of designing and producing the physical form, would negatively affect the creation and the essence of design idea. So far, the focus on the matter of value has only been made on the quality and value of the design (well-designed) as a final product, but they have never considered the designing mechanism, thus further investigation still needed.

Within this context, the need for measurable value strategies within the framework of designing buildings is more pressing than ever to combat the subjective and rational beliefs in determining value in design. This demands a fundamental re-thinking of the essence of **value factors** in the designing of buildings. Therefore, further analysis and experiments are required for the formulation of measurable strategies in possessing and evaluating the value-added in architecture design which is suggested to be treated in the context of architectural design progress offered by the making of models in making ideas buildable.

Another study conducted by Marc A. Sallette; (2005) addressed the new intellectual framework developed in the United Kingdom that made the issue of identifying and evaluating a good design measurable and possible. Accordingly, the study proposed a developed assessment tool that could assist everyone involved in the design, production, and use of the building to be involved in the assessment and evaluation of the quality of his or her design. It is stated that in addition to aesthetic and style, the need for a good design is to be judged in a wider sense in terms of “construction, quality, functionality, and impact” (Sallette, M.A., 2005). Based on that, the study investigated the challenges on how to recognize, evaluate and define a good design in a measurable way.

Accordingly, two organizations in the United Kingdom, the construction industry council (CIC) and the commission for Architecture and the Built Environment (CABE), have been building an intellectual framework to determine the key attributes that constitute good design with respect to both individual buildings and urban spaces. It stated that the CIC's intellectual framework includes an assessment tool derived from the ancient themes of Vitruvius, the Roman author from the first century B.C., whose "Ten books on Architecture" is the earliest surviving theoretical treatise on building in western culture. Thus, it is a "Vitruvian" assessment

(Commodity, Firmness, and Delight), measuring design in the broadest sense, focusing on everything from a building's functionality, to its built quality, to the impact the building has on its occupants and surroundings. These are mainly considered recently for developing an analysis tool called "design quality indicator" (DQI), a method of assessing the quality of buildings that is based on the following three criteria as addressed by Sallette, M.A., (2005) (Figure 2.21):

- **Built quality:** involves the performance of a building by considering structural stability, the integration and robustness of systems, finishes, and fittings.
- **Functionality:** concerns the arrangement, quality, and interrelationship of space, and the way in which the building is designed to be inhabited.
- **Impact:** Involves the building's ability to create a sense of place and how is positively react to the local community and environment; it also includes the aesthetics and art of the building and its impact on the architecture of neighborhoods.

Based on the above mentioned factors, the proposed 'design quality indicator (DQI) sought to set a measurement criteria that could determine the performance, functionality and quality of the structure of the building, the interrelationship among the design spaces as well as the impacts of that design on the architecture of surroundings. Accordingly, the 'DQI' set to provide feedbacks and capturing perception of design quality embodied in building based on three main elements namely, 'conceptual framework, data-gathering tool and weighting mechanism'. Therefore, these elements are to map the value of the building according to its different uses, the ability to meet a variety of physical, inspirational and emotional needs of occupants and users. DQI was designed to be used by everyone who is involved in the production of the proposed building such as 'architects, planners, public officials, clients, designers, developers, contractors, project managers, facilities managers, occupants and users'(Sallette, M.A., 2005).

In brief, the two main issues that the "DQI" was made for are; "measuring design and understanding the views of users". On the one hand, in measuring design it stated that 'design quality' is difficult to quantify as it consists of both 'objective and subjective' components. On the other hands, in understanding the views and satisfaction of the users which are given priority when evaluating the quality and usability of building design that is also not easy to measure it is an emotional based assessment. That is, there might be many different and conflicting views held by individuals and groups. (Sallette, M.A., 2005)

To sum up, the 'DQI' criteria is based in the use of a short questionnaire, where respondents are involved in the assessment of evaluating the building quality by choosing among various attributes related to the building quality with choices scaled from 1 to 5. Each attribute falls under one of the three primary fields of quality. By doing so, DQI responses are aggregated and plotted on axes arranged in a star shape with a scale of 1 (basic) to 5 (excellent) for each attribute (Figure 2.22). Each axis corresponds to a different indicator, with points farther from the center having a higher rating for quality. A building that is regarded to reflect good design will form an overall shape approaching a circle along the outer edge of each axis, while various portions missing from the optimal rounded shape will identify a building with shortcomings in the design. In short, the study argued that the benefit of the DQI is a 'tool for thinking' and estimation, rather than an absolute measure. (Sallette, M.A., 2005)

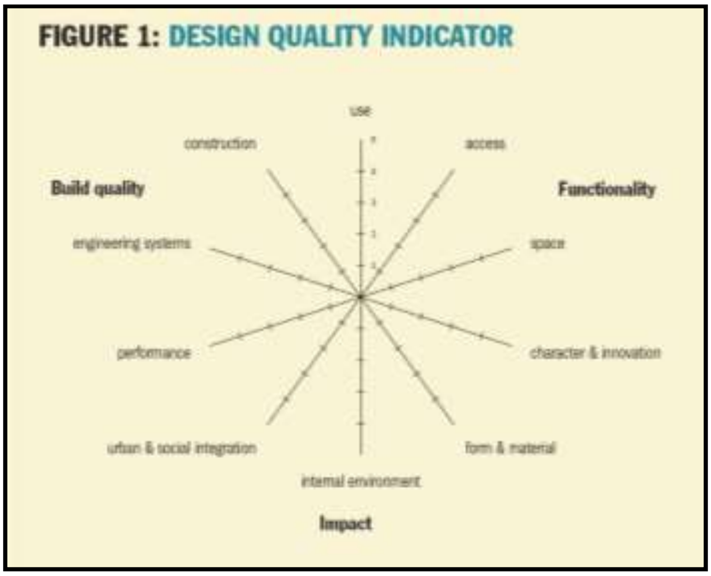


Figure 2.20: The spider diagram of "DQI". (Sallette, M.A., 2005)

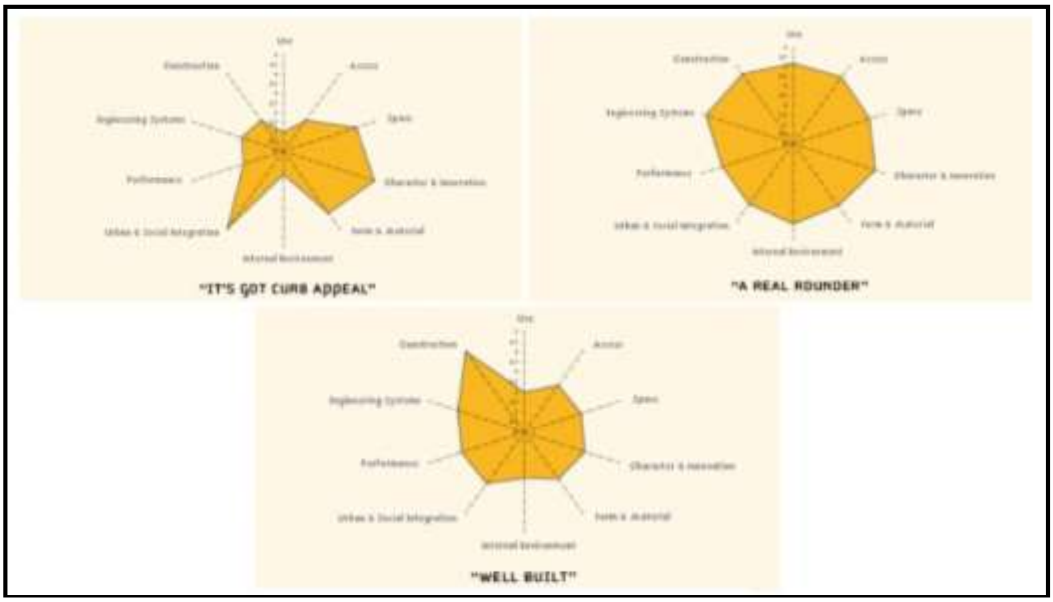


Figure 2.21: The spider diagram is the signature output of the DQI. The "chunks" missing from the pie represent deficiencies in the building. (Sallette, M.A., 2005)

2.5. Concluding Remarks

Chronologically, it is remarked that throughout history, physical models were considered as a powerful method of communication in the description, exploration and evaluation of architecture as a whole. Thus, for over 500 years, the architectural model has been used as an important method of communication in the understanding of new ideas in architecture. Recently, although the significant increase and developments of new technology has enabled Computer-aided Drafting (CAD) to become a powerful design tool in architecture, the use of physical models (conventionally) remains a key aspect of education and design practice within the discipline around the world.

In the learning environment, architectural models have been used as a means of communication and representation rather than a way of thinking and generating ideas. Often the problem that is facing many students during their design studio is how to externalize the idea of their design for facilitating the understanding of the relationship between the idea and contextual circumstances (the site). Despite the active and prominent roles that models can play in creating multiple interactive learning environments, the significances of these models has not been given due appreciation. Learning environments that are entirely based on design studios need to consider that the significance of models in the following manners:

- Visual appreciation of three-dimensional properties.
- Tactile interactions (in physical modeling only) (tangibility).
- Facilitating various design/tasks manipulations.
- Easy to carry from one place to another (mobility).
- Flexibility through dismantling and rebuilding.
- Rearrangement and enhancement of components.
- Varying degrees of information to be communicated from basic formal inquiries to highly detailed models.
- Testing the build-ability of the design.
- A design development process to be recorded.

In practice, this study identified the appropriate applications and supplementary uses of both modeling mediums (digital and handmade models). Although both "Laser cutter" and "Rapid prototyping" are among the techniques that facilitate the production of design, the impacts of modeling (digital and handmade) on the creativity of design ideas were not investigated. In other words, the role of modeling as a thinking tool rather than a tool for fabrication was not identified

Finally the matter of measuring value in design seems to be a problematic issue that is assessed subjectively. That is, the value of design has always been assessed subjectively and therefore cannot be measured as an absolute value.

CHAPTER 3

MATERIALS AND METHOD

This section includes details about the research materials and method that were used to conduct this research.

3.1. Materials

Since the major concern of this study is to investigate the phenomena and impacts brought by the presence and the making of architectural models within several domains, namely: the public, educational and the professional domain, so the study will comprise the following materials:

3.1.1. For Public domain

a) Interviews with Miniaturk visitors & local authority officials:

- 70 visitors in Miniaturk (tourists & visitors) were interviewed.
- Statistics regarding the number of foreign and Turkish visitors were obtained for the period 2003-2012 (from local officials).
- 3 local officials were interviewed in Miniaturk and 2 were interviewed in Sultan-Ahmet and Suleymaniye mosques and 1 in Haghia Sophia.

b) Number of visitors before and after the establishment of Miniaturk:

- Statistics from Ministry of Culture-Turkey.
- Number of foreign visitors from 2003-2012 and number of Turkish citizens visitors from 2003-2012.

c) Data of visitors from each historic building (density of visitors in each chosen building)/Visitors of Miniaturk.

d) Photographs of popular models and building (the most visited one).

- 107 physical models were photographed:
    - 46 Models from Anatolian period were photographed.

- 45 Models within and around Istanbul were photographed.
- 12 Models abroad were photographed.
- 4 models of mobile machines, trains, and transportation systems were also photographed.

- 16 of the most popular historic monuments of Istanbul were re-created in crystal (models) by means of laser technology.

3.1.2. For Educational domain

a) Interviews with students and teachers

- METU: **9** undergraduate students & 2 instructors were interviewed.

b) Design grades from national & international schools (final grades in design studio from 1st-up to graduation year)

- METU: Grades of **133** undergraduate students (1st, 2nd, 3rd and 4th year students) and their performance in the design studios (Arch101, Arch102, Arch201, Arch202, Arch301, Arch302, Arch401, Arch402).
- Photographs of METU students' model (for old projects & previous terms) Benghazi University: Grades of **144** undergraduate students from different levels and their performance in the design studios (course codes AC111, AC112, AC211, AC212, AC311, AC312, AC411, AC412, AC511, AC522, AC162) from 2005 to 2013.
- Elmergib University- El-Khoms: Grades of **106** undergraduate students from different levels and their performance in the design studios (course codes AR213, AR314, AR315, AR416, AR417, AR518) from 2010 to 2013.

c) Building science courses -- grades from national and international schools

For all schools, students' grades on other courses (such as building science courses) were also checked and compared with grades obtained on studio courses.

- For METU: GPA, CGPA and Grades for Building science courses were obtained from METU information system. Courses codes are: (Arch 231, Arch 232, Arch 251, Arch 252, Arch 282, Arch 331, Arch 332, Arch 351, Arch 381, Arch 382, Arch 452)
- For Benghazi University: GPA, CGPA and Grades for Building science courses

were also followed from Benghazi information system. Courses codes are: (AC131, AC132, AC141, AC142, AC151, AC241, AC242, AC251, AC252, AC351, AC222, AC262, AC271, AC272, AC341, AC342, AC361, AC362, AC381, AC322, AC351, AC352, AC382, AC441)

- For Elmergib University: GPA, CGPA and Grades for Building science courses were also followed from Benghazi information system. Courses codes are: (GE121, AR141, AR224, AR221, AR213M, AR261, AR222, AR262, CE211, AR323, CE371, CE309, AR324, AR335, AR318P, AR425, AR418, EE400, CE422, AR426, AR401, ME521, AR490)

d) Online questionnaire survey

- 87 national and international participants, undergraduate and graduate students & architects answered the online survey questions. Additionally, the 20 students of University of Benghazi and 32 students of Elmergib University who are enrolled in the proposed studio course have also filled the questionnaire (APPENDIX **C)**.
- The 52 students (20 students in Benghazi University & 32 students in Elmergib University) were also invited to participate in a special questionnaire made for the evaluation of the conducted experimental design studio course after submitting their projects (APPENDIX: E and F). Only 33 students from both groups have participated.

e) Photographs of models with different materials (For the work of METU, Benghazi and Elmergib University's students)

f) Experimental studio course based on design with models (conducted at Benghazi University and Elmergib University).

3.1.3. For Professional domain

a) Interviews with practicing architects (6 out of 22 architects were also interviewed).

b) Online questionnaire survey (22 architects participated in the online questionnaire).

c) Photographs of Models with different materials (different projects' models are photographed, these models belongs to the interviewed architects).

3.2. Method

This study is designed to examine the impacts of models and its utilization in public, education, and professional domain. The study was conducted as a mixed-method approach based on combined strategy framed into three main phases: in public, education and professional domain. The previously set objectives along with the comprised materials has been implemented as follows: The questionnaire survey is published online (questionnaire form was created using Google-drive web tools) the form was then sent via emails, and published on many social networks (Facebook and twitters).

3.2.1. In Public domain

For the material collections (models photographs, identifying the number of visitors, ages, sex, nationality, interview with visitors, statistics from authority) Miniaturk was visited several times (1^{st} and 2^{nd} visits on 15 October 2013 and 3^{rd} visit on 26 April 2014). At first, permission from Miniaturk authority was taken for touring and examining the contents of exhibition**.** This park contains 107 physical models done in 1/25 scale. 48 of the models are for buildings that exist within the territory of Istanbul, 47 are from Anatolia, and about 12 are from the Ottoman territories that today lie outside of Turkey. Additionally, about 4 models of mobile machines, trains, and transportation systems are also presented. Each historic building's model was photographed and classified with its related information such as the location of the actual building, brief history, construction date, etc. and physical models photographs are shown in Appendix B: (Figures from B1-B12). To investigate the impacts of models in public domain, Miniaturk was visited during the high season on 28 April 2014 in order to conduct as many **face-to-face interviews** as possible with the visitors to the park. These interviews have been made by making a random selection of visitors. Table (3.1) presents the interview questions and answers to these questions are given in table A3 in Appendix A

Table. 3.1. Interview questions used for "Miniatürk" visitors.

No	Type of questions
1-3	Nationality; Gender: Age:
4.	Have you ever been to “Miniatürk” before? (Number of visits)
5.	Which of the models did you appreciate more? (selection of buildings from models)
6.	Do you have any historical information about the model(s) you appreciated? (How they appreciate the information offered by the model)
7.	Have you already visited or intend to visit the actual building of the chosen model? (before or after Miniatürk)
8.	If not, do you have any plan to visit the real building after visiting “Miniatürk”? (exploring the impacts of models)

- Based on what has mentioned so far, the historic buildings identified by tourists (from the models) as the most remarkable ones were visited **(real buildings)** to collect data on the number of annual visitors. Therefore, these buildings and their models have also been photographed. As a result, interviewing visitors determined information on the advantages and disadvantages of models as well as the impacts of models as a motivational factor for visiting the historic buildings. To illustrate, visitors are asked whether they may decide to visit the real building after seeing its model at Miniatürk exhibition. They may already have been there or visited other buildings; this information determines the motivation and impacts of the models.

- The data obtained from the visitors determined the most visited and/or planned to visit (selected) building(s), which were visited to find out the annual increase and decrease in the number of visitors. Concerning the interview with local authority officers, when these buildings were visited the aim was to obtain data that could identify the number of visitors before and after the establishment of Miniaturk that would show the annual increase and decrease in the number of visitors for each building (Appendix A). However, the interviews with local authority officers (Sultan-Ahmet and Suleymaniye mosques, Haghia Sophia and Topkapi Palace) yielded that it is very difficult if not impossible to identify whether or not the visitors came after they had visited Miniaturk. Thus, data gathered from interviews made with Miniaturk visitors could determine the impacts of models on public much more accurately (from the most chosen models) than the statistics obtained from the ministry. Consequently, based on data acquired from interviews, 6 buildings were identified as the most popular ones to be visited were, in order of preference: Haghia Sophia, Topkapı Palace, The Blue Mosque (Sultan Ahmet), Aspendos Amphitheatre, Fairy Chimneys (Cappadocia), and Suleymaniye mosque. The interview findings reflected a clear and significant impact of the models in motivating tourists to visit the real buildings.

3.2.2. In Educational domain

A random selection of students and teachers has been made among various national and international schools of architecture. These schools are; Middle East Technical University (Ankara, Turkey), University of Benghazi (Benghazi, Libya) and Elmergib University (El-Khoms, Libya). In each of these Universities; undergraduate students enrolled in design studio courses were randomly selected and their grades were obtained. Initially, these students' grades were traced back within a 4-year period. This helped to determine the students' performance in the design studio courses. These students from different design studio levels were classified and their design studio grades sorted (courses codes for each university are mentioned in the research materials section). Additionally, grades obtained on building science courses were also checked and sorted.

The students' modeling skills were also evaluated according to their model-making classes. Based on the data obtained, a comparison between design studio grades, building science grades and modeling skills evaluation is made to find out whether there is any correlation between the modeling skills and grades of the afore mentioned courses. Accordingly, students from each university were interviewed also and the focus was basically on their design approach and modeling ability. Each student's project and models were also photographed which would signify whether there is a relationship between their modeling skills, design approach and getting high or low grades.

In METU, 133 students were randomly selected (1st, 2nd, 3rd and 4th year students) and their grades (in the 8 design studios that mentioned previously) were obtained from METU information system. Students CGPA and other grades on building science's courses are also checked and sorted. Among these students, 34 students were identified as having high grades (AA, BA grades), 12 students having low grades (DD, DC grades) and the rest (about 87) were identified as average students. Instructors were also interviewed and asked about how each of the selected students is performing during the studio work. Consequently, comparing the grades obtained on studio courses with those obtained in building science courses and modeling skills evaluation as well as instructors' comments could show if there is any correlation between students' modeling skills, performance in the design studio, performance in building science courses and their overall CGPA as well.

Additionally, in spring term 2012-2013, 75 undergraduate students at METU were randomly selected, and their jury discussions were attended, their projects & models were photographed, as well as their grades on that projects were obtained (the models that are photographed were for only that term "spring 2012-2013", Arch102, Arch202, Arch302, Arch402) but at the same time it was a chance to trace back the students previous grades in other studio works accordingly. It should be noted that these students are among the 133 students sorted previously, and therefore are not excluded from the overall number of the samples selected. For the spring term (2012-2013) projects and models photographs, almost every jury were attended and for those whose jury could not be attended, their models' photographs were obtained from the METU architectural design studios catalog (also available online).

With regard to the University of Benghazi, 144 undergraduate students from different levels are selected randomly and their grades were sorted (for the studio courses mentioned in the materials part) from2005 to 2013 (the term 2011-2012 could not be included due the Libyan war). It should be noted that among the 144 students, there are 20 students who also enrolled in the proposed experimental design studio course conducted for this study. Among the 144 students, 42 students identified as high graded and 27 students as low graded and 75 as average. As in the case of METU's students, for Benghazi also instructors were chosen randomly and interviewed. These instructors were asked about how each of the selected students is performing during the studio work. Furthermore, other grades on building science courses were also checked, sorted and compared with those obtained from design studio courses. Additionally, students were also asked to fill the online questionnaire (Appendix **C**).

In Elmergib University (El-Khoms), 106 undergraduate students from different levels were selected randomly. It should be noted that, among the 106 students 32 enrolled in the proposed experimental design studio course that was conducted for this study. Interestingly, Among 166 students only 4 students are regarded as high graded, and 62 are regarded as having very low grades, and the rest as average. This apparent disparity between the grades is believed to be one of the reasons for the lack of modeling techniques courses or training within the school's curriculum. Randomly chosen students were also interviewed (high, low and average graded students) and their instructors as well. The students' grades obtained in building science courses were also checked and compared with those obtained in design studio courses. Students were also asked to fill the online questionnaire (Appendix **C**). From these questionnaires it is easy to identify obstacles, weakness, skills and any background experience related to the students as well as the educational methodology within the Architectural program.

In all the three universities, GPA, CGPA, design studio grades, building science courses grades, term dates and modeling skills evaluation were used for the correlation analysis.

Experimental Studio Course

Details on experimental studio course which was based on **design with models** are given in a separate chapter along with the course evaluation by the participating students

3.2.3. In Professional Domain

A random selection of professional (architects) from various design offices has been made, and the selected architects were asked to fill an online questionnaire, which was sent to them by e-mail. As the questionnaire is published online over social networks (Facebook & Twitters), this increased the overall number of participants (architects). The selected architects were also interviewed and photographs of their project models were obtained. 22 architects participated in the questionnaire survey. Among them 6 architects had already been interviewed and some of their projects' models were photographed (digital and handmade models with different materials).

Interviews with participants (architects/model-maker) are made as face-to-face and some were done through Skype with architects who were abroad. These interviews provide information on advantages and disadvantages of modeling for design projects. Data from interview as well as questionnaire survey determined the design approach of every designer. In terms of tangibility, the interaction between the designer and the model (physically or virtually) is another investigated issue. Another crucial issue that concerns most of today's designers is the software limitation and characteristics of materials (on models and real ones). i.e. what material is representative of which one? and why? Appropriate representation of actual material and forces? These issues were also tackled during the interview. Finally, the relationship between the production of models and marketing was another important issue that could be determined from the interview and questionnaire survey.

The interview discussion was formulated according to the following issues and questions:

1- The definition of design.
2- How do you start designing? How do you initiate your design process?
3- What types of digital software/tools have you mastered?
4- Which technique would you prefer to make your physical design? (Handmade & Digital model), and why?
5- When do you consider making a physical model? And when to use a digital one?
6- How many models do you usually make for your design?
7- Are there any aspects of model-making you find particularly difficult, don't

enjoy or resent having to do?

8- Does that difficulty limit your imagination & creativity? And why?

9- Concerning modeling problems, what are the complications and limitations that you experienced during the modeling process (in handmade OR digital modeling)?

10- How do you find the advanced digital technologies and tools in assisting the design process or production?

11- What materials do you habitually use for model-making (if you are free to choose?)

12- Is there any relation between the materials used in the model and the real one?

13- How do you test your design proposal(s)?

14- What scale do you usually make your model in?

15- How do you define the relationship between the designer and client?

16- Do you think clients are usually appreciating the models you make?

17- Which types of models are appreciated much by the clients (physical or digital model)?

18- Do you think that NOT having made a physical model lost you the chance of getting the job or convincing the client?

CHAPTER 4

EXPERIMENTAL STUDIO COURSE

In order to investigate the impacts of designing with 3D models an experimental design course was devised. Of the three universities included in this research, the Middle East Technical University (METU) in Turkey possesses some rapid prototyping tools which are available to the students, i.e. there exists a spacious workshop area in the Faculty of Architecture with various 3D fabrication equipment and laser cutter machines for the students' use. The impacts of models on the design studios of METU have already been mentioned in the previous section where correlation analysis were conducted between design studio, building science courses and students' modeling skills. On the other hand, in Benghazi University where some modeling (physical and digital) courses are offered there are no model-making facilities. While in the Elmergib University neither modeling courses nor model-making facilities are available to the students. Therefore, an experimental studio course based on designing with models was conducted in both, the University of Benghazi and the Elmergib University, where modeling practices are usually neglected.

20 students from the University of Benghazi and 32 students from Elmergib University were enrolled in this course where the students could choose between the handcrafted or digital modeling technique. In this experimental course, models were to be the medium for design activity and it aimed to investigate the matter of creativity and innovation in architectural design and education through 3D models. How students think, imagine, convey their design ideas are among the concern of this design methodology; as well as the model as a tool for adding value to design.

Moreover, the evaluation of students' tasks or design projects has been a controversial issue in that the assessment of students' projects and is usually based on the subjective (instructors) evaluation and opinions or even attitudes that may vary from person to another. Therefore, the purpose of conducting such a studio methodology in various architecture schools is to find out the possibility of having standard evaluation criteria in determining the common assessment factors and measuring value in design studio. Determining the students' performance and the value of peer learning in the model-making environment are among the major concerns of the research objectives. Hence, all the above mentioned issues should be able to clarify whether model making has any significant impact on architectural education and physical practice.

4.1. Course Objectives

Contrary to the conventional design approach, which starts with analytical studies at the beginning and then moves on to the actual design process (2D sketching and diagrams to work on plans), the methodology used in this course mainly depends on using three-dimensional methods from the start of the design project (3D digital software Or Hand-made techniques). This is to let the student or designer deal and think in solving the design issues (matter) in three-dimensional manner without relying on the traditional methods of design, that is based on conventional two-dimensional studies. This experimental studio course was proposed with the following objectives:

- To reinforce the practice of learning by doing.
- To strengthen tangibility in order to develop perception through tactile senses by relying on their hands when making objects.
- Increase flexibility in design concepts (through observation of models within the context of the site).
- To promote freedom in design thought.
- To increase students' creativity by considering design activity as play and models as toys through a vivid and cooperative environment.

4.2. Course Content

The proposed course comprises of five scheduled stages. Each stage is performed within the proposed scheduled period (unless otherwise stated). The course schedule program and details were as follow:

Stage 1, students start their design project by building models; these models are managed more or less like the 3D basic design studio exercises at the beginning. Basically, in this stage students are NOT informed about the design topic or its program (or brief). They are also NOT informed about the characteristics or location of the site. All they have to do is to create a composition that applies one or more design principles (harmony, symmetry, hierarchy, contrast, etc.) within a limited cubic area (already given to the students), which is specified at the beginning. Handout sheets are also given to the students to clarify some basic design principles that can assist their work (handout samples are given in Appendix I).

The principles that were mentioned in the handout sheets were; "*elements, point, line, plane, volume, form, shape, regular, irregular, transformation, surface, edges, form & space, defining space, openings, light, view, relations, organization, entrance, movement, stairways, proportion, scale, principles, axis, hierarchy, datum, rhythm"*, some reading materials from 10 books were also given.(Oswald, A. (2001), Ching, F.D.K. (1996), Mills, B. C. (2005 and 2011), Denel, B. (1979), Neat D. (2008), Dunn, N., (2007 and 2010), Frascari, M., Hale, J., and Starkey, B., (2007), and Healy, P. (2008)). Students could choose any modeling technique they liked (digital or handmade).

Interestingly, in the case of University of Benghazi, all students chose to use the handmade modeling technique to work for their design concepts. The selection of one type of technique (the handmade) satisfied the instructors in order to achieve equality in the assessment of students. Similarly, in the case of Elmergib University the students also chose to start with handmade modeling techniques, although some of them did not take any modeling courses. The students decided to take it as challenge and they suggested that any use of digital tools or 3D software might be left at later stages, for presentation purposes.

As a start, students were asked to bring model building materials and tools as varied as possible. These can include any type of material they prefer or are familiar with. The more varied the materials the better it is. Thus, students are advised to be as flexible as possible with their design ideas and with what they model their ideas, in order to be open to changes. During this stage, studio tutors go around and see what the students have produced (without telling the students how to do what). Students are left free to create whatever they like. When they are finished with the first model they are asked to make another one and another one, each time applying different design ideas, creating different forms and compositions. According to the specified schedule, an open discussion is made in which tutors and students express their thoughts about at least one chosen model from each student's work for a better understanding of the exercise (the schedule of activities in this stage is specified in the next table).

Table 4.1. The course content during the three weeks of the 1st stage

Stage 1		
Weeks	**Events**	**Notes**
1st Week	▪ Course definition & Introduction. ▪ The total volume in m^3 will be specified. ▪ Defining students groups: (Group using 3D software & Group using hand-skills techniques) ▪ Requesting the materials and modeling tools (students are free to choose, they're just advised). ▪ Discussing basic design principles ▪ Requesting several models (compositional models) with different ideas (at least two concepts)	Students will be given handout sheets (reference) with a brief information about design principles such as: ▪ Primary elements (line, point, square, etc) ▪ Forms (primary solids, regular, irregular forms, transformation, subtractive, additive forms, articulation of form, surfaces, etc) ▪ Forms & space (form defining space, elements (horizontal &vertical) defining space, openings between planes. ▪ Organization (of form and space) (spatial, centralized, linear, radial, clustered, grid organizations) ▪ Spatial relationships. ▪ Proportion & scale (material proportion, structural proportion, scale, visual scale, human scale) ▪ Principles (ordering principles, symmetry, hierarchy, repetition, transformation, etc)
2nd Week	▪ Open discussion ▪ Student present their models for the 1st time ▪ This should be preliminary model(s)	▪ To improve students models according to the given principles. ▪ Students can criticize each other's work. ▪ The discussion should prepare the students for the next stage (choosing between their concepts)
3rd week	▪ Students' models are developed within the design studio under the supervision of tutors. ▪ Students are left free; they are just advised with some design principles when necessary. ▪ Students can work in group, cooperate & communicate.	▪ Design studio workshop

Stage 2, After having made a few models, an open discussion is made to guide students to choose among their proposed models (at least one model is selected for each student), and now students are told to convert it into an “architectonic model”. In doing this, they should foresee some changes in their initial models. They are advised to keep their conceptual ideas but try to express them in an architectural language – (by thinking of the structural elements). Here, they are informed about the design topic and site location. This is to encourage them to consider sizes, scale, proportions, materials and organization of functions as well. At this time students start checking and placing their models in the site location and detect what needs to be modified according to the site circumstances (orientation, topography, site shape and outline and surroundings). Therefore, students make a site analysis according to their concepts and discuss it in the studio.

Students are asked to check their design decisions according to the conditions of the site. They should not be asked to make a site analytical study, but to take their models to the site and check the validity of their ideas by seeing the site, and by placing the model in the most suitable way on the site. They have to foresee changes according to the site circumstances, orientation, etc. This is done in an open discussion in the studio, and instructors from other design studio are invited to join the discussion as a jury member to evaluate the work. Thus, half of the design work is accomplished and they can move on to the next stage. Details regarding the 2nd stage are given in the rubric below:

Table 4.2. The course content during the three weeks of the 2nd stage

Stage 2		
Week	**Events**	**Notes**
4th week	**Open discussion:** each student's models will be presented and criticized. At least one model for each student will be chosen, and then he/she is asked to convert it into "architectonic model" for the next discussion.	▪ Student will be informed about the design topic and the site location. ▪ Each student is going to place his model in the site and make design analysis accordingly (orientation, topography, site shape and outline and surroundings) ▪ The model is going to be improved by specifying preliminary structural elements.
5th Week	**Preliminary presentation:** Preferably other instructors should be invited from other studios to evaluate the preliminary design (the model after change) for each student. ▪ Instructors are left free to decide the evaluation factors (techniques, skills, harmonization with site conditions, etc) ▪ Each student should present his/her model placed in the site location. ▪ This is to foresee changes according to the site circumstances, orientation, surrounding, etc.	▪ Placing the model in the site and the detection of its circumstances should offer a close relationship between the student and their design better than working on just a piece of paper. ▪ Site analysis should be performed according to: (Size, scale, proportions, materials, organization and function are to be considered). ▪ Orientation, topography, site shape and outline as well as surroundings are to be considered. ▪ Instructors should define their evaluation criteria to other jury members after evaluating the students' work
6th week	▪ Students have to develop their work (models) based on the observations, comments and tutors' feedbacks noted in the previous phase (presentation).	▪ Design studio workshop

Stage 3, At this stage students should have produced a more or less finished model that fits in with the design topic, its program and site location). This means that they have to start working on plans, elevations and sections; translate the 3D design into 2D representation. Students are allowed to make few individual changes for the design program when it is reasonably approved according to their design analysis. It is claimed that such ability (the ability to understand how to modify the design program) is to make students aware of how to deal with the design problems and provide scientific solutions by simulating the design with reality. Therefore; the only limitation is in the total volume of the space in m^3 and total covered area they have to keep to achieve some equality amongst them.

In this stage students may be told that their initial design ideas (concept models) can or have to be changed in order to create a better functional distribution or site usage – without necessarily giving up their ideas or making radical changes in them. After this the final stage is reached. Students start working on more detailed elevations, which are more or less defined by their previous studies and design exercises. They have to design the elevations also in accordance with their design ideas developed on their models and make necessary changes according to the local environmental conditions. (3rd stage details are shown in the table below)

Table 4.3. The course content during the three weeks of the 3rd stage

Stage 3		
Week	**Events**	**Notes**
7th week	**Open discussion:** ▪ Discussing the preliminary plans and elevations. ▪ Discussing how they manage the structure system. ▪ Discussing the types of materials in both the model and the design.	▪ Design studio workshop ▪ Architectural drawings, rendering, photographs need to be presented. (Not necessarily all, but these need to be considered by the instructor between the two groups (the one using 3D software and other using hand-skills techniques). ▪ Students should also comment upon each others' work.
8th week	**Open Discussion: presentation** ▪ More detailed plans; sections and evaluations are presented and evaluated. ▪ Evaluating the students' work in terms of structural solutions. ▪ Evaluating how they manage the selection of materials in both the model and the design (checking what they think about the representation of actual material). ▪ Evaluating the students' design program.	▪ Other tutors may be invited to join the evaluation; in any case they are left free to choose the evaluation factors.

Stage 4, this is the second last stage, i.e. the dress-rehearsal, at which students are asked to deliver a finalized project, with all plans, sections, elevations, site plan, etc., additional requirements may also be asked such as of the structure or construction system, etc. They also build a final model – which now looks like a building but still reflects their first design ideas.

Table 4.4. The course content during the three weeks of the 4th stage

Stage 4 (the dress-rehearsal)		
Week & Time	**Events**	**Notes**
9th week	**Pre-final presentation:** ▪ Students are asked to deliver a finalized project, with all plans, sections, elevations, site plan, etc. ▪ Additional requirements may also be asked such as of the structure or construction system, etc. ▪ Building a finalized model is requested.	
10th week	**Day off:** students will be free to work on their final submission by themselves, unless they have any inquiries.	Students are given one week to present their work for the final submission. (Depending on the school schedule)

Stage 5: The evaluation stage

Several studio tutors are invited for the assessment; they have the right to set their own criteria to assess the students' work and performance. For the evaluation process, tutors are asked to set a clear and brief evaluation factors that are based on scientific and scaled measurable values. These criteria are adopted in the proposed methodology for using the models as a tool to design and learn, as essential keys for evaluating the performance of the students so that the evaluation of the students work will be based on more objective and clear evaluation factors (measurable scale). These criteria also serve to measure the value-added by the architectural models to evaluate the performance and the level of students through the design studio. After the students' projects are finally submitted and evaluated (graded), the students are asked to fill up a special questionnaire to elicit their opinions about the design course (Appendix **C.II**) (Details are shown in the table below)

Table 4.5. The course content during the three weeks of the 5th stage

Stage 5 (The evaluation stage)		
Week	**Events**	**Notes**
11th week	**Final presentation:** ▪ Students should present their final project with final physical models, all plans, sections, elevations, site plan, etc. ▪ The structure or construction system is also presented. ▪ Several studio tutors should join the assessment, they will have the right to set their own criteria to assess the students' work and performance ▪ Students are asked to fill up special questionnaire	▪ Criteria for assessment of students' work and performance should consider the making of models as a way to design and learning. ▪ Evaluation factors should be set clearly and briefly (e.g. the accuracy and quality of modeling should be evaluated as poor, average, excellent, etc.)

4.3 Course Conduct

Three international schools of Architecture were selected to participate in this experimental studio course, namely; University of Benghazi, Tripoli University and Elmergib University (El-Khoms). Unfortunately, students of Tripoli University were unable to start the proposed experiment during the current semester due to some technical problems, so they were excluded from the research experiment. In the University of Benghazi, the experimental studio course started on the 1st of March 2014 and continued until June. 20 students from 3rd year design studio were enrolled and divided into three groups (A & B and C); each group was supervised by 4 instructors.

Unfortunately, due the Libyan conflict the course could not be completed and the final projects could not be submitted. Therefore, it was crucial to communicate with the students through social networking (Facebook), and a closed group was made, not only for Benghazi University students but also for Elmergib University students. These closed groups provided an opportunity to follow the design of students with updated developments of the work. Based on these reasons and constraints, many of the projects (even if they were not finalized) have been collected and evaluated outside Benghazi University by instructors from Elmergib. Thus, the incomplete experiment in Benghazi has still contributed positively to this research.

On the other hand, the proposed design course in Elmegib University started on the 21st of September 2014 for three different design groups (3rd, 4th and 5th year design studios). All the three groups submitted their final projects and the course ended on the 25th of December 2014.

4.3.1. Benghazi University group (course code AC311)

The course was held during the spring term in 2013, 20 students were enrolled in the experimental design studio course (AC311 for 3rd year students), and were divided into three groups A, B and C. Four instructors supervised the students, and these students were also asked to fill two questionnaires: the first one was the general questionnaire (Appendix C.I) and the 2nd one was (Appendix C.II) prepared specifically for the evaluation of studio course. This was done to find out how students found the course methodology, and what sort of complications they faced.

All of these students opted for handcrafting techniques for making their compositions and design proposals. The instructors were satisfied as choice of the same techniques by all students brought a sort of equality in their assessment. In fact, after the first stage some students used both techniques (handmade and digital modeling) together. The following charts and figures summarize the course progress from the 1st stage up to the 3rd stage. The students work reached the “dress-rehearsal” but none were able to present their work due to the Libyan conflict. Thus, the charts and figures below represent the three evaluated stages for the submitted work with the evaluation factors employed by the instructors. Each of the students’ design proposals and progress are sorted and classified into various slides, nevertheless only one sample will be presented here; while further details can be followed from (Appendix E: Figures E10-E16).

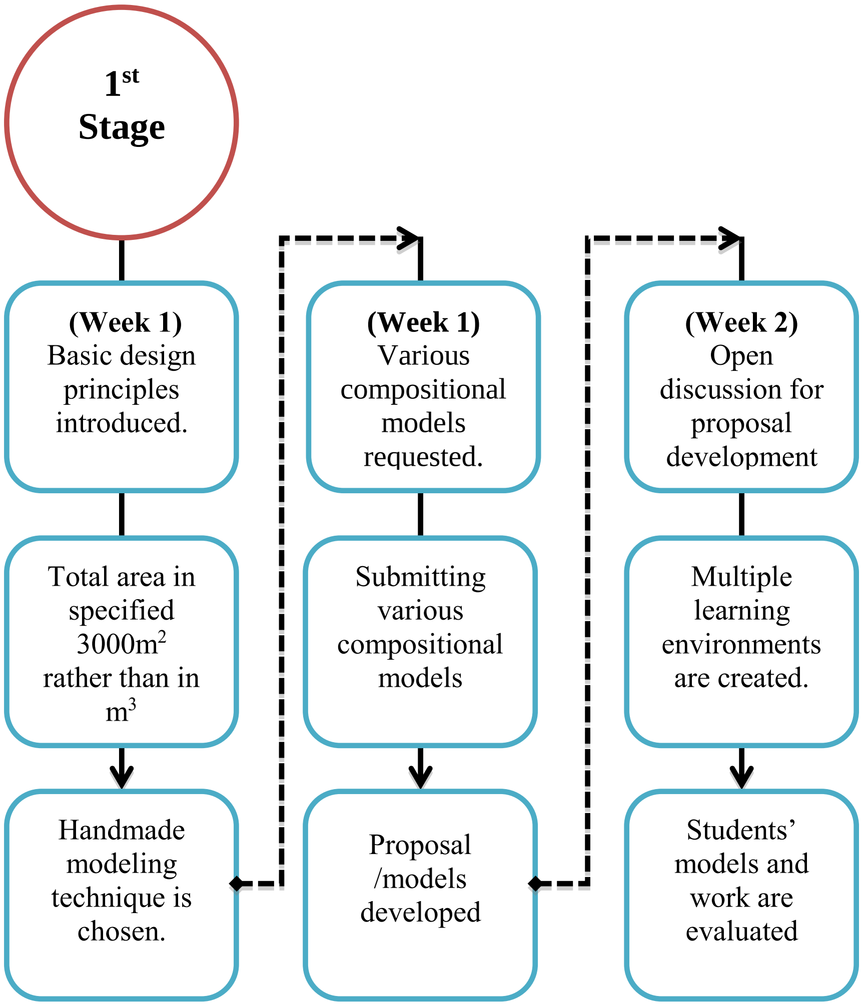


Figure 4.1 Flow-chart showing the course progress in the 1st stage at University of Benghazi.

Figure 4.2. Initial design proposals submitted at 1st stage by student-1 from University of Benghazi University.

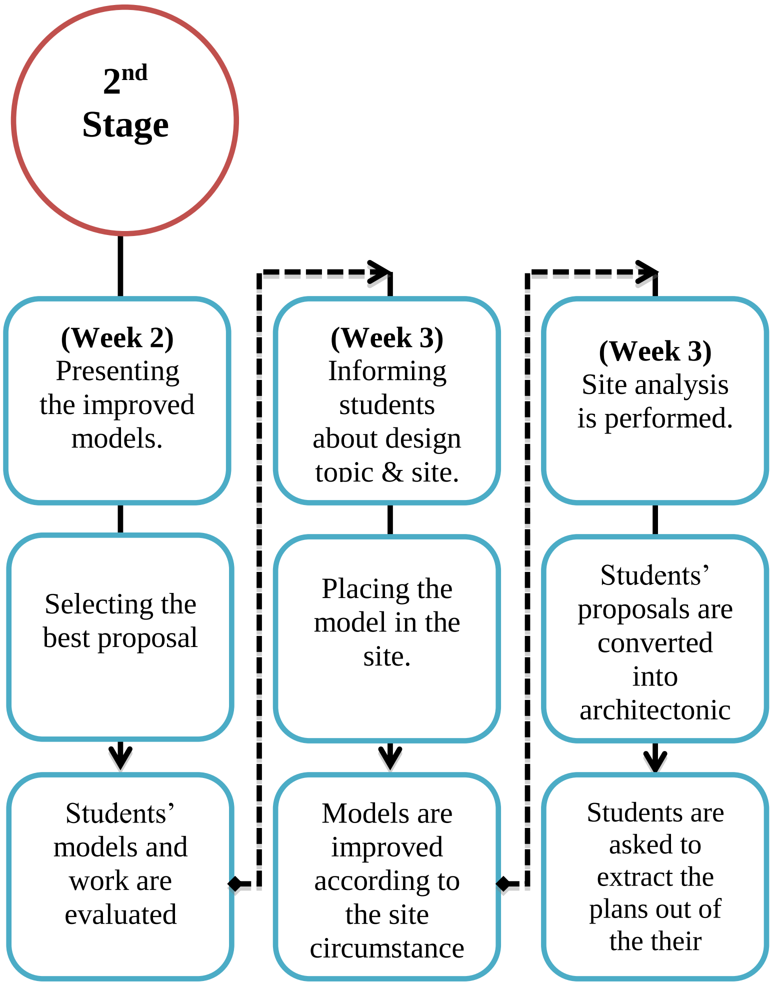


Figure 4.3 Flow chart showing the studio progress in the 2nd stage at University of Benghazi

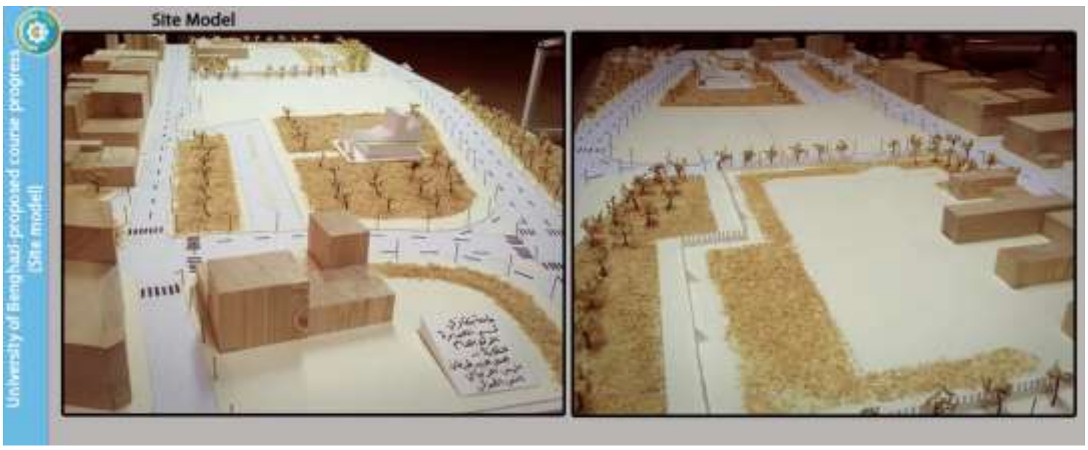


Figure 4.4. Physical model of the site location (work group)

Work of the University of Benghazi students (course code-AC311):

Having informed about the topic and site location, students were advised to work in-groups for making the site model. This created a kind of cooperative learning environment where students can share their experience and learn from each other. Additionally, every part of the site context was perceived and accomplished tangibly (Figure 4.4). Figure 4.5 shows a student's (ST-1) selected proposal and his improved proposed design model inserted in the site model. Instructors urged the students to adapt their proposed models to site conditions.

Figure 4.5. The chosen proposal placed in the site location for student-ST-1 from the University of Benghazi.

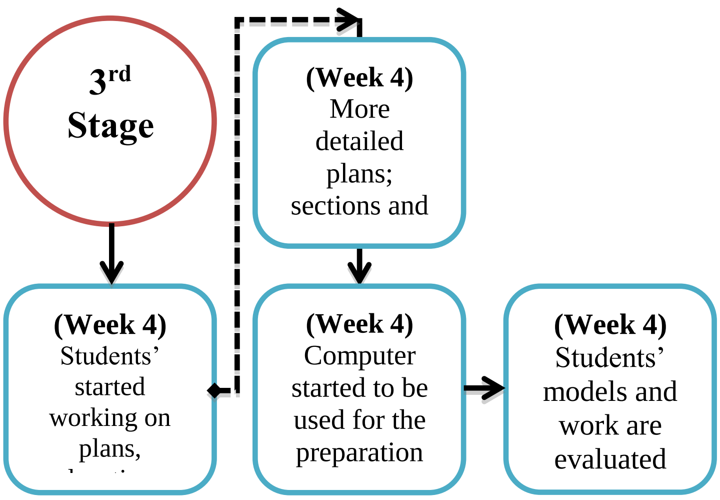


Figure 4.6 Flow chart represents the studio progress in the 3rd stage at the University of Benghazi

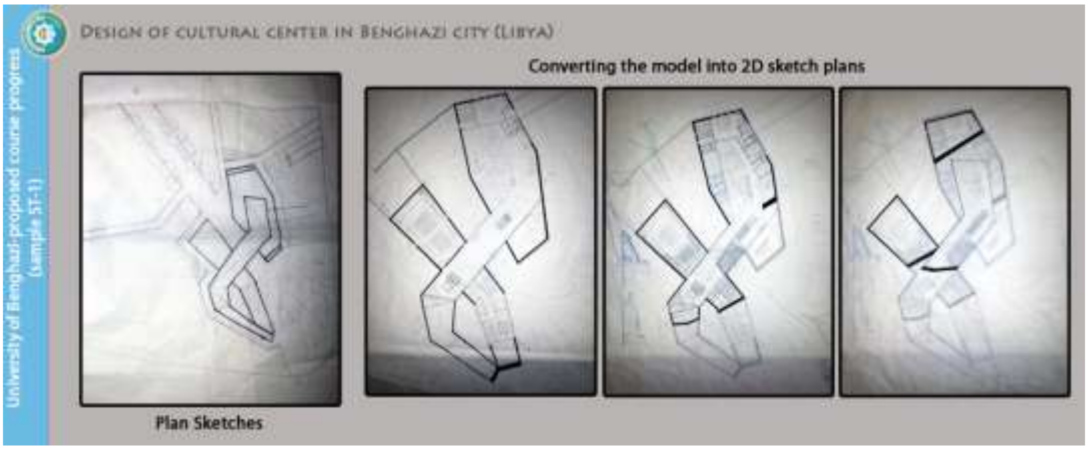


Figure 4.7. Transferring the 3D idea into 2D representations (ST-1)

In the 3rd stage, almost all the students started to convert their models into readable and scaled 2D plans. Working on plans was initiated by first making hand sketches, although students were told that they may use computer software to speed up the process (Figure 4.7). Thereafter, students stated that the use of computer becomes easier when most of the design outlines are defined. It is noted that the commonly used software among this group was Revit, AutoCAD, and Google SketchUP. Students were left free to choose any drawing tools that may assist their design process. Figures 4.8-4.10 show the adaptation of both techniques (hand sketches and computer software) during the 3rd stage to prepare the architectural drawings for the dress-rehearsal stage.

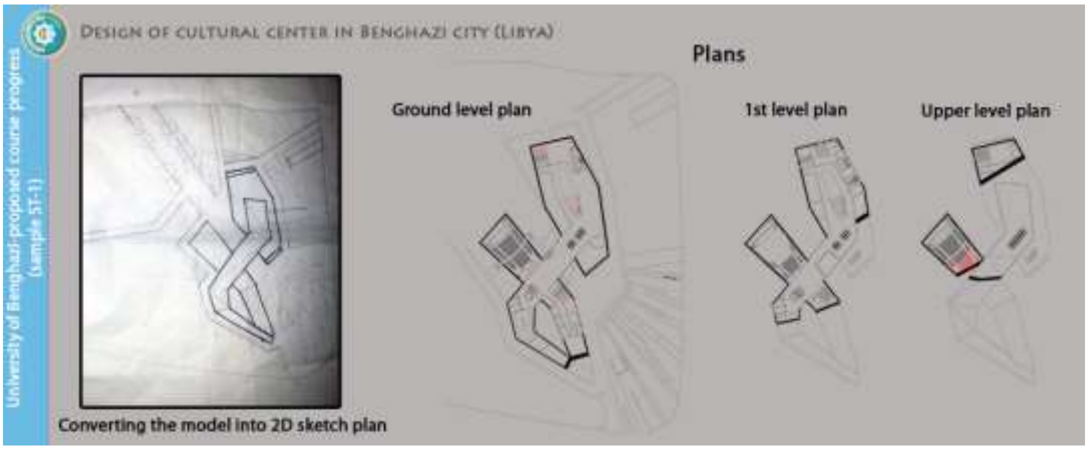


Figure 4.8. More detailed plans are submitted, work of student ST-1.

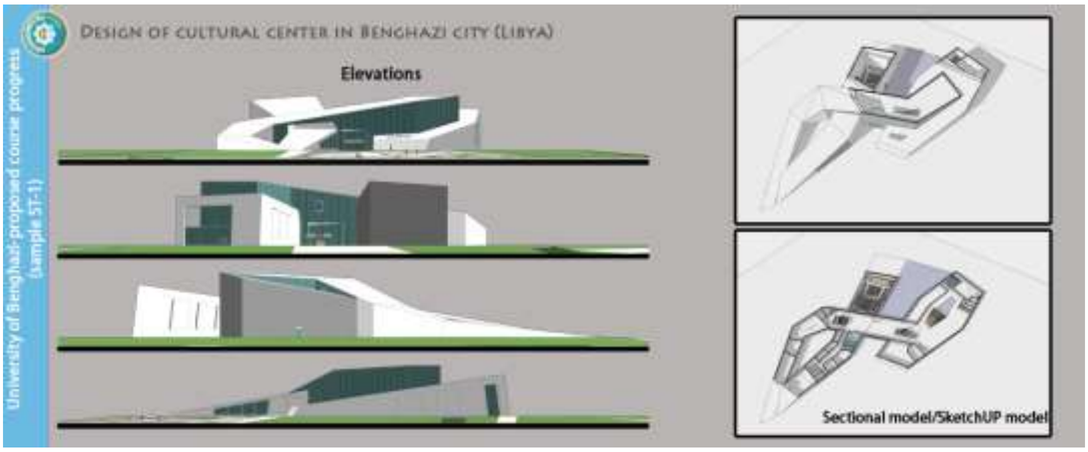


Figure 4.9. Student ST-1 proposed elevations and sectional model made with Google SketchUP software.

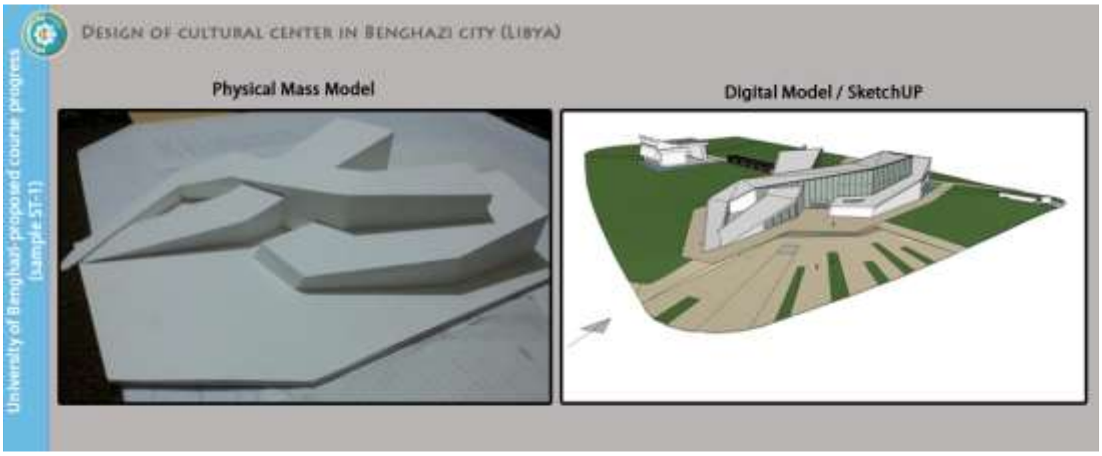


Figure 4.10. Physical model and digital model for student ST-1, proposing more details for the final elevations and landscaping.

At almost every stage there was an evaluation of the students' work and design progress. Accordingly, the table below presents the evaluation factors that were considered at all stages of design studio course (AC311). The instructors were also asked to define their planned evaluation factors for the next stages. It was crucial for the study objectives to define uniform evaluation criteria among the various architecture schools in order to establish an integrated evaluation strategy in the assessment of design projects that are clearly measurable. Accordingly, tutors indicated every factor in their evaluation strategy according to its weight/scale and the stage at which it was involved. It should be noted that, only the evaluation of 1st, 2nd and 3rd stages are included in this study, and the average of these stages is considered to be the final evaluation for each student for the sake of data analysis. The instructors were also interviewed and their comments concerning the performance of the 20 students were obtained. The table below summarizes the instructors' notes for each of the enrolled students.

Table 4.6. Instructors feedback on the students performance in the experimental studio course at the University of Benghazi.

No	ST-codes	Gender	Nationality	Instructors' comments
1	ST-16	F	IRAQ	Very weak student. She has a problem in 3D
2	ST-7	F	LIBYA	Intrepid student, she is very patient and hardworking.
3	ST-14	F	LIBYA	Hardworking student.
4	ST-6	F	LIBYA	Below average
5	ST-4	F	LIBYA	Steady student.
6	ST-19	F	LIBYA	Below average. Unstable student.
7	ST-5	F	LIBYA	Among the best students in school
8	ST-8	F	LIBYA	Talented student, she has a good design approach.
9	ST-20	F	LIBYA	She is among the outstanding students, intrepid in
10	ST-2	M	LIBYA	Below average; cannot be regarded as talented
11	ST-17	F	LIBYA	Average. Quite traditional, despite her hand skills
12	ST-1	M	LIBYA	Above average. Skilled and talented student.
13	ST-12	M	LIBYA	Among the best students in school. Talented & very
14	ST-3	M	LIBYA	Hard-working, but an average student.
15	ST-13	F	LIBYA	Creative student, but she needs to trust herself. Her
16	ST-10	F	LIBYA	She has a good vision of design, diligence and
17	ST-15	F	LIBYA	Below average
18	ST-16	F	LIBYA	Weak student, lazy and with limited design vision.
19	ST-7	F	LIBYA	Average student. Lacks the competitive spirit in
20	ST-14	F	LIBYA	Hard-working student; has the spirit of challenge to

Table 4.7 summarizes the commonly set factors for the assessment of the students projects. These factors are suggested by the four instructors and determined for the evaluation during the course progress. The table below ideates the stages and grades at which the proposed factors are considered.

Table 4.7. The evaluation factors that were used for the assessment of experimental studio course AC311 for Benghazi University's students

No	Evaluation Factors	Stage & weight				
		Stage				weight
1	Proposal(s) in terms of design principles	1^{st}	2^{nd}	3^{rd}		5
2	Ideation & concept improvement (positive OR negative)	1^{st}	2^{nd}	3^{rd}	4^{th}	10
3	Employment of the proposal in site location (site outline & topography)	2^{nd}	3^{rd}	4^{th}		5
4	Relationship with neighborhood (site context)	2^{nd}	3^{rd}	4^{th}		5
5	Scale and precision & accuracy	2^{nd}	3^{rd}	4^{th}		5
6	Spatiality (sense of space)	2^{nd}	3^{rd}	4^{th}		5
7	Orientation	2^{nd}	3^{rd}	4^{th}		5
8	Employment of spaces	3^{rd}	5^{th}	5^{th}		5
9	Function	3^{rd}	5^{th}	5^{th}		10
10	Structure stability & solution(s)	4^{th}		5^{th}		5
11	Selection of materials	3^{rd}	5^{th}	5^{th}		5
12	Plans	3^{rd}	5^{th}	5^{th}		10
13	Elevations	3^{rd}	5^{th}	5^{th}		10
14	Special details and sections (if any)	4^{th}		5^{th}		2.5
15	Adherence and commitment of the project program (any changes made to the total area)	3^{rd}		4^{th}		2.5
16	Presentation & (final presentation model)	4^{th}		5^{th}		10

4.3.2 Elmergib University Group (course codes-AR315, AR417 & AR518):

The proposed studio course was conducted in the fall term 2014-2015. Unlike Benghazi University, the experimental design studio was offered to three different groups of undergraduate students i.e. 3^{rd} 4^{th} and 5^{th} year courses AR315, AR417 and AR518, respectively. Almost every student in these three groups lacked model-making skills, because the existing modeling course did not fully cover the required modeling principles and techniques. Furthermore, for almost all students in the school, it was not required or compulsory for the students to submit a physical model even for their final submission. Thus, the lack of the students' modeling experience provided a better environment for conducting the proposed studio course.

During the experimental studio course in Elmergib University, students had a chance to learn, improve and practice the techniques of making models along with their design. There were a total of 32 students enrolled in the three different design studio courses: 9 students in AR315, 7 students in AR417, and 16 students in AR518. As was the case in Benghazi University, each group was supervised by different instructors; and each group had 2 tutors. The 6 instructors participated in the evaluation of the three groups interchangeably. Contrary to the case of Benghazi's students, the course progress went smoothly from the 1st up to the final stage, where very few changes occurred. The following flow charts and figures summarize the studio work progress for all of the groups.

For the three groups, stage 1 (Figure 4.11) was started by introducing general design principles that are mentioned in section 4.2 on course content. Students were asked to choose between two modeling techniques, handcrafting or digital modeling using any software they can master. Like in Benghazi University, almost all the students decided to start with handmade physical models and left the use of computer for later stages (for drawing plans, elevations, etc). For the three groups, students were given the design space defined in m^3 within which students had to propos design solutions according to certain principles. Accordingly, students created and presented several models based on the constraints that were given to them (Figures 4.12 to 4.14).

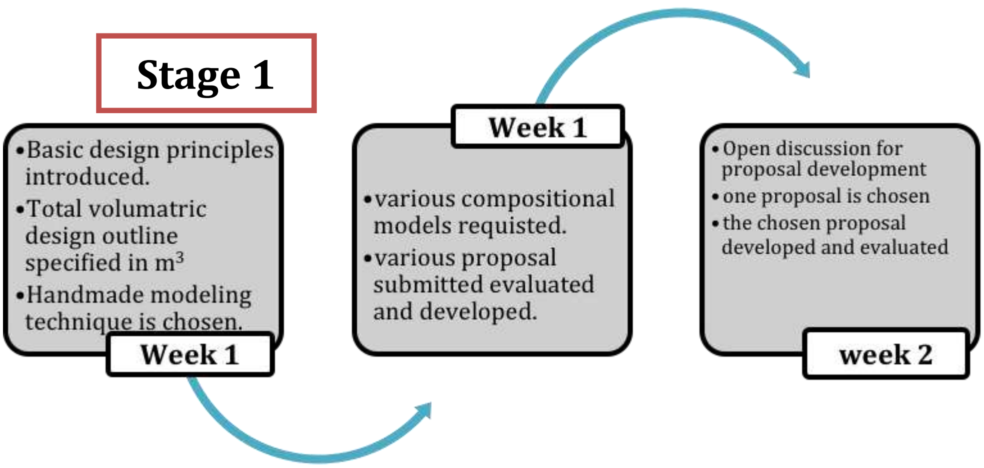


Figure 4.11. Flow chart represents the studio progress in the 1st stage at Elmergib University.

Figure 4.12. Work of an AR315 student (ST-7) presenting different compositions ideas for stage 1 and the selected proposal for stage 2.

Figure 4.13. Work of an AR417 student (ST-1) representing different compositions ideas for stage 1 and the selected proposal for stage 2.

Figure 4.14. Work of an AR518 student (ST-1) presenting different compositions /ideas for stage 1 and the selected proposal for stage 2.

When evaluating the first proposals, the tutors realized that most of the students' ideas were just an imitation of some elements of their environment. Students imitated what they were seeing in their everyday activities, even though they had been given an introductory lecture and handout sheets to clarify some basic design principles. In most cases, the students insisted on not giving up their initial proposal ideas until they shifted to the 2nd stage where design topic and site information were determined.

The AR315 group was requested to design a primary school, whereas the design of a Mini-Bus terminal was given to AR417 group and design of a Physiotherapy center for AR518. Thereafter, site visit was made for all design groups, where students took various photographs and collected data for the location and the context. Additionally, all the groups had a chance to visit similar built projects where they had the chance to collect data and make converse with local authorities. Thereafter, the students' models were placed in the site location and developed according to the site conditions. It took almost two weeks for the students to build their site model (Figures 4.16 to 4.18). A brief presentation of model making tips was made for the students to overcome some modeling obstacles. Although, in the past students were given some modeling courses, they asserted that none of the tips used in making their site model had been taught before.

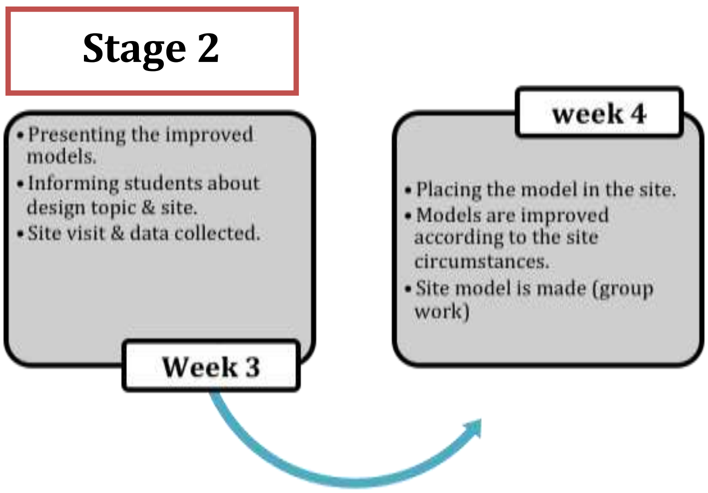


Figure 4.15. Flow chart represents the studio progress in the 2nd stage at Elmergib University.

Figure 4.16.. AR315 Group work for the site model.

Figure 4.17. AR417 Group work for the site model.

Figure 4.18. AR518 Group work for the site mode.

Having placed their models in the site the students projects were refined to move to stage 3, that required changes to be made to their proposed models. Consequently, the students realized that their models should be converted into architectonic language and adopted to the site location. Almost all the students' models had serious changes and most of them started with new model ideas to fit the site conditions. For converting the conceptual models into plans, most of the students tended to use computer software such as AutoCAD and SketchUP for the interior spaces and plans details. When all these changes were made, the developed models and plans were presented for assessment (Figures 4.20 – 4.22.).

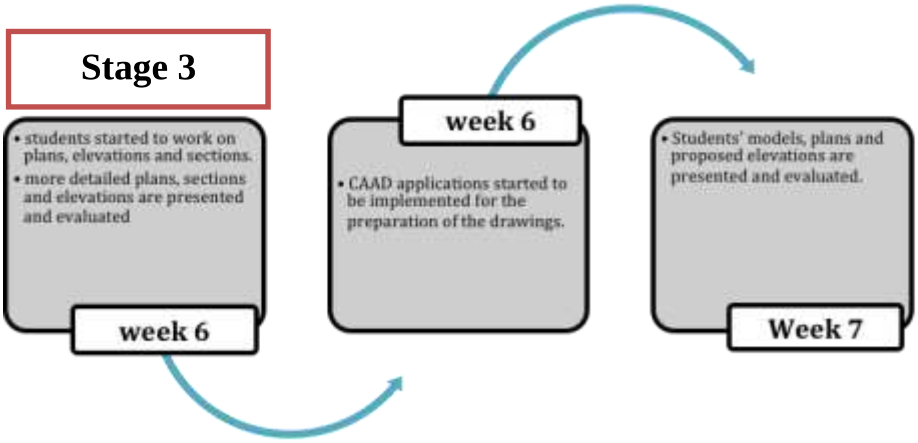


Figure 4.19. Flow chart represents the studio progress in the 3rd stage at Elmergib University.

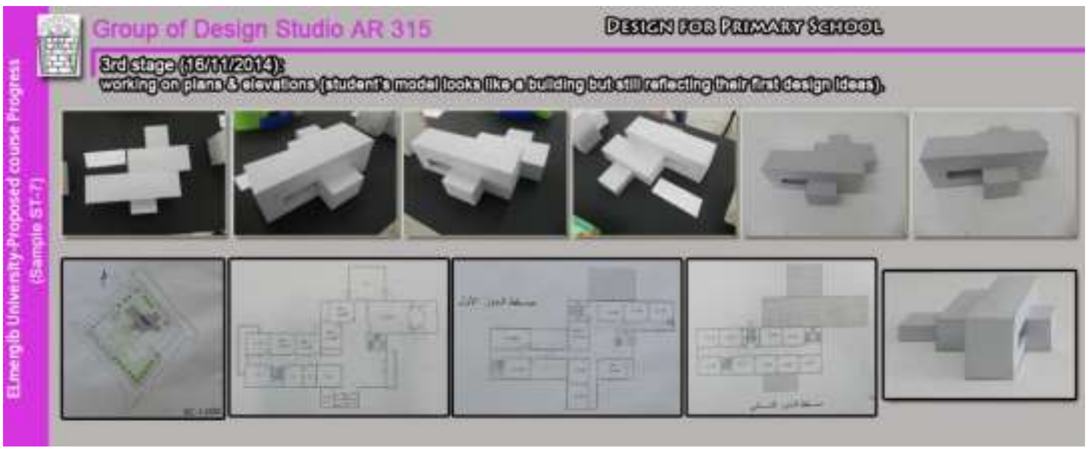


Figure 4.20. Work of an AR315 student (ST-7), presents the extracted plans out of the improved design model (stage3).

Figure 4.21. Work of an AR417 student (ST-1), presents the extracted plans out of the improved design model (stage3).

Figure 4.22. Work of an AR518 student (ST-1), presents the extracted plans out of the improved design model (stage3), preparing for the dress-rehearsal stage.

Stage 4 took more time than expected for the students to finalize their plans and elevations. This was due to the lack of skills in mastering the techniques of drawing and presentation either by the use of CAD applications or handmade drawing techniques. For the dress-rehearsal stage, students were asked to present all their work starting from the development of their proposal ideas, changes made according to the site conditions, detailed plans, elevations and sections as well as the summary of their design program (Figures 4.24 to 4.26). The students' projects were submitted and tutors were invited to give critiques and assessment in an open discussion. The tutors were asked to set very clear evaluation factors with a scaled grading strategy. Table 4.8 presents the evaluation factors used for the assessment of AR315 group and is in the same format as for other design groups. Each design group was evaluated by two instructors and the average of their assessment was taken. Other groups' evaluation details can be followed in Appendix F (Tables F6-21).

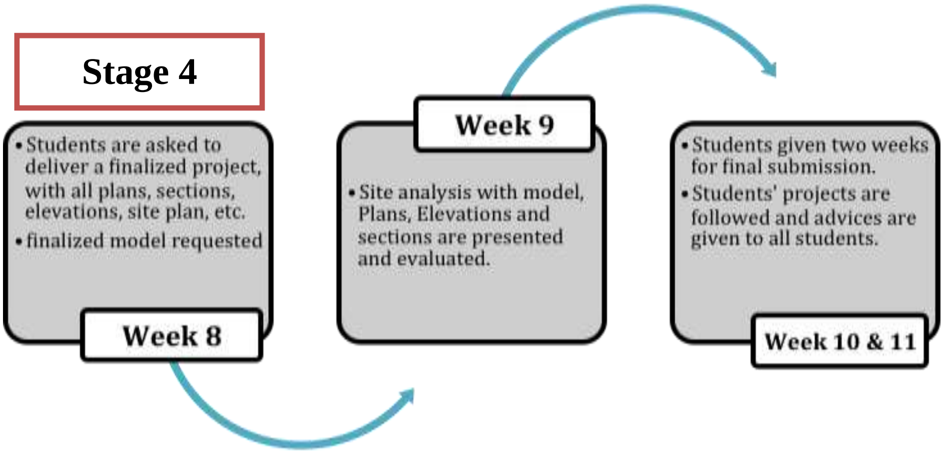


Figure 4.23. Flow chart represents the studio progress in the 4th stage at Elmergib University.

Figure 4.24. Work of AR315 (ST-7), students represented their project before the final submission (dress-rehearsal stage).

Figure 4.25. Work of AR417 (ST-1), students represented their project before the final submission (dress-rehearsal stage).

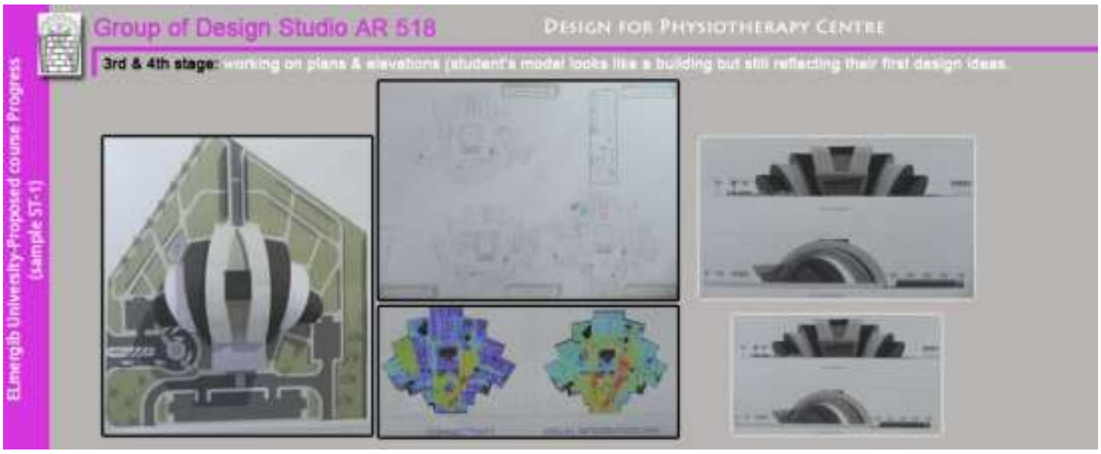


Figure 4.26. Work of AR418 (ST-1), students represented their project before the final submission (dress-rehearsal stage).

Table 4.8. Evaluation of modeling skills during the design studio: factors set for evaluating the development of student's models and design (plans, elevation, etc.)

Sample Code	Model evaluation									
	Site						Mass & Conception			
	Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	scale (10)	accuracy (10)	sense of space (10)
ST-4	20	7	3	7	4	7	15	6	7	7
ST-3	13	7	3	2	3	7	17	7	6	7
ST-2	22	7	3	3	4	7	17	8	7	8
ST-1	17	7	4	7	4	7	0	0	0	0
ST-9	20	8	4	7	4	7	16	7	7	7
ST-7	22	8	3	0	2	6	18	7	6	8
ST-8	23	7	3	2	3	7	7	8	8	8
ST-6	22	7	3	4	3	7	12	7	6	8
ST-5	17	8	3	7	3	7	13	7	5	6

Table 4.8. (Continued)

Sample Code	Plans Evaluation							Overall Grade	Final Grade (200)/2
	Design program (10)	Activities & function (15)	relationshipe indoor & outdoor (10)	orientation (10)	circulation (15)	interior design (10)	Arch-Drawings (15)	200	100%
ST-4	6	12	8	10	10	7	8	144	**72**
ST-3	9	13	6	4	12	8	8	132	**66**
ST-2	8	12	7	6	12	8	7	146	**73**
ST-1	7	12	0	10	10	**0**	7	92	**46**
ST-9	9	13	8	8	13	**0**	13	151	**75.5**
ST-7	8	13	7	10	12	7	8	145	**72.5**
ST-8	8	12	8	7	14	8	7	140	**70**
ST-6	8	13	8	10	13	9	12	152	**76**
ST-5	7	14	7	7	12	7	10	140	**70**

Although it was requested that students should submit a final and detailed model for their projects, only mass models were submitted for the final stage. This is due to the unavailability of modeling equipment, tools, and work space (Figures 4.28 to 4.30). In the final evaluation, tutors suggested to add a new factor to the previously defined assessment criteria, i.e. evaluating the overall presentation of the students' projects (Table 4.9).

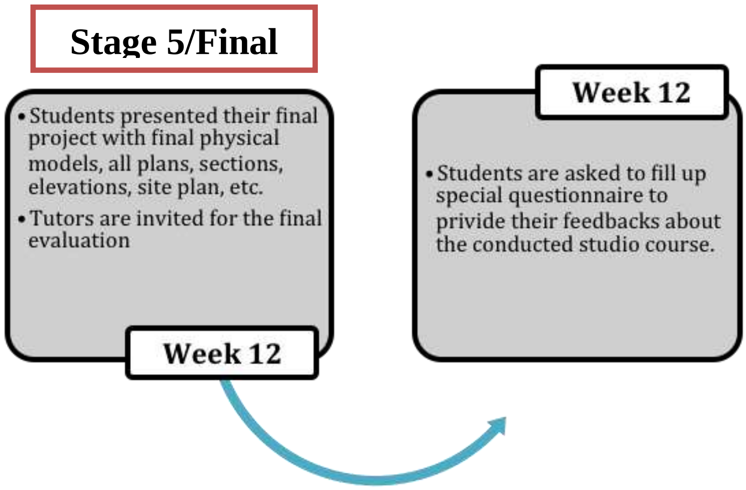


Figure 4.27. Flow chart represents the studio progress in the 5th stage (final) at Elmergib University.

Figure 4.28. Final submission for an AR315 student (ST-7)

Figure 4.28. (Comtinued)

Figure 4.29. Final submission of an AR417 student (ST-1)

Figure 4.30. Final submission of an AR518 student (ST-1)

Table 4.9. Evaluation of modeling skills during the design studio AR315: factors set for evaluating the development of student's models and design (plans, elevation, etc.) after the dress-rehearsal stage.

Sample Code	Model evaluation									
		Site					Mass & Conception			
	Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	scale (10)	accuracy (10)	sense of space (10)
ST-4	19	7	2	7	4	7	17	7	7	6
ST-3	19	7	4	6	3	6	16	7	6	6
ST-2	19	7	4	3	2	6	17	7	7	5
ST-1	19	6	3	5	2	5	17	5	5	7
ST-9	19	9	2	7	5	4	18	8	5	7
ST-7	19	8	4	7	4	7	17	8	7	8
ST-8	19	7	3	6	3	7	16	7	6	7
ST-6	19	7	3	6	3	5	17	7	7	6
ST-5	19	8	3	7	2	6	19	6	8	7

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Table 4.9. (Continued)

Sample Code	Plans Evaluation								Overall Grade	Final Grade (200)/2
	Design program (10)	Activities & function (15)	relationshipe indoor & outdoor (10)	orientation (10)	circulation (15)	interior design (10)	Arch-Drawings (15)	Presentation (10)	200	100%
ST-4	7	12	7	6	10	7	12	6	150	**75**
ST-3	6	13	7	8	12	6	12	6	150	**75**
ST-2	7	12	6	8	12	7	12	7	148	**74**
ST-1	7	10	6	4	10	**6**	10	5	132	**66**
ST-9	7	13	7	5	10	**8**	13	6	153	**76.5**
ST-7	7	13	7	8	13	8	13	8	166	**83**
ST-8	7	13	7	9	13	8	12	6	156	**78**
ST-6	7	12	6	7	12	7	12	7	150	**75**
ST-5	8	12	7	6	12	7	13	7	157	**78.5**

4.4 Course Evaluation Criteria (Benghazi and Elmergib University)

One of the main objectives of this study was to define clear evaluation criteria for the assessment of design projects, particularly in architectural education. Accordingly, studio instructors in both Beghazi and Elmergib universities, where the experimental design studio courses were conducted, identified the evaluation criteria separately. Table 4.10 below presents these criteria along with the grading weight assigned to each.

Table 4.10 The evaluation criteria used for the assessment of design studio projects in Benghazi University and Elmergib University

No	Evaluation Factors	Benghazi University	Elmergib University
1	Site model workshop (25)	✓	✓
2	Employment of the proposal in site location / context (10)	✓	✓
3	Roads (5)	X	✓
4	Parking (10)	X	✓
5	Entrances (5)	X	✓
6	Landscaping (10)	X	✓
7	Design principles/ Ideation & concept (20)	✓	✓
8	Scale (10)	✓	✓
9	Accuracy (10)	✓	✓
10	Plans (10)	✓	✓
11	Sense of space (10)	X	✓
12	Development of design brief (10)	X	✓
13	Activities & function (15)/ Employment of spaces (10)	✓	✓
14	Relationship indoor & outdoor (10)	X	✓
15	Orientation (10)	✓	✓
16	Circulation (15)	X	✓
17	Interior design (10)	X	✓
18	Structure stability;(10)	✓	X
19	Elevations (10)	✓	✓
20	Selection of materials (10)	✓	X
21	Arch-Drawings (15)	X	✓
22	Presentation ;(10)	✓	✓
23	Final presentation model (20)	✓	✓

It was seen that Benghazi evaluation system was based on equal weighting and some factors had been combined under one criterion; while Elmegrib had a more detailed breakdown with different weights. Nevertheless both evaluation systems were transparent enough and could be used for a comparison between the students performance in the experimental design studios.

4.5 Course Evaluation Survey

When all groups finally submitted their projects, they were asked to participate in the online questionnaire prepared to find out the students' impression about the proposed design methodology. The online questionnaire was distributed among the groups of both universities, Benghazi and Elmergib University. The questionnaire form is presented in (Appendix C.II). Accordingly, 32 students had participated from both universities; out of the 23 students from Elmegrib University 5 were in 3rd year studio (AR315), 8 in 4th year studio (AR417), 10 in 5th year studio (AR518); while the 9 Beghazi University students were in the 3rd year studio (AC311). Hence of the 32 Libyan students 20 were male and 12 were female (Appendix: Figures C1-C10).

According to the students' responses, 71% of the participants had never started their design by making a physical model(s) first, whereas only 29% stated that they usually start their design by making 3D physical models instead of 2D sketches.

During the proposed studio course it was noted that there is an apparent weakness in the modeling skills of the enrolled students, although both universities have recently incorporated some modeling courses in their curricula. However, when the participants were asked whether they had studied or practiced the model making techniques in the school 50% stated "Yes". Most of them mentioned that even if they did take a "modeling" course it was not satisfactory as the modeling techniques they had been taught were very basic and general. The students also confirmed that they did not have a modeling workshop either in their schools.

In the questionnaire, the participants were asked whether they faced any difficulties during the experimental studio course when they tried to design with models only;

most of the participants (27 out of 32 responses) stated “Yes” and their answers were attributed to the following reasons as comments:

- The availability of materials
- Difficulty in the distribution and usage of the interior spaces.
- The time constraints, costs and lack of modeling experience.
- Unavailability of modeling courses.
- There is no support from the school (lab, materials, tools, equipments, etc).
- Difficulties were only at the beginning of the course because this method has never been implemented before in their design studios.
- Modeling details, accuracy, scale, cutting, folding, bending edges, etc. (technical issues)
- Difficulties in starting design not knowing the design topic and site information.

Those participants who answered “No”, i.e. they did not face any difficulties, stated that:

- the implementation of such a design method gave them a positive motivation
- improved their design creativity,
- their modeling skills have significantly improved,
- they felt every part of their design (tangibly) and
- their sense of space and scale improved as they think that they lived (inside) their design.

The making of several proposals at the beginning of the studio course contributed to increasing the possibility of having better grades and evaluation for a student’s project. According to the questionnaire responses, 31 out of 32 stated “yes” the continual development of their design through the making of several models did contribute to a better evaluation for their design.

To verify the usefulness of the conducted studio method, the participants were asked whether they supported the adaptation of the proposed design studio method for all the design studios in their schools. Accordingly, it is apparent that the strategy implemented in the proposed course had its positive impact on the students because 25 students out of 32 supported the adaptation of the proposed method, and only 7 were against it.

Respondents' whose answers were "Yes" associated their answers with the following reasons:

- Because I started to think, create and produce my thought in 3D, also every part of my design became tangibly controlled. Above all, instructors appreciated my efforts.
- This method has developed the students' imagination and thinking ability during the design progress.
- Things became real 3D objects that can be tangibly controlled, rather than rough 2D sketches.
- Assisted to save more time when preparing design plans (specially during the first stages)
- The method helped and contributed to give various design options.
- The method assisted to overcome many construction difficulties.
- The method assisted to create distinct ideas that came out from the nature of the site itself.
- It gives a kind of motivation and excitement as the design becomes a more enjoyable activity.

Whereas, participants whose answers were "No", attributed that to the following reasons:

- Some students saw that this method takes too much time and efforts.
- By the use of 3D software, models can be created with less effort and shorter times.
- Some stated that because of the insufficient support from the school in terms of equipment, tools and labs made the progress of the course more difficult.
- More reasons are attributed to the unavailability of modeling courses and practice.

Further questions were allocated in the questionnaire to find out why 62% of the participants think the proposed design studio method (design with models) was "complicated" and only 38% think "easy". Accordingly, most of the reasons can be summarized as follow:

- At first it the students felt it was difficult, as everything was ambiguous (no title, no design program, no site information, etc.) only the volume and design space was given. But after a while step-by-step things started to come together and interrelated (when site and design program is given). But even before that, it seemed they had forced their imagination to focus and create multiple compositions, which they believed reflected their thought freely and brought many design possibilities. This facilitated the way they learn and produce ideas out of the site nature. (Ideas produced from the site itself)
- Difference of opinions from instructors in selecting the best proposal at the beginning.
- Modulating the proposed composition in the site.
- The division of internal spaces while retaining the external form.
- The up-side-down way of design was very entertaining for them; it freed them from being stuck basically in functionality.
- It gives the possibility of seeing the project in all respects and solving the obvious and clear design defects.
- As it is a new design method with which most of the students are not familiar, they recommended model-making courses that would be a very effective and useful for all design levels in the school.

Finally, the participants were asked to evaluate the design method by choosing between (bad/good/excellent). Responses showed that 19 out of 32 participants said "Excellent", 12 said "Good" and only 1 said "Bad" (Figure 4.31). This reflected the overall satisfaction of the students towards the proposed design methodology despite some obstacles that have been identified earlier. In other words 97% of the students were satisfied with the design methodology of the experimental studio.

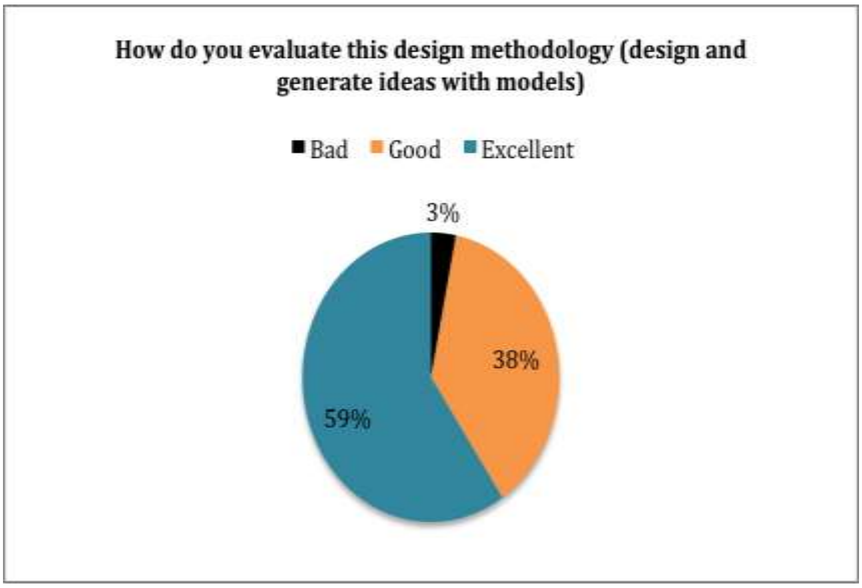

Figure 4.31 Data on satisfaction with the design methodology adopted for the experimental design studio courses in Benghazi and Elmergib Universities in Libya.

CHAPTER 5

RESULTS OF SURVEY AND DISCUSSION

Based on the materials, data collected and issues discussed in the methodology for the three major domains; i.e. Public, Education and Professional this section presents the results of the surveys, while data on the Experimental Studios has been given in the next chapter. As the study is concerned with the impacts of architectural models on the three domains, the impacts on each will be discussed one by one, and then the resultant outcomes will be presented. Data and information gathered as a result of this research are presented below in the following order; public, educational and professional domains.

5.1. Public Domain

One of the challenges of this study was to investigate whether or not there is a significant impact of architectural models on the public, and what kind of impact might be brought about by a building model? Also, how an architectural model may affect the public at large, whether positively or negatively. Therefore, it was proposed to conduct a field study to obtain data that would provide an answer to these questions.

Not only in Turkey but also in many other countries architectural models have become the focus of public attention, and many countries tend to rely on models as a way to display their historical legacy, in dedicated parks. For example “Madurodam” which is the first miniature park in the world, is located in the Scheveningen district of The Hague in the Netherlands. Others may be identified as Walcheren Park in Middelburg city, Holland, “Minieurope” Located in Belgium’s capital Brussels and Miniatur “Wunderland” in Hamburg, Germany, the largest model railway in the world. Besides Miniaturk which is situated at the north-eastern shore of the Golden Horn in Istanbul, there are two other miniature parks in Turkey that have adopted the idea of attracting tourists and public through architectural models: Minicity in

Antalya and 80 Gün’de Devr-I Alem Park, in Konya.

5.1.1 Results of the Survey

Miniaturk was chosen to investigate the related questions because it is amongst the world's largest miniature parks and it attracts many local and foreign tourists. Consequently, it offered an opportunity to interview many visitors from different countries. Miniaturk park contains 122 models (including crystal models) done in 1:25 scale. It contains structures mainly from Turkey, a few religious buildings abroad, as well as interpretations of historic structures.

At first, statistics were obtained from Miniaturk authority concerning the annual increase and decrease in the number of visitors (Appendix A: Tables A1 & A2). However, these statistics only gave the total number of visitors who had visited the Miniaturk Park annually, and could not be used to signify any impacts of the models on the visitors. Subsequently, it was intended to find out the number of tourists before and after the establishment of Miniaturk that might provide any significant sign to relate as a factor that caused any increase or decrease in the number of visitors. Hence demographic data on tourists were obtained from the Ministry of Culture in Turkey. Unfortunately these data were very general and could not represent any correlation with the impacts of models in any way. To achieve this aim, Miniaturk Park was visited during the high season, on 26 April 2014, and 70 visitors were interviewed; the raw data is given in (Appendix A. Table A3). These data were obtained from two days of survey in Miniaturk. The interviewed visitors were asked whether they had decided to visit any of the buildings after seeing their models in Miniaturk. Also, they were asked to choose models of the buildings they would like to visit. 26 out of the 107 models were selected by the various responders, and among these six were identified as the most popular ones with the visitors (Table 5.1).

Table 5.1: Data on buildings selected from the models by the visitors at Miniatürk,

No	Selected models by visitors	Frequency of selection	Definite plans to visit		Indefinite plans	
			No of plans	(%)	No of plans	(%)
1	**Haghia Sophia**	**27**	**25**	92%	**2**	8%
2	**The Blue Mosque (Sultan Ahmet)**	**24**	**24**	100	**0**	0%
3	YEREBATAN Cistern (SARNICI)	4	4	100	0	0%
4	**Suleymaniye MOSQUE**	**17**	**17**	100	**0**	0%
5	The Ruins of MT. Nemrud	6	6	100	0	0%
6	Amasya Yaliboyu Houses	1	1	100	0	0%
7	**Fairy Chimneys (Cappadocia)**	**18**	**18**	100	**0**	0%
8	Bursa Grand Mosque	2	2	100	0	0%
9	The great Mosque of Diyarbakir	3	3	100	0	0%
10	Twin minaret Medrese	1	0	0%	1	100%
11	Sumela Monastery	11	6	55%	5	45%
12	**Aspendos Amphitheatre**	**20**	**13**	65%	**7**	35%
13	Houses of Safranbolu	8	8	100	0	0%
14	TEM- trans European Motorway	5	0	0%	5	100%
15	The Chamfered Minaret Mosque	1	0	0%	1	100%
16	The Halil-ür Rahman Mosque	2	2	100	0	0%
17	Pamukkale	4	4	100	0	0%
18	**TOPKAPI Palace**	**25**	**25**	100	**0**	0%
19	Bosphorus Bridge	1	1	100	0	0%
20	Temple of Artemis (Artemision)	3	3	100	0	0%
21	Al Aqsa Mosque	1	0	0%	1	100%
22	The Dome of the Rock	1	1	100	0	0%
23	Ataturk Olympic Stadium	2	0	0%	2	100%
24	Istanbul Ramparts and Yedikule	11	11	100	0	0%
25	Rock houses of Mardin	1	1	100	0	0%
26	The Anatolian Fortress	5	5	100	0	0%
	Total	**204**	**180**	**24**		

Three officials in Miniaturk were interviewed to gather further information: e.g could they identify any touristic programs for directing the visitors to the original buildings of the presented models. This interview yielded that such tourism programs are generally organized independently by tourism companies, in other words, Miniaturk authority are not responsible for directing tourists to any areas outside their authority.

The buildings represented by the models selected by the Miniaturk visitors were visited. Three local authorities offciers were interviewed, 2 in Sultan-Ahmet & Suleymaniye mosques and 1 in Haghia Sophia. These interviews also confirmed that it is not possible to define the destinations from which the visitors of each building came from; all that can be determined is the daily, monthly and annual visit rates (by counting the number of shoe bags provided to visitors in Sultan Ahmet and Suleymaniye mosques, and the tickets sold at Hagia Sophia).

According to the department of research and evaluation in the Ministry of Culture in Turkey, it has been confirmed that distribution of foreigners arrival in Turkey as well as for the Turkish citizens can be identified only by the increase and decrease according to daily, monthly, and annual visits. Statistical data are recorded only according to nationality, most visited cities, means of transport, borders and airports, arrivals and departures. Therefore, no correlation can be attributed to these statistical data to find out any positive or negative impacts of models on the public (number of visits). Nevertheless, these data are included in Appendix A. Tables (A4-A8), while photographs of the complete set of “Miniaturk” models that were photographed in October 2013, are given in Appendix B. Figure (B1-B8). Additionally, some of the real buildings that were identified from the models were visited and their photographs are also given in Appendix B. Figures (B9-B12). Models selected by the visitors. Photographs of the 26 buildings selected by the visitors (listed in Table 5.1 above) are presented in Figure 5.1 below.

5.1.2 Discussion of the Results

The field study showed that models do have a significant impact on the cultural heritage of societies. Table 5.2 below represents the number of visitors who decided to visit the real buildings after seeing the presented models. When these visitors are classified according to their nationalities it is seen that the great majority are from Turkey, as can be expected.

In addition to the impact of the models on the public, who were appreciative of the opportunity to see 3-D representations of important buildings located all over the country, in the same place, a trend can be seen based on the comparison between the number of visitors who definitely planned to visit the real buildings and with visitors who were “uncertain” due to time constraints to make their visit. There is a clear indication that architectural models do have a significant impact on increasing the motivation of public to decide and make their plans for visiting and appreciating their cultural legacy and heritage.

Overall 15 nationalities participated in the interview and are listed in (Table 5.2). Also included in the table are the number of respondents from each country and their responses classified into two categories, namely definite and indefinite, according to the certainty of their plans for visiting the real building after they had seen the Miniatürk models. It was also noted that visitors with Turkish nationality appreciated the value added by the models to their cultural heritage, and were keen to visit many buildings after seeing their models also.

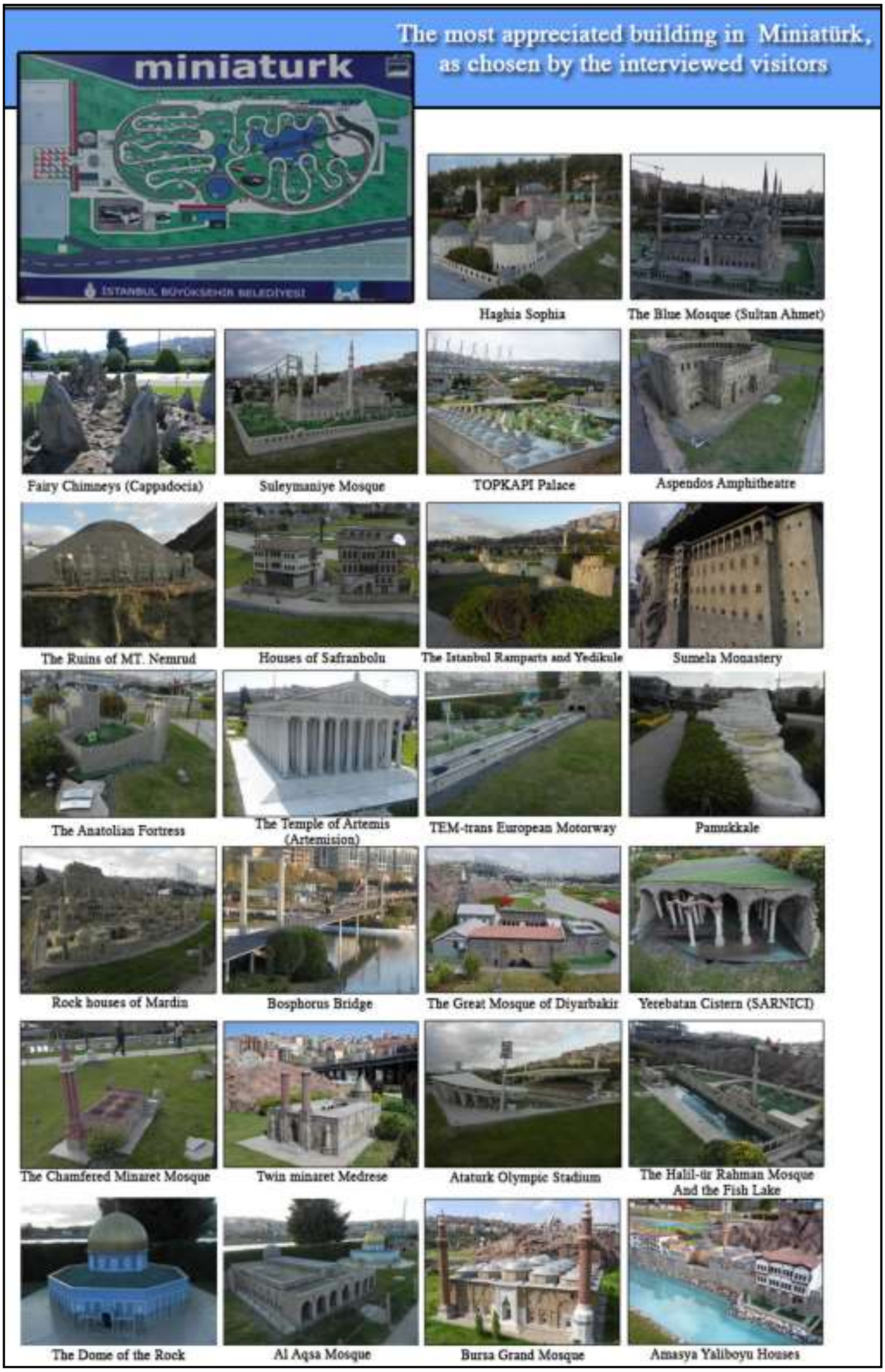

Figure 5.1 : Photographs of models of the most appreciated building in Miniatürk, as chosen by the interviewed visitors .

Table 5.2: Data on buildings selected by the visitors at Miniatürk according to their nationality and certainty of their plans to visit them.

				Plans to visit the selected buildings (204)		
No	**NATIONALITY**	**No of visitors**	**No of buildings chosen**	**Certain**	**Uncertain**	**% Of Certainty**
1	CANADA	4	6	12	0	100%
2	TURKEY	29	18	45	8	84.91%
3	IRAQ	1	2	2	0	100%
4	IRAN	6	4	15	0	100%
5	RUSSIA	6	4	12	2	85.71%
6	BOLIVIA	1	1	1	0	100%
7	SYRIA	2	2	4	0	100%
8	KUWAIT	2	7	5	2	71.43%
9	BAHRAIN	1	3	2	1	66.66%
10	LIBYA	1	5	5	0	100%
11	SAUDI ARABIA	2	3	6	0	100%
12	INDIA	5	6	25	5	83.33%
13	GERMANY	6	6	30	6	83.33%
14	NORWAY	2	4	8	0	100%
15	SPAIN	2	4	8	0	100%
	Totals	70	26	180	24	88.24%

Among the important and effective procedures in providing the historical overview and definition of the architectural legacy of the presented buildings is the use of barcode scanner technology. The barcode machine works when a visitor passes the entry card over the machine scanner for providing brief information about the building, history, designer, location, materials used, technique of construction and the current status of the building as well. This technique offers the possibility of translation into more than 12 languages.

5.2. Educational Domain

This section presents the outcomes of the face-to-face interviews, and the questionnaire survey before the experimental studio.

5.2.1 Face to Face Interviews

To begin with, interviews with randomly selected students and instructors from different national and international universities were made. On the one hand, Students and instructors from METU University were interviewed (on May 2013); they were regarded as samples attributed to the national university. On the other hand, students and instructors from Elmergib and Benghazi University were also interviewed and regarded as samples attributed to the international universities. The informal interviews were conducted mainly to highlight some basic concepts of students' design approach and modeling abilities. For instance, students were asked "how do they start designing", what are the first steps they usually anticipate when they propose and make their design idea. They are also asked about the preferred modeling technique they usually master (handmade or digital modeling). Students' modeling skills as well as some modeling tips were discussed. Each student's project and models were also photographed which signify the relationships between their modeling skills, design methodology and performance during studio courses, i.e. how design models are appreciated by their instructors. Some of the interviewed students' final juries were attended and their models were photographed (Figure 5.2).

Figure 5.2: Project models used as the platform for discussing the students' final design at METU (models of Arch 102 on right and Arch 302 on the left).

This procedure was carried out for almost all the students; whether in METU, University of Benghazi, or Elmergib University. Apparently, architectural models have an obvious impact in defining the workshop and learning environment. Based on the attended workshops and juries, architectural models had an evident impact in defining multiple learning environments within the framework of a single space. Creating such kind of plurality is due to the need for different work spaces and privacy for each space (Figures 5.3 to 5.6).

In METU, 9 undergraduate students were interviewed, all of which are from different academic levels, 1st, 2nd, 3rd and 4th year. Almost all the interviewed students stated that their design approach begins with collecting data for the proposed site, diagramming/zoning the collected data, making 2D sketched and sometimes making handmade compositions. Only one student stated that have usually starts with making several physical compositions using as varied materials as possible.

Figure 5.3: Learning environment in METU. Students work in groups preparing their models for the final jury, while others are having their juries; models created multiple learning environments within a single space as represented by the diagram in Figure 4.4.

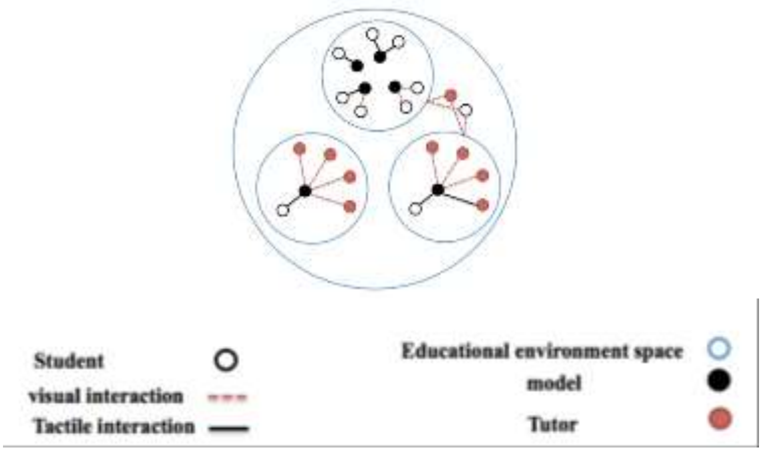

Figure 5.4: The situation where physical models assisted in defining multiple learning environments by students' workshops and final juries' discussions.

Figure 5.5: 1st year students preparing models in the studio before the design jury

Figure 5.6: 3rd year students in Elmergib University individual and group workshop (fall 2014-15).

With respect to the preferred modeling techniques, most students, if they are given the option to chose, prefer to use digital models rather than using the handmade techniques. They think that making models by hands takes much more time than with computers. Moreover, students lack sufficient experience on how to master the handmade modeling techniques and tips. Most students likely attributed such constraints because most of the courses in the school are extensively focused on the use of digital technology, while there are no training courses for manual techniques. Accordingly, when students are asked why they do not prefer handmade modeling, most of the time the reason was because of time constraints, availability of materials and the lack of experience. However, some of the interviewed students declared that they had practiced the handmade modeling as a hobby even before they entered the school of architecture.

How students are transferring their design ideas from the unknown or invisible state into physical state was among the issues discussed in the interview. This was to touch upon how they think and express their design approach, not necessarily for their studio discussion but even for themselves. Accordingly, some students still were confined within the conventional design method based on 2D sketching and zoning, despite their preference for the use of digital technology. Other students preferred not get stuck between “X and Y” coordinates (as they stated). Defining the ideation progress for each student was very complicated to identify. In other words, students were asked to define the transitions of ideas from their minds (unseen concept) until it is visually formulated. Students declared that most of the time what externalized from their minds did not correspond with the nature of their idea that they already had in their minds; they attributed this failure also to the lack of their sketching and modeling abilities and experience. Therefore, many training and practical courses with respect to the modeling techniques may contribute to help students overcome many of obstacles during their design process.

Other issues such as the sense of scale and modeling materials properties were also discussed during the interviews (Figures 5.7 and 5.8). Some of the interviewed students were tested for their sense of scale by asking them to estimation dimensions of random parts of their models without using any measuring tools; this was to ensure that they did not already know the sizes and dimensions of the mentioned parts. Interestingly, some students responded quite positively in that the difference between their estimation and the exact dimension of the desired parts was very close, while other students' estimation was too far compared to their friends.

Figure 5.7: Discussing handmade modeling materials and techniques, and pointing out to problems with using them in conjunction.

Figure 5.8: Testing the perception and sense of scale based on the estimation of the student.

Both data acquired from interviews and the general questionnaire highlighted various critical issues concerning the students' design approach, modeling ability and background. They also defined the most appreciated modeling technique as well as the complications the students may face while making their models. The interviewed students were also invited to participate in the online questionnaire survey.

5.2.2 Online Questionnaire Survey

In this questionnaire 65 students and 22 architects contributed to survey questions **(Appendix C)**. Among the 87 participants there are 52 male and 35 female, all of whom are from various education levels (Figure 5.9). The age groups of the participants are given in Figure 4.10.

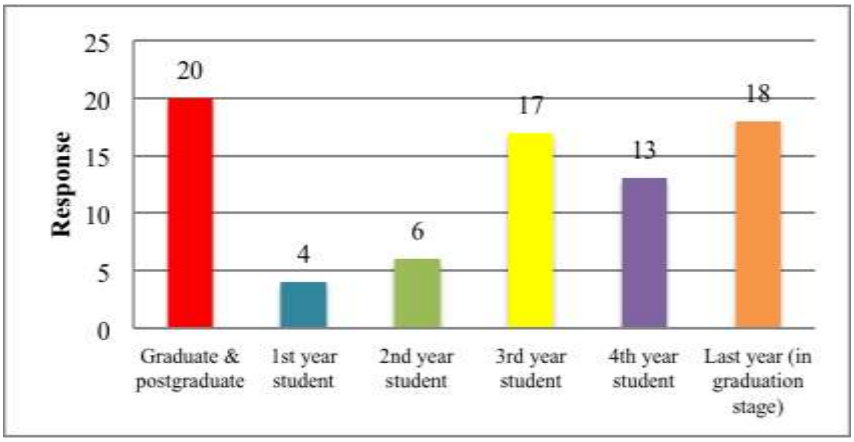

Figure 5.9. The levels of education for the participants of questionnaire survey.

The online questionnaire was both sent by email and published online in many social networks such as Facebook and twitter in two different languages, i.e. English and Arabic. Students from various nationalities participated in the survey; 3.4% were from Turkey, 78.2% from Libya, 2.3% from UK, 3.4% from Canada, 8% from USA, 2.3% from Japan, 1.15% from Sudan, and 1.15% from Iran (Figure 5.10).

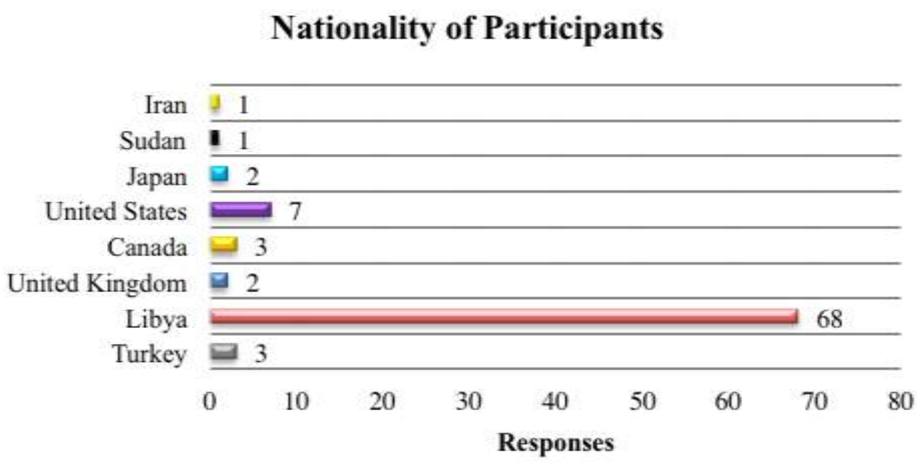

Figure 5.10. The enrolled participants according to their nationality

The participants were initially asked why a designer should make a model. They were given multiple choices to answer in addition to the possibility of adding their own comments. Accordingly, 54% of the participants chose the option that a model should be made for integrating ideas that may not have been seen in the drawings, which identified the most selected answer. Whereas, the least selected option (9%) was "other" and participants added extra comments in this option; while most of them considered the model as a thinking tool allowing the designers to control their ideas tangibly. The data on their answers is summarized in Figure 5.11.

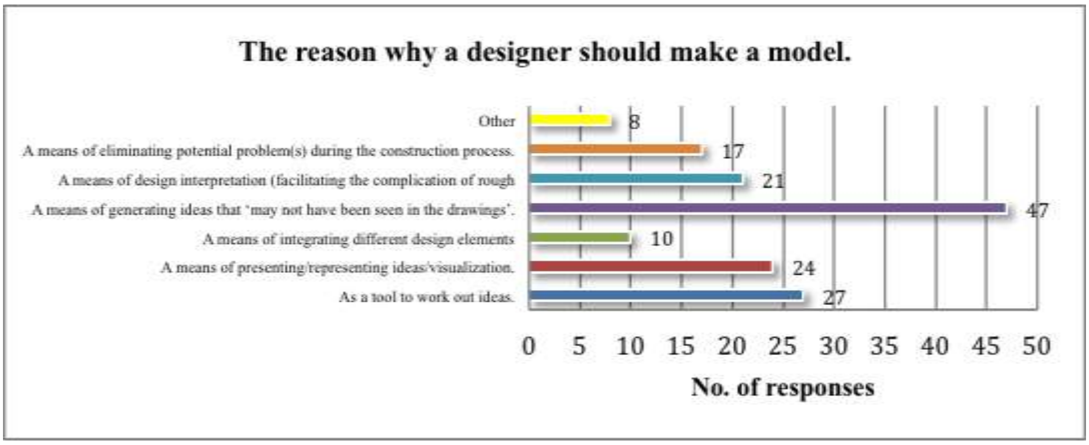

Figure 5.11. Primary purposes for which designers should make their models.

When given a choice between two different modeling techniques, handcrafted and digital modeling (rapid prototyping) the 61% of the 87 participants, preferred to use handmade modeling techniques while 39% chose digital modeling techniques.

About 59 participants (68%) feel that there are some aspects of model-making they do not like, and 28 (32%) of them confirmed they had no difficulties. In spite of this declaration 55 of the 87 participants rated themselves as good model-makers, 13 as excellent (Figure 5.12).

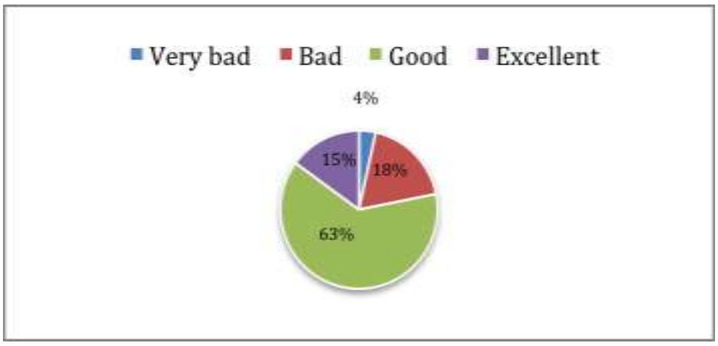

Figure 5.12. How participants rated their modeling abilities.

Additionally, when participants were asked whether any difficulties in model-making limit their imagination and creativity as designers, 64% answered NO while only 36% answered YES. To find out the reasons behind these two different ratios, participants whose answers marked (YES) were asked to specify their reasons, which can be briefly summarized as follow:

- Expression possibilities become poor.
- I had to change or modify my design idea according to what I can manage, neglecting what I wished to do.
- Complex shapes & free surfaces sometimes are tough to manage manually, which leads me to rethink about the whole idea, sometimes change it completely.
- Irregular shapes and complex forms are difficult to be made by hand.
- Just some irregular forms needs only specials calculations & skills.
- Shortage of technological tools.
- I Hate or avoid making irregular shapes in my designs for not being able to model them manually (by hands).
- Not having the skills of making irregular shapes by hand forcing me sometimes to change some parts of the idea and sometimes change it completely.

There is a conceivable relationship between the quality of materials, its availability, characteristics, price and experiencing the modeling techniques that probably also has an impact in determining the medium of presenting an architectural idea. For finding out such an impact, the most commonly used materials in making models are derived from the participants' answers. Among all the mentioned materials, cardboard, foam and wood were the most chosen and preferred materials to use in model making. This may reflects that students look for specific properties, prices, or even characteristics to present their design ideas efficiently. Ratios concerning all the materials mentioned by participant can be seen in (Figure 5.13).

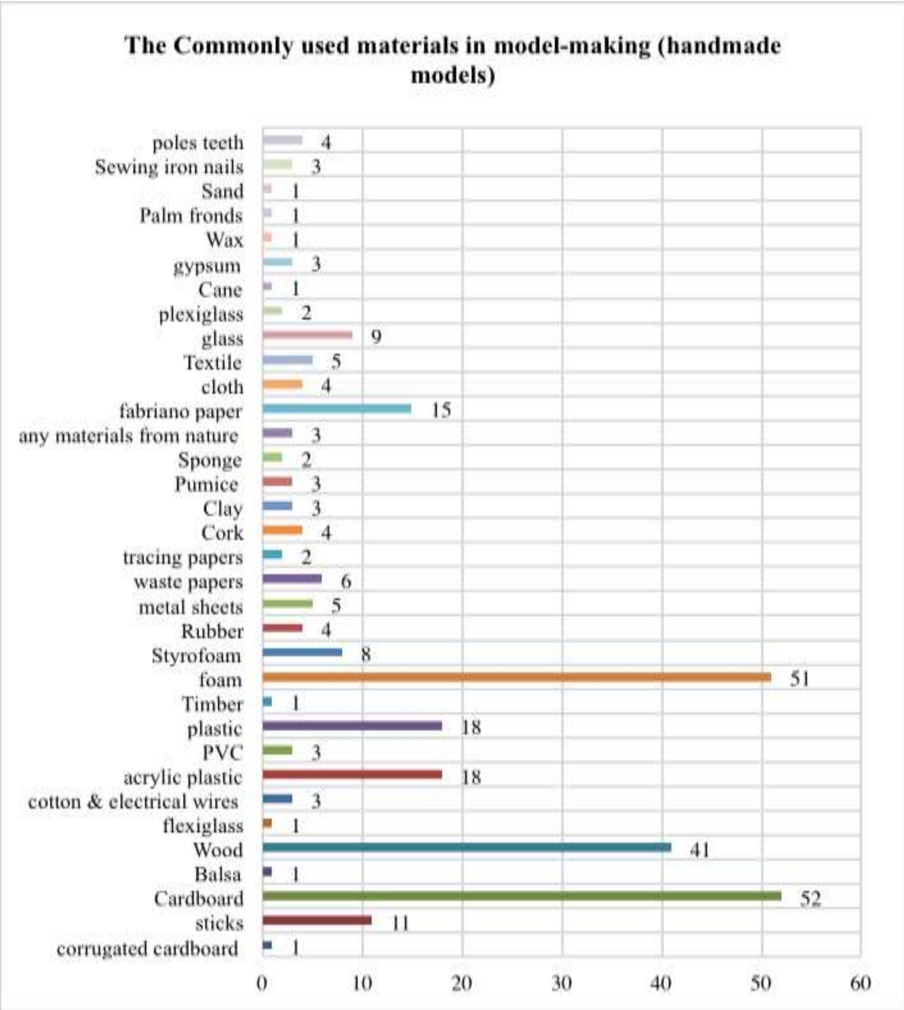

Figure 5.13. The commonly used materials in model-making (handmade models)

Participants' revealed that the availability and properties of materials might force a student or a designer to change his/her decision-making in selecting the applicable material to make his/her model. The use of some mentioned materials such as plastic, PVC, styrene, acetate, acrylic, Styrofoam were attributed to overcome some technical problems like building structure, long spans spaces, making domes, sectional and interior models, mass models, context of a proposed design and in making urban fabric. Additionally, some other uses were mentioned, like furniture components, cladding facades, and in making some decoration details as well.

When asked “what may force a student & designer to change his/her decision- in selecting the applicable material for making their models” Among the 87 participants, 55 chose the availability of materials, 29 chose properties of materials, 24 chose standard dimensions (size & thickness), and 14 the price (Figure 5.14). When asked about the fastest and easiest medium preferred to present an architectural idea in a hurry, most participants indicated their choice to be hand sketches, while only one opted for animation (Figure 5.15).

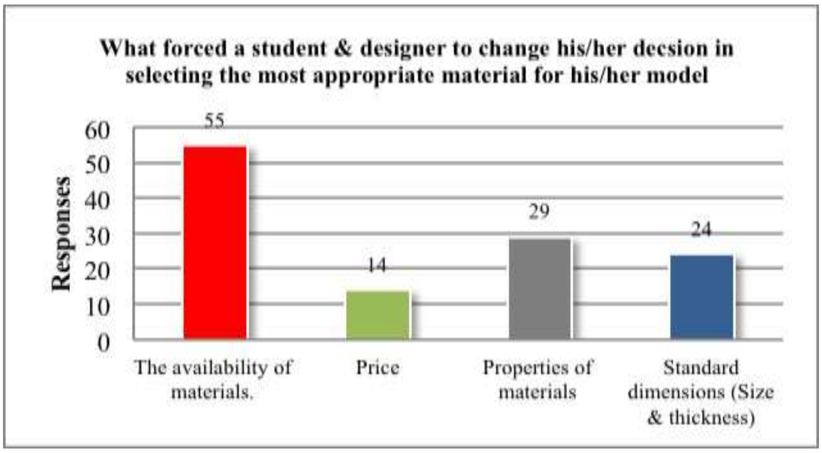

Figure 5.14 Responses to the question “what may force a student & designer to change his/her decision- in selecting the applicable material for making their models”.

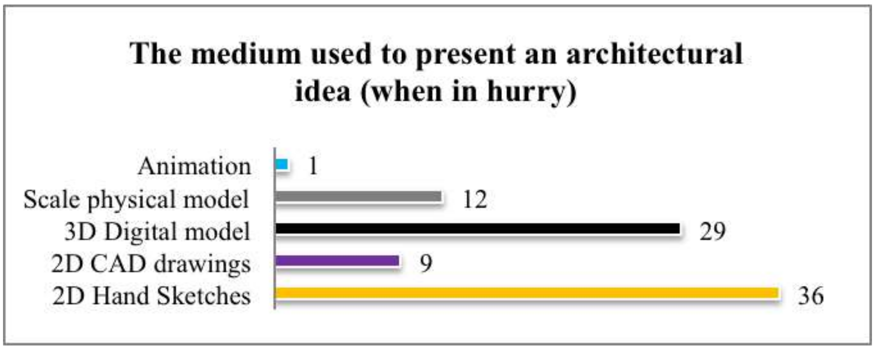

Figure 5.15. The quickest and easiest way (for most participants) to present an architectural idea.

Most designers tend to choose the easiest and shortest way to express the idea of their design and this is what might be inferred from answers to the question whether they had ever done any casting for their models 24% answered “yes”, while 76% answered “no”. The reasons for this can be attributed to complexity, lack of equipment and training programs, and shortage of time.

Having attempted to find out more details of what may be restricting or influencing the design approach of a student or an architect, 67% of the participants say that their design approach is almost influenced by their modeling skills, while 33% did not think so. Accordingly, for having more additional information about the reasons that restricted a students’ design approach, it was necessary to investigate whether students had practiced or had some modeling courses to improve their skills. Thus, participants were asked whether they had any courses allocated to model making training in their schools. 38% of the participants stated that they had model-making training in schools, while 62% declared that there were no model-making courses in their schools program. Some mentioned that model making training and practice was usually organized unofficially between the students, i.e. some experienced students offered to train other students to learn some modeling techniques.

To find out how students/architects start their design process, 45% opted for making 2D sketching (on sketch paper) then moving on; 9% preferred starting by 2D sketching using CAD application software then moving on; 13% for 3D sketching using CAAD application software, 30% for those making composition models by hand, and 3% devoted for using both techniques, making 3D composition and 2D sketches together (Figure 5.16).

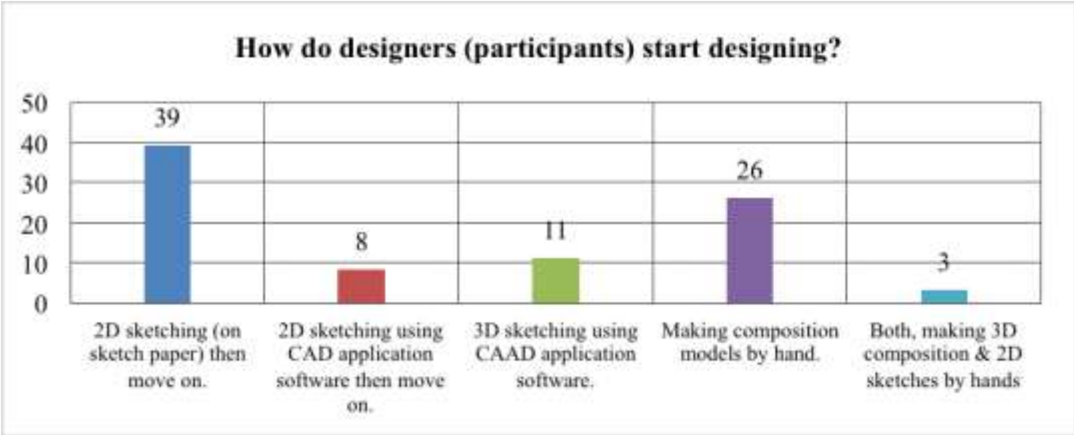

Figure 5.16. Five different design criteria preferred by questionnaire participants.

Interestingly, although the highest percentage (45%) was given to the use of 2D sketching when starting a design process, most of them (63%) declared that a designer should start working in 3D at the beginning of the design process (Figure 5.17).

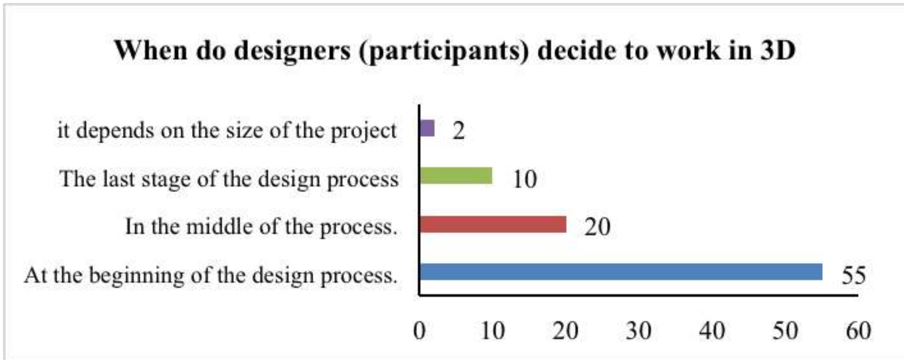

Figure 5.17. Four situations when designer decide to work in 3D to clarify their design idea.

This gives a kind of conflict in the participants' understanding of the design sequence and progress. However, when participants were asked which modeling method they usually choose to make their models, 38% indicated the use of 3D software applications and 33% for using their hand skills, whereas, 17% chose both 3D software and hand skills, (Figure 5.18).

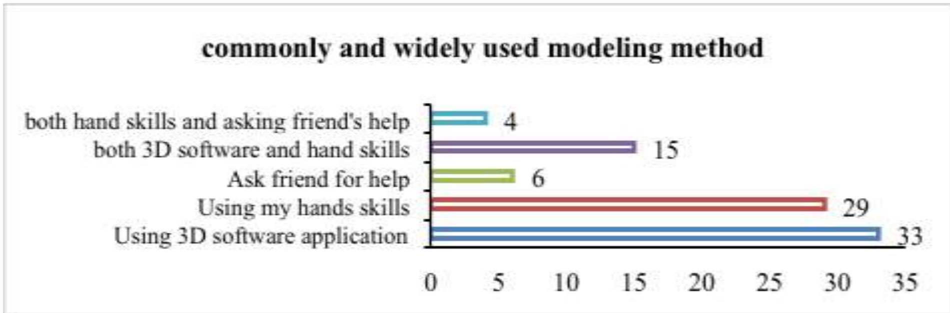

Figure 5.18. The commonly used modeling method among participants.

Based on this concern; the participants stated many reasons for choosing the selected modeling methods, as follow:

- **Using 3D software:**

- Time is an issue
- Easier to interoperate fixing details (It is easy, quick, manageable and more accurate)
- 3D digital models impresses the clients and is more effective and quick to finish. Clients do not care about how the models are made, rather they care about how to see and feel their needs, thus with 3d virtual models they can be as close as possible to reality.
- 3D applications allow to reconcile the two-dimensional drawings and three-dimensional model at the same time.
- By relying on 3D software I can somehow compensate the weakness of my hand skills, and sometimes I ask friends for help.
- Because of the weakness of hand-skills.
- Unlimited rendering options.

- **Using hands skills:**

- Easy to think further and I use my mind to imagine.
- Working with my hands enables me to control all the elements of design idea tangibly, in addition to the spatial sense of the design spaces through dealing with compositions.
- I became much involved in the design… I can control, feel, and understand every step of my design process.

- Relying on hand skills when making models provide a stronger closeness between the designer and his idea.
- Relying on the senses and hand skills enforce the relationship between the designer and his idea, so that he can control all the elements of a design tangibly at once.
- Lack of experience in using 3D software applications.
- I can master both techniques (handmade and with CAAD applications), but I prefer to use my hands because when it is made in computer I feel as if this design does not belong to me.
- Whatever the reliance on digital technology, in the end the final touches require the intervention of human hands.
- More fun and exciting

▪ **Asking friends for help:**

- Lack of experience and weakness in hand-skills.
- Lack of experience and practices specially in using digital equipment (laser cutter, etc)
- Due to the weakness of my hand skills and prior experience in model-making.

▪ **Using both techniques (hand-skills & 3D software):**

- To compensate the possible weakness in making some complex forms & shapes (that it is hard to manage by each technique)
- Every part of the idea can be physically manipulated, controlled, tested and improved while designing. In short the tangibility becomes stronger.
- Time and spatial relationships are important
- Easy & quick and every step and part can be tested during the design process.
- Easy & quick & manageable
- Usually I rely on my hand skills, whereas the help of 3D software is to individualize the blocks in order to exploit the time and ensure accuracy and cleanliness of compositions.
- The reason I call it "design all at once": place the idea, control it, generate it, develop it, test it, analyze it & build it.

Participants were also asked to specify which 3D application they had mastered and how well they know the logic (algorithm) behind the mastered software. Answers of the participants are given in Figures 5.19 and 5.20.

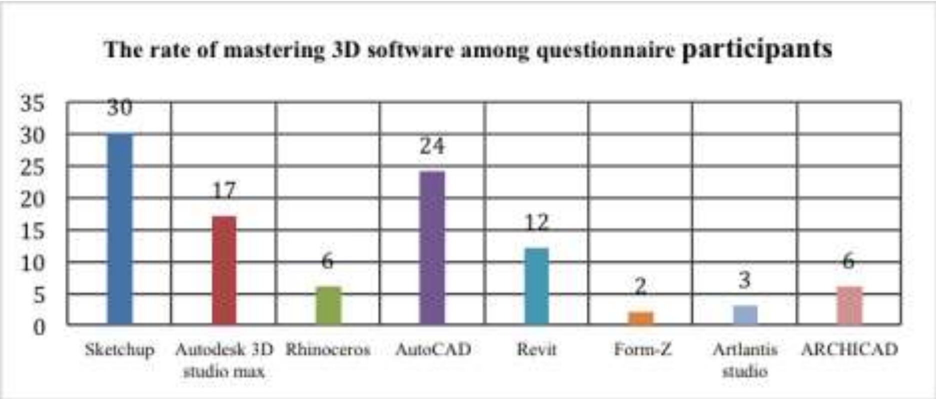

Figure 5.19. The rate of mastered 3D software indicated by questionnaire survey participants

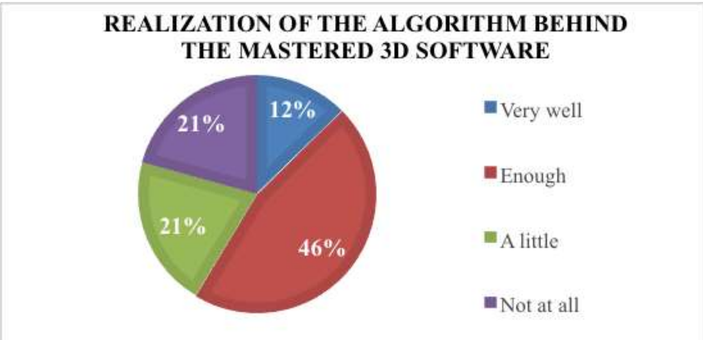

Figure 5.20. Participants' realization of the algorithm behind the mastered 3D software

General opinions about the usability of models in design are elicited from the survey, 68% stated that models contributed to the design development, while 30% of the participants think that a model may just convey the design intention and 2% for both answers and only one mentioned that models do facilitate the vague of design issues to the client.

Those who used the model in their design analysis (64%) indicated that mostly working with several models helped in the development of generating design ideas and detecting orientation deficiency, i.e. for placing the proper proposal in the location. Others mentioned their used for testing structural behavior and stability and the analysis of the inefficiency of spaces (gaining and emitting heat, and functionality of materials). Observing the real context of their design allowed them to promote the desired analysis, that is, physical observation allows the designer to detect where problems may occur. Other participants considered that the mass is the basis of design stability and balance to the rest of the primitive architectural elements. Accordingly, it is believed that the design when design starts from a very strong and stable form and mass it will definitely be a working structure and functional design. In the same context, further explanations were added discussing the use of model for testing the structural stability & testing the interactions between the design and the surrounding. To illustrate this, it is mentioned that for testing the structure certain loads are applied & for testing the design efficiency by relying on some computer software such as Ecotect & Designbuilder software. Some other comments mentioned that the making of models is by itself an analysis that a designer uses to control, modify, observe, detect errors and deficiencies in every part of his idea, so the making of models and analysis process should not be isolated.

However, those who did not use the model in the design analysis, were mostly students who complained that using the model as an analysis tool for their design was not obligatory in their schools, i.e. instructors never told them to do any sort of analysis, their models were only used for presentation purposes. Additionally, the given reasons for not using the model in design analysis were attributed to "no training or practical courses allocated in schools" & students were never encouraged to do any analysis using their models, due to shortage of time, other reasons generally attributed to the lack of experience in model-making.

Figures 5.21 and 5.22 represents the commonly used scales in 3D modeling among students and architects, and shows whether or not they work with different scales at various modeling stages. Some students mentioned that in schools, scales are usually defined by their instructors. While 38% believe that the use of scale depends on the degree of details for the work required.

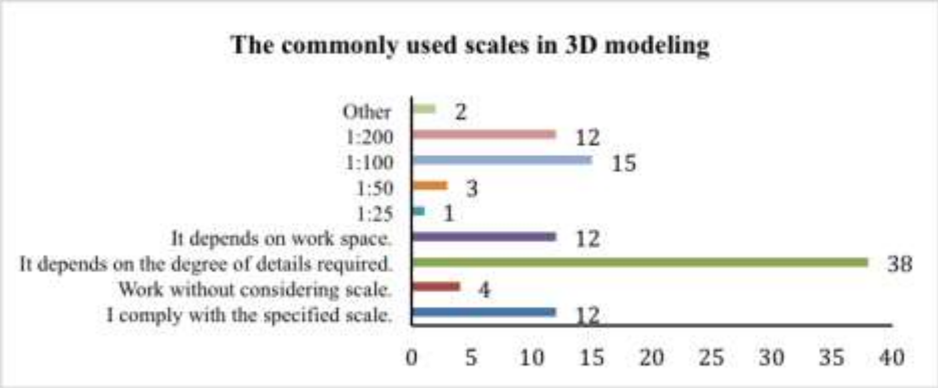

Figure 5.21. The commonly used scales in 3D modeling.

On the other hand, 46% of the participants stated that they tend to work in different scales when they came up with the main idea of their design, and this is the highest percentage among other selections. 24% usually tend to work in different scale at the detailing stage.

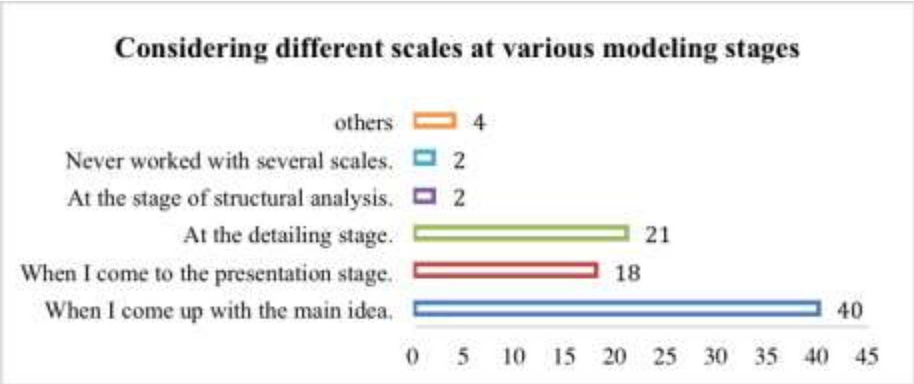

Figure 5.22. Considering different scales at various modeling stages.

Time is another issue in model-making and 3D modeling. Based on the questionnaire survey we see that 43% mostly finish their models on time, and 54% declared that they usually need more time, whereas only 3% believed they usually finish in less time.

The ideal working environment for a student or architect in which they prefer to make their models was also investigated in the survey. 65% of the participants like to listen to music while making their models while 25% preferred quiet (Figure.5.23)

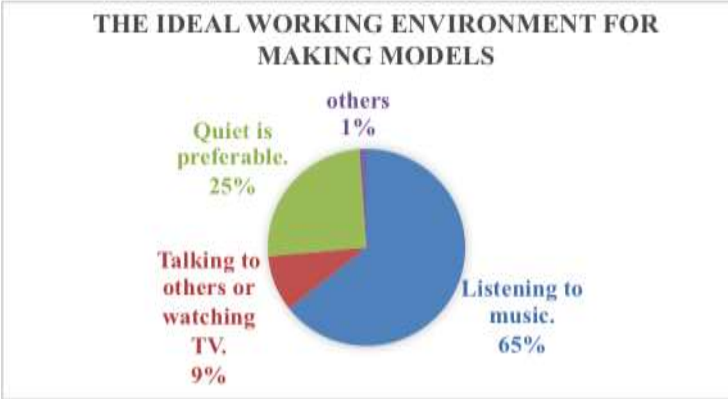

Figure 5.23. The ideal working environment for making models

In the questionnaire survey, students were also asked to choose between making their models in home or school and give reasons for their selections 55% of the 87 participants, always prefer to make their models at home rather than at school, 23% usually make at home, 16% sometimes at home and 6% in school. The reasons for their choices are given in Figure 5.24 as no disturbance (63%), the availability of equipment (12%), and materials (10%), and for other reasons (15%) such as; preference for working late at night, being away from curious people, or feeling more comfortable and free at home**.**

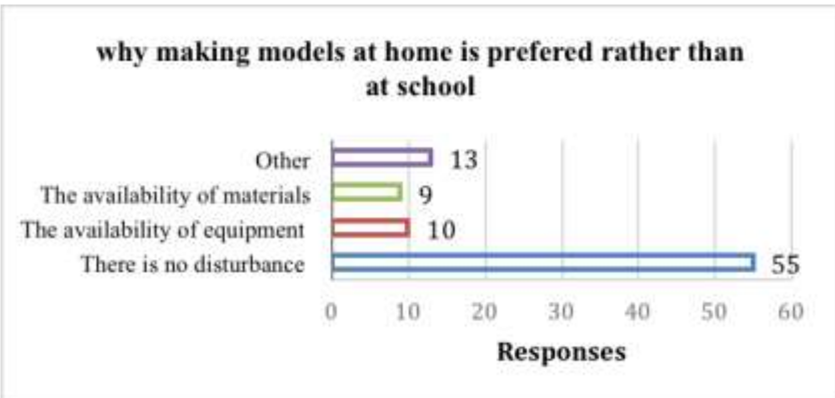

Figure 5.24. Why students prefer making their models at home rather than at school.

On the other hand, students who preferred making their models at school rather than home, gave the reasons as opportunity for cooperation (48%); there is more space (19%); it is quieter (4%), equipment is easily available (23%), although no one mentioned availability of materials; and 3% stated that to be near instructors & supervisors (Figure 5.25).

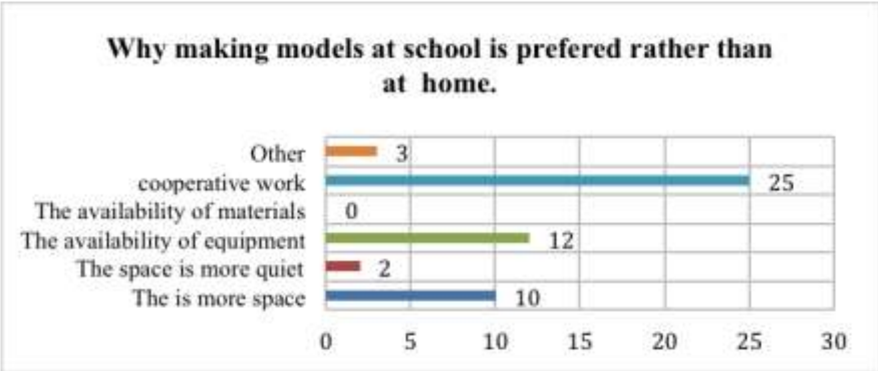

Figure 5.25. Why students prefer making their models at school rather at home.

Expense is another mentioned issue in the survey, participants were asked how often they could afford to pay for their models and the results are given in Figure 5.26. Moreover, students were asked at what point they may consider alternatives to make their models 11% may consider alternatives when the cost of materials is high, 36% when the time is limited they may consider other alternatives, and 53% stated that they usually tend to consider other alternatives when materials are not available.

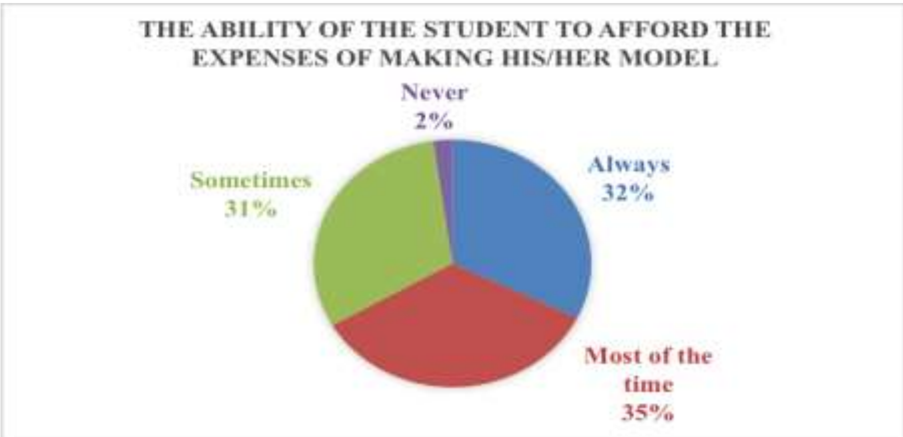

Figure 5.26. The ability of students to afford the expenses of making their models.

The amount that students usually spend on their physical models ranges from 10-15 Euro (14%) to 20-40 Euros (44%); and none elected to spend more than 500 Euros. Additionally, 73% of the students do not rely on finding free or cut-price materials, while only 27% of them do.

Regarding support provided by the institutions 71% of the participants stated that there is no support for model making practices. While those who said support was provided listed it to be workshop (10%) tools (14%), materials (1%), and financial support (3%).

When students or architects were asked, how the model contributed in project collaboration process, 2 responded 100%, 17 said 75%, 32 participants said 50%, 28 participants said 25%, and only 8 participants said the model did not contribute anything towards collaborative design**.**

For finding out whether a model has an impact on student's grades and how the model is appreciated by their instructors (or for an architect: how it is appreciated by their project directors), a few questions were allocated. When asked whether a student would have a better grade if he/she submitted a good model to the tutor. 92% agreed and only 8% disagreed. Further, when participants were asked if the instructors or project directors appreciated their models, most of them replied in the affirmative (43% said "sometimes", 33% "often", 20% "always"); only 4% believed that their models were "never" appreciated by their superiors. Furthermore, participants were asked if the models have any impact on increasing or decreasing the chance of a designer for getting the job? 77% said "Yes" and asserted that not having made a physical model would lose their chance of getting the job, while 23% believed there was no impact

Participants were also requested to state how their models were being used (students or architects). Figure 5.27 presents the responses

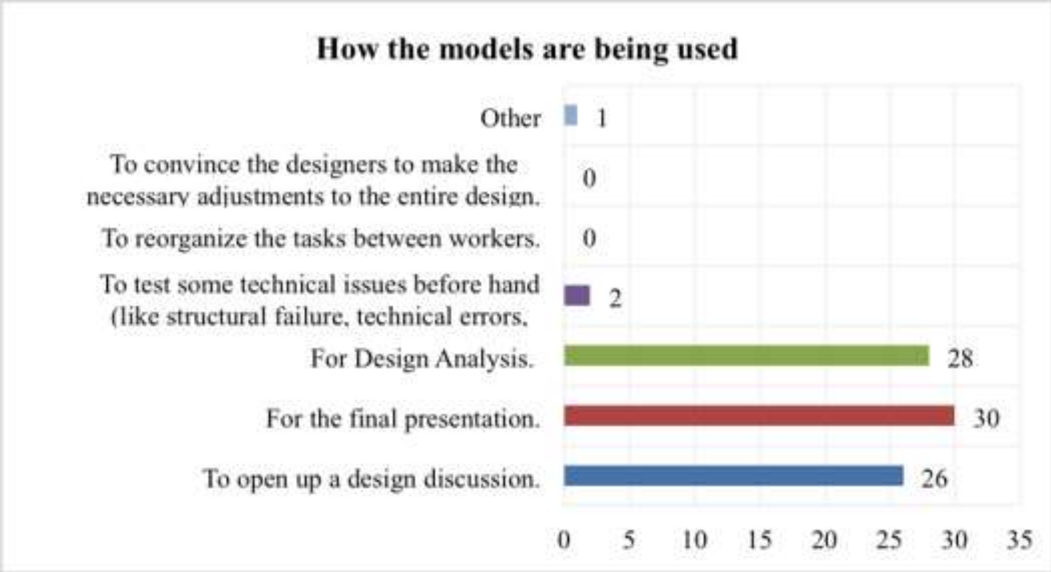

Figure 5.27. For what purpose are the models being used.

Another impact (of models) that was investigated was the usefulness of models in conveying the design idea when presenting their project model to others or in a discussion. Figure 5.28 gives data on the 5 possible responses.

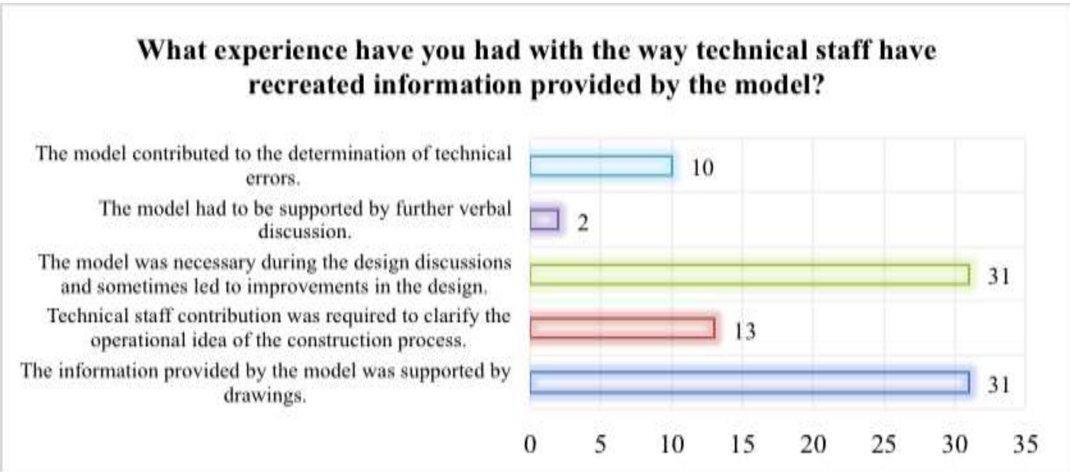

Figure 5.28. Represents what experience may a designer/student had when presenting or sharing their project model to others or in a discussion.

Finally, all participants (students and architects) were asked for how many of their projects have they made physical models. Figure 5.29 shows that almost one-third of the 87 participants had made physical models for 75% of their projects, and only a few bothered to make models for all of their projects.

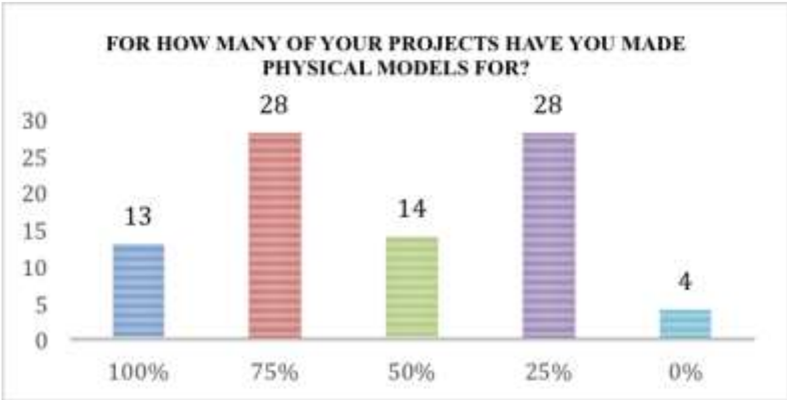

Figure 5.29. Represents what experience may a designer/student had when presenting or sharing their project model to others or in a discussion.

5.2.3 Data on University Grades

As part of the research materials, students' grades for the three universities have been collected; namely, the Middle East Technical University in Ankara (national), University of Benghazi (International) and Elmergib University (International) in Homs, Libya. A random selection of students from these universities was made, i.e. 133 students from METU, 146 students from University of Benghazi, 143 students from Elmergib University. For all the mentioned students, their grades were collected and their performance was evaluated based on the design studio courses grades, building science courses grades, CGPA, and modeling skills (raw data are in Appendixes D, E and F). Since the focus of this study is to find out the impacts of models on education and the learning outcomes of students in architecture, a correlation analysis is made between the obtained data. To illustrate, correlation between design studio grades versus building science course grades; design studio grades versus student's modeling skills; building science grades versus student's modeling skills, etc.

5.2.3.1 Analysis of the Middle East Technical University Data

For both groups of courses, the sorted grades are for 133 students. These courses are listed in Tables D1 and D2 in Appendix D while detailed data for the students' course grades are presented in Appendix D. It should be noted that any grades left empty in the sorted data means that this student has not taken the course yet, this is applicable to all the collected data for the three universities unless otherwise specified.

- **Design studio grades vs Building Science grades**

In the case of METU students, there is a moderate positive correlation between the Design studio and building science courses, that is; The value of **"R"** (linear correlations) is **0.5785** which means there is a tendency for students with higher design studio grades to score higher building science grades (and vice versa); although the coefficient of determination, $\mathbf{R^2}$ is only **0.33469** (Figure 5.30).

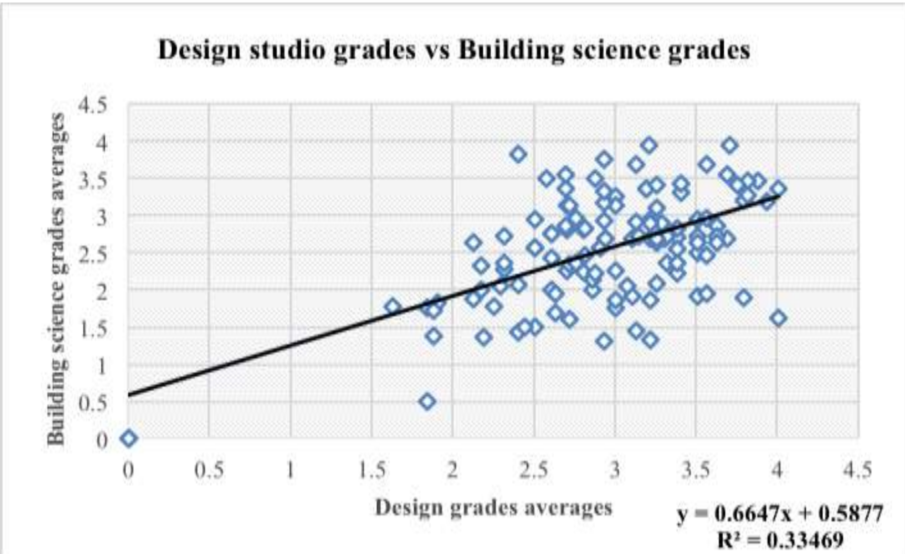

Figure 5.30. Correlation coefficient between design studios grades vs building science grades of METU's students.

- **Evaluation of Modeling skills**

For the evaluation of students modeling skills 24 students from METU were randomly selected and their project models were photographed. The photographed models for each of the selected students were presented and evaluated by foreign instructors in Elmergib University, this is to ovoid bias. Photographs of these models were classified and sorted into individual and coded slides. Each students work took more than one slide to present for the evaluation; the following Figure 5.31 contains only one photograph from each model. Other photographs of the students' models and classification can be found in Appendix (D7-D12).

Figure 5.31. Photographs of students' models that involved in the modeling skills. More details about the presented models can be checked in Appendix (D7-D12).

The evaluation by three Elmergib University instructors was done according to ten main categories, namely:

- Composition & typology
- Selection of materials
- Status of the model in the site
- Relationship with neighbourhood
- Expression

- Scale
- Precision & accuracy
- Fairness of workshop (finishing)
- Spatiality (sense of space)
- Structure stability

Each category was evaluated on a maximum of 10 points and then totalled to get an overall grade over 100 for the student. These grades are presented in Tables D4-D6 in Appendix D. The average of the three instructors' grade was obtained over 10 points, which represented the degree of modelling skills of the student. These averages are given in Table 5.3 below.

Table 5.3: METU students' modelling skills evaluated by three instructors from Elmegrib University in Libyan (Inst-A1/Inst-A2/Inst-A3)

Model-code	Instructor-A1	Instructor-A2	Instructor-A3	Average Evaluation (max 10 points)
ST-1	4.2	4.2	4.35	4.25
ST-2	6.7	6.85	7.05	6.87
ST-3	5.5	4.5	4.35	4.78
ST-4	4.1	4.3	4.2	4.20
ST-5	5	4.75	5	4.97
ST-6	4	3.9	4	3.97
ST-7	7.4	7.2	7.45	7.35
ST-8	7.3	7.3	7.3	7.30
ST-9	4.85	4.6	4.75	4.73
ST-10	7.2	7.3	7.3	7.27
ST-11	7	7.4	6.95	7.17
ST-12	6.7	6.95	6.7	6.78
ST-13	4.2	3.95	4.15	4.10
ST-14	5.15	4.65	5.2	5.00
ST-15	4.55	3.9	4.6	4.35
ST-16	7.05	7.1	7.15	7.10
ST-17	7.3	7.4	7.25	7.37
ST-18	7.3	7.4	7.3	7.33
ST-19	7.55	7.5	7.5	7.57
ST-20	6.9	7.2	6.95	7.02
ST-21	4.05	3.9	4.1	4.02
ST-22	7.3	7.3	7.3	7.30
ST-23	4.85	4.3	4.8	4.65
ST-24	4.4	4.2	4.3	4.30

- **Modeling skills grades vs Building science grades**

The above-mentioned tables given in Appendix represent the evaluation criteria for the METU students. These tables also presented the factors suggested by the three tutors to evaluate the students' modeling skills. Table 5.3 represents the average evaluation by the three instructors to avoid bias in the assessment of the students' models. The value of **"R"** (linear correlations) is **0.5861.** This is a positive correlation, which means that when modeling skills improve building science grades also improve (and vice versa). The value of **"R^2"**, the coefficient of determination, is **0.3436** (Figure 5.32).

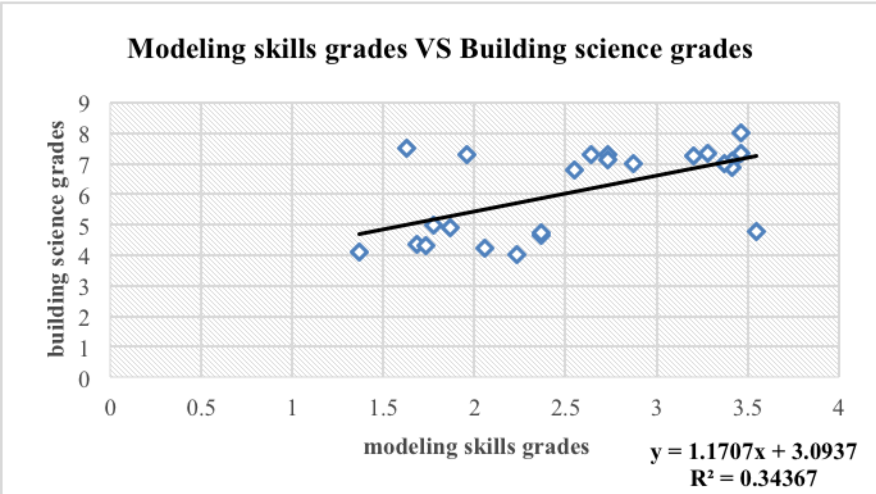

Figure 5.32. Correlation coefficient between modeling skills vs building science grades of METU's students.

- **Modeling skills grades VS Design studio grades**

The value of **R** (linear correlations) is **0.8569**. Apparently, when a correlation is made between two practical courses grades a strong positive correlation is obtained, which mean that high modeling skills scores go with high design studio grades (and vice versa). The value of "R^2", the coefficient of determination, is **0.7343** (Figure 5.33).

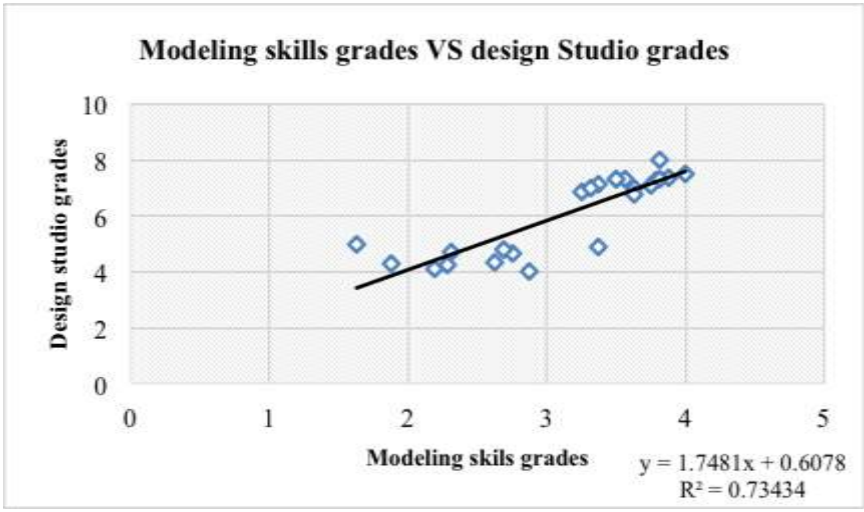

Figure 5.33. Correlation coefficient between modeling skills VS design studio grades of METU's students.

- **Modeling skills vs CGPA**

The scatter chart below represents the value of **R** (linear correlations) as **0.7932**. This is a strong positive correlation, which means that high modeling skills grades go with high CGPA (and vice versa). The value of "$\mathbf{R^2}$", the coefficient of determination, is **0.6292**. (Figure 5.34)

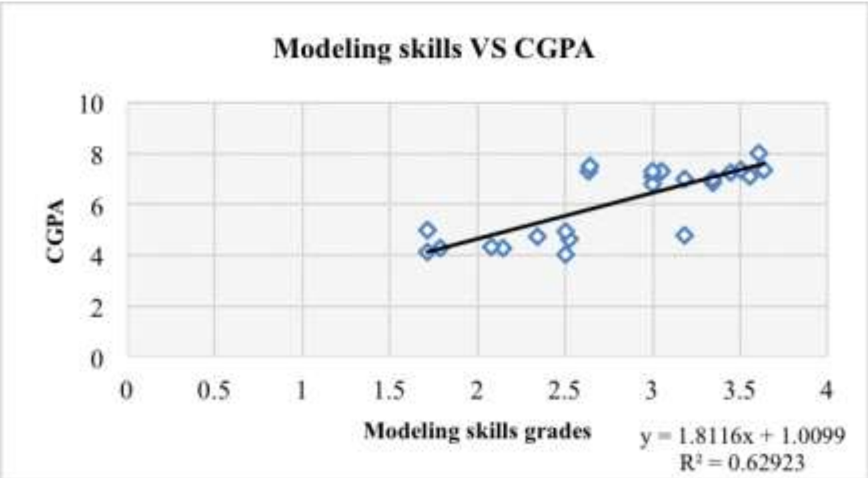

Figure 5.34. Correlation coefficient between modeling skills VS CGPA of METU's students.

Modeling skills grades are also correlated with other courses grades such as structural design, professional practice and environmental design courses. Accordingly, these courses grades showed hardly any correlation with modeling skills grades, thus they are excluded from this section. However, for further details scatter charts can be found in Appendix (D13-D15).

5.2.3.2 Analysis of University of Benghazi Data:

For the University of Benghazi's students the raw data is given in Appendix E and the tables present the university courses accompanied with their codes (Tables E1 & E2). The listed courses are used for the correlation analysis to identify the relationships between architectural design studio grades and building science grades for each of the identified student samples.

Due to the circumstances of Libyan conflict, specifically in Benghazi city, it was not possible to obtain the grades for all the students. Therefore, data on only for those students who were already enrolled in the experimental design studio course and had taken the courses listed in the table were included in the analysis (Appendix E3-E5).

- **Design studio grades VS Building Science grades**

The value of **R** (linear correlations) is **0.7734**. This is a strong positive correlation between design studio GPA and building science GPA, which means that high building science GPA scores go with high design studio GPA (and vice versa). The value of $\mathbf{R^2}$, the coefficient of determination, is **0.5981** (Figure 5.35). Raw data presents the list of students' grades for both courses can be found in Appendix E10.

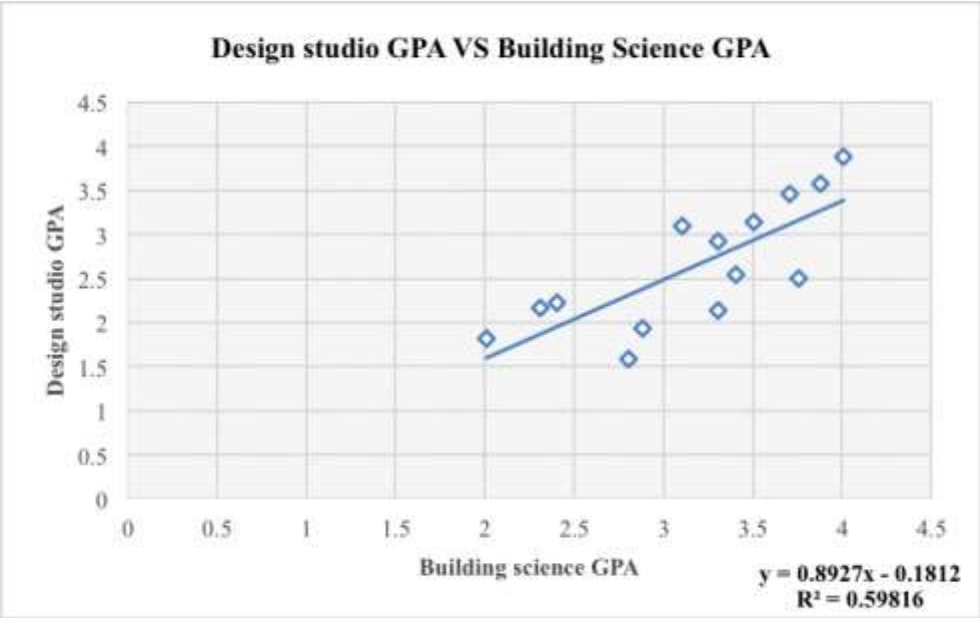

Figure 5.35. Correlation coefficient between design studio GPA VS building science GPA for the students of Benghazi University.

- **Evaluation of Modeling skills**

As in the case of METU students, photographs of the students' models were classified and coded for each student individually. It should be noted that, the 20 students here are those who were enrolled in the experimental studio course proposed in the research methodology. The same instructors who evaluated the work of METU's students evaluated these students modeling skills based on the same assessment criteria (Appendix E6-E9). The models photographs presented in (Figure 5.36) are just a small sample; more details can be followed in Appendix E10-E16.

Figure 5.36. A sample of physical models made by3rd year students of Benghazi University, whose modeling skills were evaluated.

Table 5.4: Modeling skills of Benghazi University students evaluated by three instructors from Elmegrib University and graded.

model-code	Inst-B1 AVG	Inst-B2 AVG	Inst-B3 AVG	Overall (AVERAGE)
ST-1	7.11	6.33	11.05	**8.16**
ST-2	6.66	5.77	5.72	**6.05**
ST-3	6.33	6.66	6.66	**6.55**
ST-4	7.66	7	7.11	**7.26**
ST-5	5.61	4.77	5.27	5.22
ST-6	6.61	6	6.22	**6.28**
ST-7	6.5	6.44	5.88	**6.27**
ST-8	6.55	6.22	6.38	**6.38**
ST-9	5.27	4.66	4.83	4.92
ST-10	6.66	6.05	6	**6.24**
ST-11	6	5.77	5.27	5.68
ST-12	8	7.94	7.16	**7.7**
ST-13	6.05	6.61	6.16	**6.27**
ST-14	6	5.55	5.11	5.55
ST-15	6.33	5.94	5.16	5.81
ST-16	4.77	5	4.5	4.76
ST-17	5.22	5	4.61	4.94
ST-18	6.22	5.83	5.72	5.92
ST-19	5.55	5.11	4.88	5.18
ST-20	7	6.77	5.88	**6.55**

- **Modeling Skills Grades VS Building Science Grades**

In this analysis, the students coded ST-16, ST-6, ST-4, ST-10, SR-15, and ST-18 were excluded from the analysis because their building science grades and GPA could not be obtained due to the unstable conditions in the country. However, for the rest of the sorted students' grades, the relationship between modeling skills and building science grades identified as a positive correlation with linear correlations value (**R**) equal **0.5829**. Figure 5.37

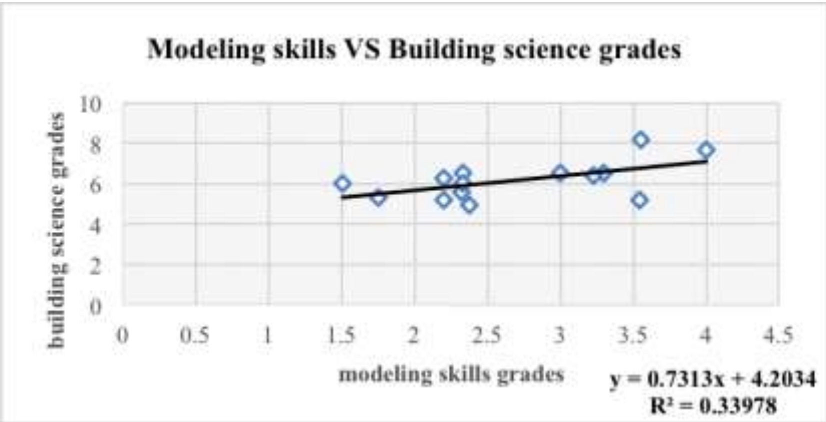

Figure 5.37. Correlation coefficient between modeling skills GPA VS building science GPA for the students of Benghazi University.

- **Modeling Skills Grades VS Design Studio GPA**

This analysis was made particularly for the students who were already enrolled in the research design method (proposed experimental studio course). Students design studio GPA before they enrolled in the study design studio method are correlated with their modeling skills. Then design studio GPA for all the enrolled students in the study are correlated with their modeling skills grades to find out if there are any changes (decrease/increase).

In this analysis the student coded "ST-18" is excluded, as his previous design grades are not available, so only 19 students are involved in this analysis. Accordingly, the value of **R** (linear correlations) is **0.4258**. Although, technically a positive correlation exists between modeling skills GPA and design studio GPA (before taking the proposed design studio course) it is identified as weak (the nearer the value is to zero, the weaker the relationship). The value of $\mathbf{R^2}$, the coefficient of determination, is **0.1813** (Figure 5.38). (from Appendix E Tables E11 and Table E12)

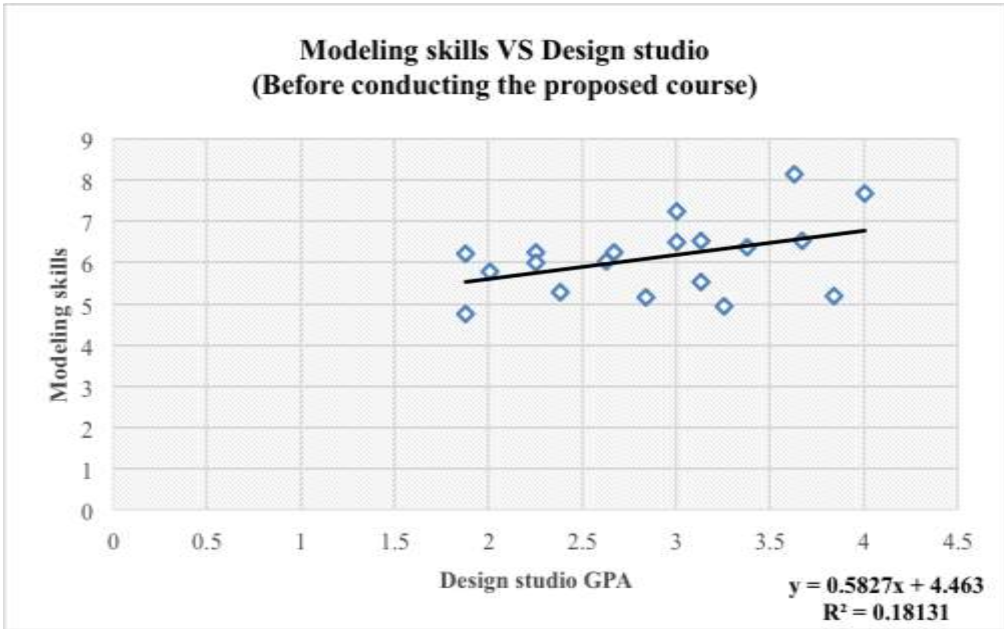

Figure 5.38. Correlation coefficient between modeling skills GPA VS design studio GPA before conducting the proposed design studio for the students of Benghazi University.

Figure 5.39 shows that a positive correlation exists between the modeling skills GPA and design studio GPA (the GPA including the experimental studio course grades) it is also identified as weak even though a slight increase in the linear correlation has been detected, about (**0.0586)**

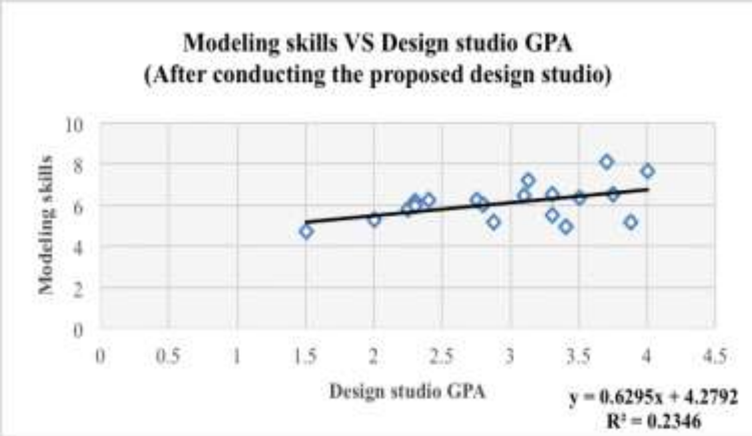

Figure 5.39. Correlation coefficient between modeling skills GPA VS design studio GPA after conducting the proposed design studio for the students of Benghazi University.

- **Modeling skills vs the experimental design studio course (AC311)**

For the 20 students who were enrolled in the proposed design studio course, the average for only three stages evaluation was considered, as due to the uncontrollable circumstances in the city the courses could not be continued. The obtained grades are converted to decimal numeric so that they can be sorted and correlated with modeling skills grades. Figure 5.40 presents the scatter plot between modeling skills and proposed studio course (AC311) which is quite weak. But since this course was not completed we cannot predict the final correlation value. (Data in Appendix Table E13).

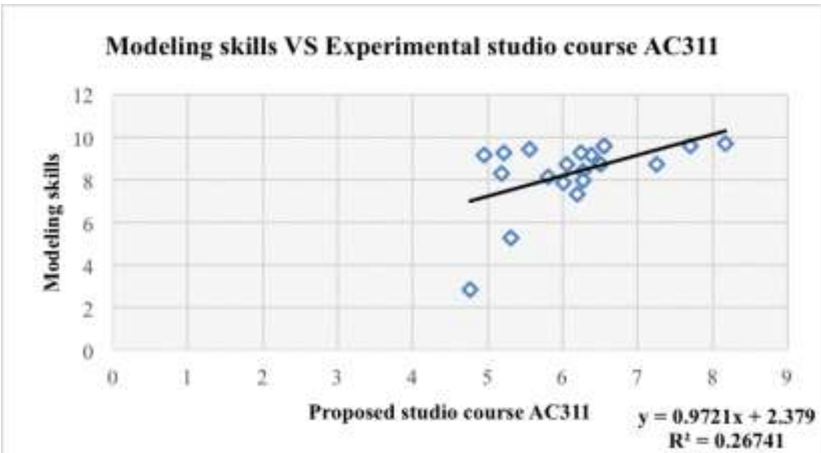

Figure 5.40. Correlation coefficient between modeling skills GPA VS proposed studio course (AC311) for the students of Benghazi University.

- **Modeling Skills VS Modeling course (AC162)**

Since not all the students had taken the course (AC162) which has a module on model making, correlation are made only among students who taken it (17 students out of 20). The value of linear correlation (**R**) is **0.3803**. Although we observe a positive relationship between modeling skills grades and modeling course grades (AC162) it is identified a weak relationship. Raw data table is presented in Appendix Table E14.

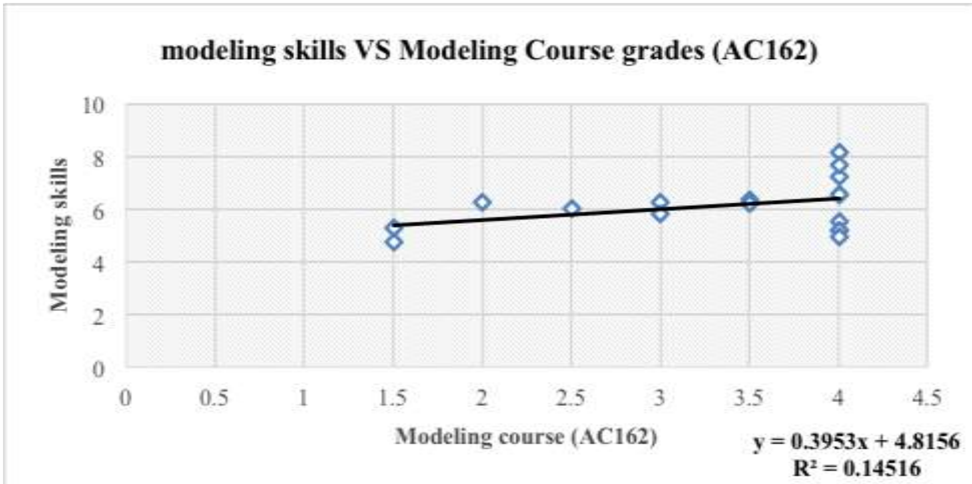

Figure 5.41. Correlation coefficient between modeling skills grades VS modeling course grades (AC162) for the students of Benghazi University.

Modeling skills grades are also correlated with other courses grades such as Architectural Expression (I & II) and Properties of Materials (I). Accordingly, the correlation analysis indicated that these courses do not have any correlation with the modeling skills grades. Thus they are excluded from this section; the related charts are included in Appendix (Tables E16 and E11; Figures E17 and E18)

5.2.3.3. Analysis of Elmergib University Data

Grades of 143 randomly selected students from different levels (1st, 2nd, 3rd and 4th year students) for design studio courses and building science courses were obtained from the university administration. These data were sorted according to student ID numbers, name & surname, instructors' comments, notes, coding for the students who are already enrolled in the proposed experimental studio course, references of information, gender, nationality, CGPA, GPA, design studio courses, modeling courses, building science courses, design studio GPA before and after the enrollment of the students in the proposed studio course and dates in which all the courses where taken. The data were then checked for correlation between design studio and building science courses, modeling skills. (More details about the collected numerical data can be followed in Appendix F (Table F1-F5).

- **Design studio GPA VS Building Science GPA**

Design studio and building science grades' averages are calculated and sorted for all the 143 students. A correlation analysis is conducted to find out if there is any relationship between design studio and building science courses of only 140 students grades because 3 out of 143 students had not registered for any design courses. (More details about the collected numerical data can be followed from Appendix F

Figure 5.42 shows that the value of linear correlation between design studio GPA and building science GPA of (**R**) is **0.6178**. This is a positive correlation, which means there is a tendency for higher design studio GPA scores goes with high building science GPA scores.

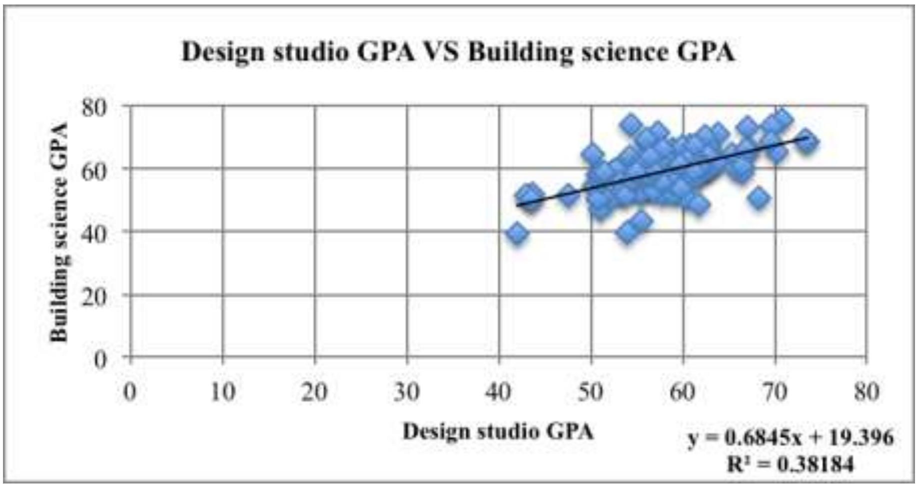

Figure 5.42. Correlation coefficient between design studio GPA VS building science GPA for the students of Elmergib University.

- **Design studio GPA VS Modeling skills:**

Among the 143 students 32 were already enrolled in the experimental design studio course proposed in the research method. Accordingly, as these students have already been followed and their projects and models are photographed and evaluated, their modeling skills are also evaluated according to their performance and submitted models for the proposed studio course. Therefore, as it is not possible to perform modeling skills evaluation for all the 143 students, the analysis are performed only for the 32 enrolled students with their other grades and GPA (Table 5.5). The students' modeling skills evaluation criteria can be followed in (Appendix F6-F21) Samples of the students models' photographs are indicted in (Figure 5.43), more details about the models and the projects are included in appendix Figures F1-F32.

Figure 5.43. Physical models photographs of Elmergib University students whose modeling skills are evaluated based on their submitted models for the research conducted studio course.

Note: Since modeling skills grades are going to take a major part in the analysis, these grades are made out of 10 as an overall for every evaluated student. However, based on Elmergib University information system, all students' grades are given as a percentage. Therefore, the modeling skills grades have been converted into a percentage to make them compatible with other data. It should be noted that one of the students (ST-3-AR417) enrolled at the beginning of the design studio AR417, was dismissed because he had exceeded absence limit.

Table 5.5: Classification of grades for the 32 Elmergib University students enrolled in the Experimental design studio course and their modelling skills evaluated by three instructors from their University .

No	**Sample code**	**modeling skills (max.10)**	**modeling skills (max 100)**	**Design GPA (excluding Experimental Studio grades)**	**Design CGPA (including Experimental Studio grades)**
1	**ST-5**	6.07	60.7	**56.00**	**58.75**
2	**ST-1**	6.61	66.1	**58.67**	**61.86**
3	**ST-5**	7.235	72.35	**56.33**	**61.29**
4	**ST-3**	0	0	**52.50**	**45.00**
5	**ST-4**	6.51	65.1	**70.83**	**72.57**
6	**ST-7**	5.36	53.6	**55.67**	**57.14**
7	**ST-2**	5.856	58.56	**63.83**	**66.29**
8	**ST-6**	5.845	58.45	**60.83**	**63.00**
9	**ST-15**	4.96	49.6	**56.86**	**57.63**
10	**ST-12**	5.75	57.5	**59.00**	**59.75**
11	**ST-16**	5.168	51.68	**58.14**	**58.50**
12	**ST-6**	5.543	55.43	**58.00**	**59.38**
13	**ST-4**	8.668	86.68	**66.86**	**70.13**
14	**ST-2**	5.735	57.35	**61.71**	**62.38**
15	**ST-7**	6.248	62.48	**62.57**	**64.00**
16	**ST-3**	6.316	63.16	**65.29**	**66.25**
17	**ST-10**	4.25	42.5	**58.86**	**59.13**
18	**ST-9**	5.915	59.15	**57.42**	**59.75**
19	**ST-1**	7.988	79.88	**69.71**	**71.88**
20	**ST-13**	6.263	62.63	**61.71**	**62.50**
21	**ST-14**	6.238	62.38	**60.57**	**62.50**
22	**ST-11**	6.93	69.3	**66.43**	**68.00**
23	**ST-8**	6.39	63.9	**60.57**	**62.88**
24	**ST-5**	6.86	68.6	**62.50**	**65.40**
25	**ST-6**	6.62	66.2	**67.00**	**69.00**
26	**ST-8**	6.88	68.8	**56.00**	**60.40**
27	**ST-7**	7.34	73.4	**60.75**	**65.00**
28	**ST-9**	7.12	71.2	**59.00**	**61.80**
29	**ST-1**	4.39	43.9	**54.75**	**56.60**
30	**ST-2**	7.04	70.4	**63.75**	**66.40**
31	**ST-3**	6.177	61.77	**60.25**	**62.80**
32	**ST-4**	6.763	67.63	**58.50**	**62.20**

- **Design studio GPA (before and after conducting the proposed design studio course) VS Modeling skills**

The value of linear correlation (R) between modeling skills GPA and design studio GPA before conducting the proposed studio course is **0.5259**. This represents a positive correlation (Figure 5.44). This shows a weaker relationship compared with the value of (R) obtained when correlating modeling skills with building science GPA.

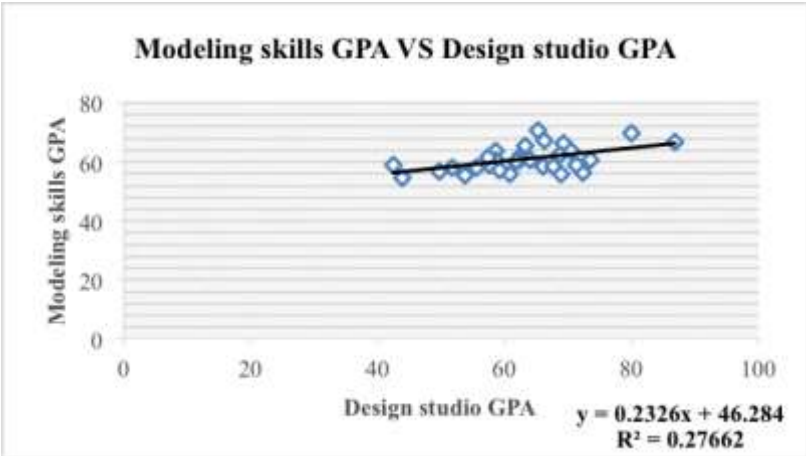

Figure 5.44 Correlation between modeling skills GPA VS design studio GPA before conducting the experimental studio course for the students of Elmergib University.

The value of linear correlation (R) between modeling skills GPA and design studio GPA after conducting the experimental studio course is **0.7021**. This correlation is higher than before and therefore an indication of a relationship between the better modeling skills and better design grades (Figure 5.45)

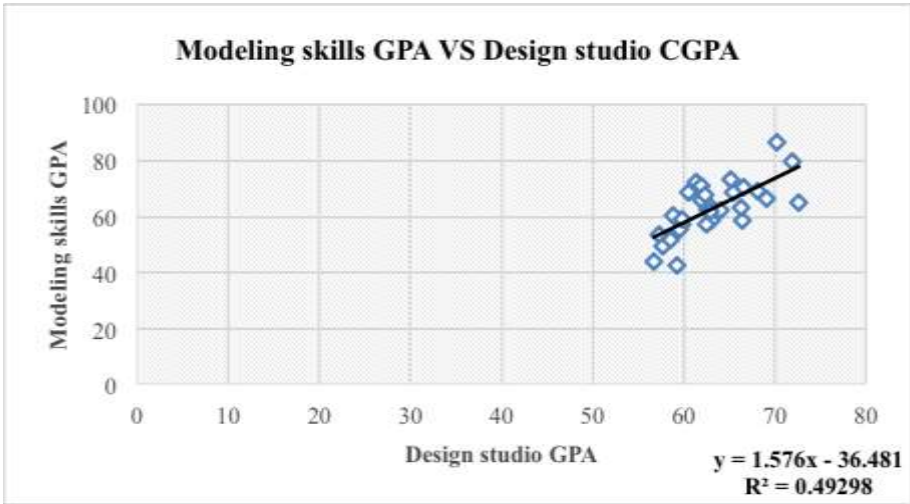

Figure 5.45. Correlation coefficient between modeling skills GPA VS design studio GPA after conducting the proposed studio course for the students of Elmergib University.

- **Modeling Skills VS Experimental studio course (AR315/417/518)**

The grades of the three groups AR315, AR417 and AR518 enrolled in the proposed design studio course are individually correlated with their modeling skills grades. The modeling skills of these students were evaluated during the proposed course. Therefore; it is necessary to find out the impacts of the students' modeling skills on their final grades. Accordingly, the modeling skills of the students are correlated with their final design studio grades for the three mentioned groups (Figure 5.46).

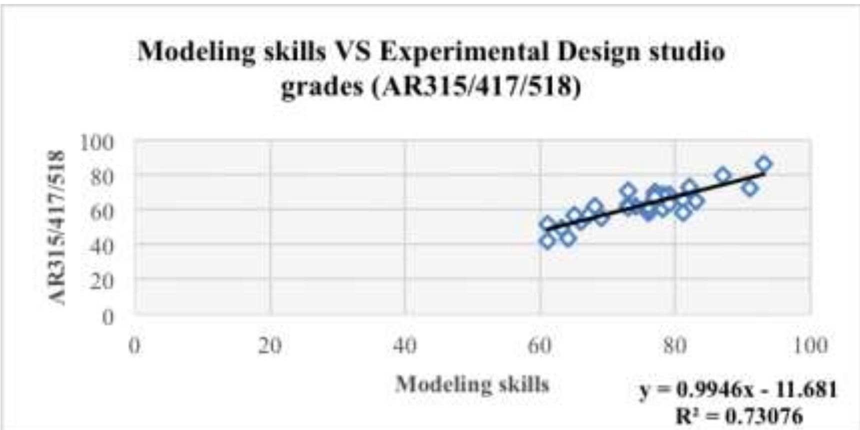

Figure 5.46 Correlation coefficient between modeling skills grades VS proposed design studios AR315/417/518 for the students of Elmergib University.

The value of linear correlation (R) is **0.8548.** Apparently, this is a strong positive correlation, which means that high modeling skills scores go with high (AR315/417/518) design scores (and vice versa). The value of $\mathbf{R^2}$, the coefficient of determination, is **0.7307.** This means that the performance of the students in design studio has improved, and the students modeling skills as well. Furthermore, Table 5.6 below represents all the coded samples enrolled students with each sample's code.

Table 5.6. The sorted design and modeling skills grades are for all students enrolled in the Experimental Studio course (AR315/AR417/AR518)

No	Sample Code	Course code	Design studio grades	Modeling skills
1	ST-5	AR518	78	60.7
2	ST-1	AR417	81	66.1
3	ST-5	AR417	91	72.35
4	ST-4	AR417	83	65.1
5	ST-7	AR417	66	53.6
6	ST-2	AR417	81	58.56
7	ST-6	AR417	76	58.45
8	ST-15	AR518	63	49.6
9	ST-12	AR518	65	57.5
10	ST-16	AR518	61	51.68
11	ST-6	AR518	69	55.43
12	ST-4	AR518	93	86.68
13	ST-2	AR518	67	57.35
14	ST-7	AR518	74	62.48
15	ST-3	AR518	73	63.16
16	ST-10	AR518	61	42.5
17	ST-9	AR518	76	59.15
18	ST-1	AR518	87	79.88
29	ST-13	AR518	68	62.63
20	ST-14	AR518	76	62.38
21	ST-11	AR518	79	69.3
22	ST-8	AR518	79	63.9
23	ST-5	AR315	77	68.6
24	ST-6	AR315	77	66.2
25	ST-8	AR315	78	68.8
26	ST-7	AR315	82	73.4
27	ST-9	AR315	73	71.2
28	ST-1/	AR315	64	43.9
29	ST-2	AR315	77	70.4
30	ST-3	AR315	73	61.77
31	ST-4	AR315	77	67.63

- **Modeling skills vs Building Science courses**

Building science grades for the 31 students who are enrolled in the experimental design studio course are also correlated with their modeling skills grades. The value of linear correlation (**R**) between building science courses GPA and modeling skills GPA is **0.3785**. Although this value reflects a positive correlation, the relationship between them is weak (the nearer the value is to zero, the weaker the relationship). The value of $\mathbf{R^2}$, the coefficient of determination, is **0.1433** (Figure 5.47 and data in Appendix F22).

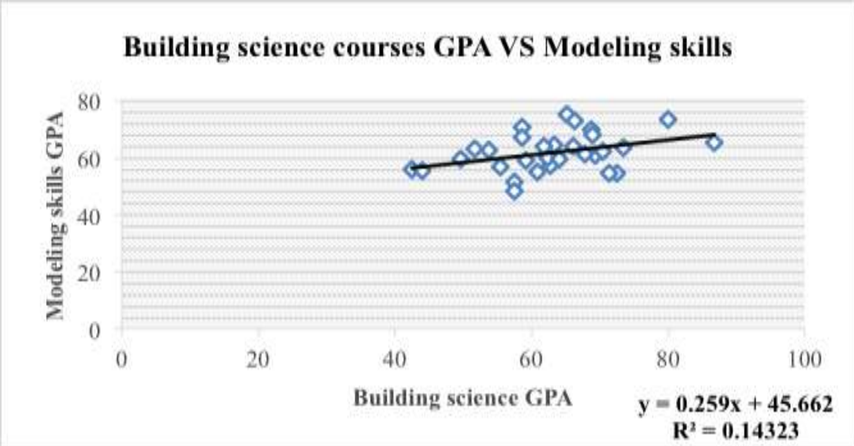

Figure 5.47 Correlation coefficient between building science courses GPA VS modeling skills grades GPA for the students of Elmergib University.

- **Modeling skills VS CGPA**

The aim was also to find out the impact of modeling skills on the cumulative GPA for students, and the value of linear correlation (R) is found to be **0.5517**, which indicates a positive correlation. (Figure 5.48 and data in Appendix F23).

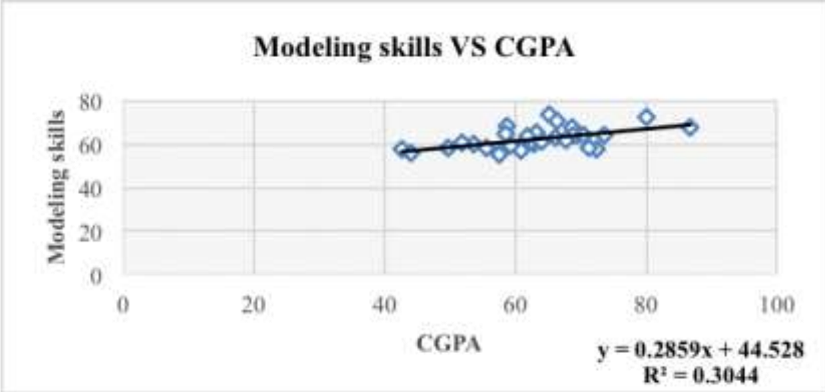

Figure 5.48 Correlation coefficient between modeling skills GPA VS CGPA for the students of Elmergib University.

Modeling skills VS Other Courses

Among the 32 students whose modeling skills were evaluated, their modeling grades were checked for any relationship against the other course groups also; (related charts are included in Appendix (F24, F35, F25, F36, F26, F37, F27, F38, F28, and F39). the results are listed as follows:

- Modeling skills grades were plotted against the **Basic Model-making** course (AR214) that had already been taken by 14 students; no correlation existed.
- Modeling skills grades were plotted against the **Building Construction** courses (AR221, AR222, AR323 and AR324); but no correlation existed. Table F25 in Appendix F lists the grades for the 22 students who already taken the courses.
- Modeling skills grades were plotted against the **Implementation drawing** courses (AR425, AR426) that had already been taken by the students; no correlation existed.
- Modeling skills grades were plotted against the environmental control course (AR490) that had already been taken by 15 students; no correlation existed.
- Modeling skills grades were plotted against the **Building materials** course (AR224) that had already been taken by 30 students; no correlation existed.

5.3. Professional domain

Twelve architects from various countries (1 from Turkey, 2 from United States, and 9 from Libya) filled the general questionnaire regarding model making (Appendix C) & (Appendix G1) five were interviewed. Since some of the architects were abroad, interviews were conducted either face-to-face or over Skype. The following are the answers to questions posed in the survey:

5.3.1. Data related to the Importance of models:

- The respondees were asked why a designer should make a model. 7 out of 12 architects indicated that a model should be used “As a tool to work out ideas”, while 5 architects allocated the use of model as “A means of presenting/representing ideas/visualization”. This reflects the necessity and importance of using the architectural model to generate ideas rather than just representing what is already visible to the designer.
- Participants were also asked about their preferred modeling technique for making their design, 3 out of 12 preferred using Digital technology (Rapid prototyping), whereas 4 preferred the use of Hand-made (Manual techniques). It is noticed that the manual techniques are slightly more popular compared to the use of digital technology (Figure 5.49). This may be an indication of the importance of the direct relationship between the designer and his idea through physical productivity.
- Regarding the question whether models have contributed in project collaboration process; 6 out of 12 architects stated that their models contributed by at least 50% in project collaboration process, whereas 4 indicated that their models contributed 75% and 1 architect declared a 100% contribution; none of the respondees mentioned any negative impact of the models in the project collaboration process (Figure 5.50).

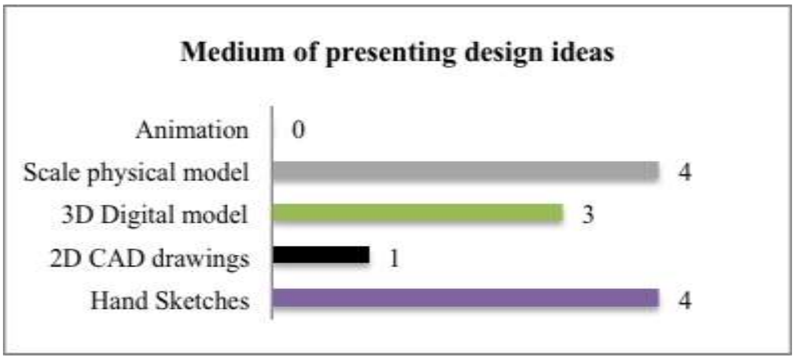

Figure 5.49. Medium of presenting design ideas.

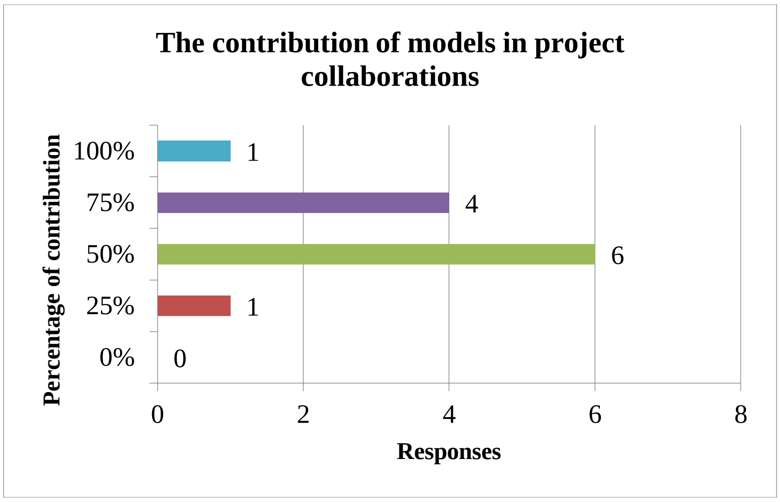

Figure 5.50. The contribution of models in project collaborations process.

- Questionnaire responses showed that models are also appreciated by the project directors of most of the interviewed architects. Accordingly, 6 of the responses indicated that "sometimes" a model is appreciated by the directors and 3 responses for each were for "always" and "often". Moreover, most of the participants' responses implied that about 75% up to 100% of their design project were done with physical models.

5.3.2. Data related to Modeling skills

- When participants (architects) were asked how they consider themselves as model-makers, 3 out of 12 rated themselves as "bad", 1 as "very bad", 4 as "good", and 4 rated as "excellent".
- Architects were asked whether there are any aspects of model-making they

may find particularly difficult that may limit their imagination or creativity. Most of the responses (8 out of 12) stated that some of their expression possibilities become poor at certain points when they try to externalize ideas physically. Respondees also indicated that the modeling skills could influence the design approach of the designer.

- Architects responded to the question whether their design approach is influenced by their modeling skills, 7 out of 12 stated "Yes" modeling skills do have an impact on their design approach, whereas 5 thought not

5.3.3. Data related to Manual or Digital

- According to the questionnaire results and the interviewed architects, the most widely accepted techniques in starting a design idea is 2D sketching and making physical compositions, whereas the implementation of digital tools is usually left to the later stages (detailing, presentation, etc).

5.3.4. Data related to commonly used materials

- To overcome most of the modeling difficulties, wood, cardboards, foam and plastic are the commonly used materials used by many architects due to their properties, availability and pliability/ workability. According to the responses from the questionnaire and the face-to-face interviews, both types of models (handmade & digital models) have their impacts on selecting the proper and efficient building materials. It is stated that while in digital models a designer may have unlimited choices of materials to use, the efficient use of these materials only became a representative of an actual one when applied in physical production otherwise many failure may occur.

5.3.5. Data related to the impacts of 3D models in the design process

- The role of architecture models in the design process is undebated and it would be unusual to find a design project that does not include a model whether physical or digital. Accordingly, among the concerns of the study is the impact of making models on the design process. In other words, when does an architect start translating his thoughts into the third dimension. Hence, participants were asked, "When do they start modeling or working in

3D?" 9 out of 12 chose "at the beginning of the design process", where only 2 voted for "in the middle of the process" and 1 selected "The last stage of the design process" (Figure 5.51).

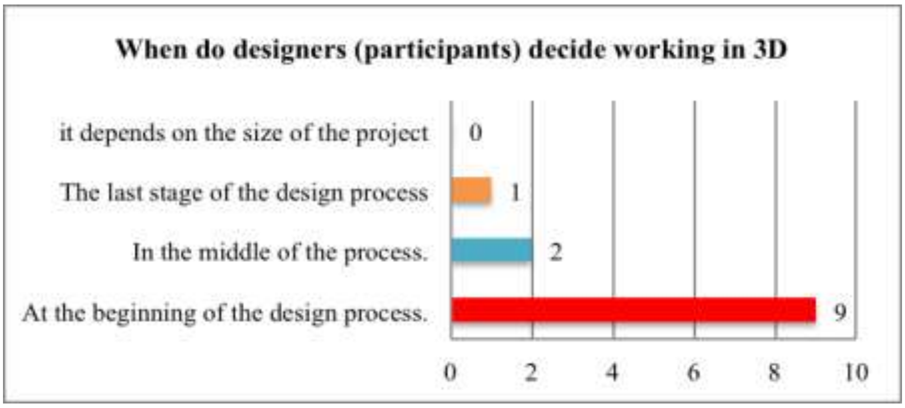

Figure 5.51. Questionnaire responses represents when designers decide working in 3D.

Furthermore, 11 of 12 the participants stated that the architectural model "contributes to the design development" (Appendix G1). Both questionnaire participants and interviewed architect appreciated the use of models in the design analysis; 10 out of 12 mentioned that they do use the model in the analysis of their design project. Among the interviewed architects, AR-3 mentioned that most his design concepts were analyzed as "structural model" for obtaining better structural solutions. Figure 5.52 shows architect (AR-3) discussing his structure idea with partners by presenting his handmade physical model. Three of the interviewed architects (AR-1, AR-3 and AR-4) believed that starting with a stable, strong and balanced form would definitely assist in obtaining a working structure and functional design. Additionally, during an interview with architect (AR-5) he stated that too many ideas are usually scattered in the designer's brain, and most of the details and concept ratios are getting lost (or forgotten) when only 2D sketching is used. Mostly losing such conceptual information cannot be retrieved (remembered) so they are lost. Hence, working directly in 3D helps to maintain every single part of "ideation & conception process". Information obtained from the interview with architects is presented in Appendix G2

Figure 5.52. Architect (AR-3) using a physical model (right) to present the structure idea of his design (left) to his team

The architects also asserted that they initiated their design approach from the site based on spatial thinking. Usually this is done by making physical mass model using cardboard or foam materials for fast and easy task manipulations, and in some cases they may tend to work on "mock-up" models. This is usually done as an ideation progresses until the main outline of the design idea is reached. Then, data collected for site location is transferred to Google SketchUP, where the form of the idea is reformed and regenerated according to the site conditions. Some of the architect (AR-3) models and projects are represented in Figures (5.53). However, other interviewed architects' models and built projects are represented Appendix H (Figures H1-H4)

In an interview with Architect (AR-2), he asserted that traditional sketching techniques (2D hand-sketches) still prevails in the design process. He believes that hand-sketches can be considered as the "alphabet" of architectural design that is hard to be dispensed with despite the obvious dominance of digital technologies. On the other hands, both (AR-1), (AR-4) believe that 2D sketching should be regarded as technical drawing rather than an artistic/professional expression. Accordingly, they asserted hand-sketches should be differentiated from “hand-crafting” in physical production, where the former can be taught in schools, while the latter is an “Innate talent” that might be improved but almost impossible to acquire in schools.

Figure 5.53. Projects & models samples of the interviewed architect (AR-3).

However, other participants who never used the model for design analysis mentioned that time was always an issue for them. Questionnaire responses showed that 9 out of 12 architects usually need more time to finish their physical model. Accordingly, making design analysis with models needs more practices and experience, so usually their designs are tested and analyzed by professional consultants. The matter of scale in the making of models is also discussed in the interview and feedbacks were also obtained from the questionnaire responses. Most of the architects stated that determining the proper scale depends on the size, design stage and type of the project. Most of them used scales ranges from 1:25, 1:50, 1:100, 1:200 and rarely 1:500 & 1:1000. It was stated that most of the time the use of scale varies according to the design stage and designers may consider working on different scales specially when they come up with the main idea (more details about the architects’ responses can be followed in Appendix G.

Expenditure on models does have an impact on the making of models. Questionnaire responses reflected different opinions about the costs of the models, which were clarified in the interview. The interviewed architects stated that the cost of the model may vary depending on priority of each design stage. To illustrate, during the 1st stages of the design process the making of compositional models may cost about 20-40 Euro and sometimes even about 100 Euro. Whereas, at later stages, i.e. when submitting final detailed models, it can costs about 500 Euro. However, this may give an indication that cost plays an important role in the making of models, but the mentioned expenses cannot be generalized, as it needs more investigations.

5.3.6. Data related to the impact of models on marketing

Based on the questionnaire results, architects were asked whether NOT having made a physical model lost their chance of getting the job? 7 out of 12 agreed that the models do have an impact on increasing or decreasing the chance of getting a job. On the other hands, 5 responses out of 12 believed that the models have no impact on the chances of getting a job.

According to four interviewed architects (AR-1, AR-3, AR-4, AR-5) it seems that architecture models do have a significant impact on architectural marketing. It is stated that while both types of models (physical & digital) increase the degree of clients' satisfactions they may vary in some certain occasions. Whereas physical models are able to reflect the real depth of the physical status of a product, digital models (rapid prototyping) have also a significant impact on the digital fabrications. To illustrate, there are some complicated details and analyses difficult to perform by using only physical models. Architect (AR-3), who worked in well-known architectural firm for many years, stated that "they never presented their design project using digital media, they always rely on hand crafted and physical models, even to their clients"

The interview also revealed that architectural models have an obvious impact in facilitating the discussion between the designer and the client. The interviewed architects stated that making various models contributed to clarifying many design ideas and solutions that may be incomprehensible for the client. Accordingly, four different types of clients are defined which may vary based on the nature and culture of the varying communities:

A) Inexperienced client: who is not aware of the basic standards, ratios, and dimensions.

B) Organized client: who has everything documented, prepared and is aware of what he needs, but he does not know how to draft them in an architectonic language.

C) Client with prior experience: this client has prior experience through previously constructed projects. He has enough knowledge to choose the right architect for his project. In short, this type can be called mature client for his possession of knowledge and expertise that enables him to distinguish between the design requirements and the design problem.

D) Client looking for a draftsman rather than a designer or architect: this kind has a predetermined concept and requirements that need only to be drawn in an architectural and engineering format.

5.3.7. Physical VS virtual models

According to the interviewed architects, 3D-object is a debatable terminology that is misjudge by many people, i.e. the differentiation between a 3D object and its representative/simulated image where the depth is missing. During the interviews, architects AR-1, AR3, and AR-5 stated that working on a computer screen does NOT give a sense of the third dimension, especially during the time of the design itself. This is because most of the focus is done through 2D planes rather than embodied 3d objects. Architect (AR-1) believed that his sense of the third dimension occurs on the site where the reality of physical interaction can be felt and evaluated. He mentioned that most of the time a designer proposes some certain ratios and proportions for some design elements which may looks fine on the paper, but when it comes to reality these elements usually have to be redesigned. That is why usually he tends to work on mock-up models, especially when working on interior spaces. Other interviewed architect (AR-3 & AR-5) agreed with AR-1 in that “presence” should be considered even though it is not the most crucial factor to define and determine the 3D characteristics of any form.

Despite his vast experience in the field of graphic design and the implementation of digital software, one architect (AR-5) stated that his design approach usually starts by making various isometric drawings. He asserted that "isometric, is far more logical to be determined as a 3D representation due to its real scale and numerical dimensions of every single part of the drawn idea" (unlike perspective). He added that digital software is generally used to represent or modify what is already created. Architect (AR-5) along with (AR-1) stated that any computer programs or graphic software could only be regarded as tools for drawing and translating sketches and design data to a numerical language. Thus it cannot be considered as a way to think and design. Accordingly, it is believed that digital tools are implemented to translate ideas to ordinary people and technical staff, but not for the designer to understand his own idea. Most of the interviewed architect agreed that working by hands or manual conceptualizing (in design) often comes out with an incomprehensible language to others, but it has a clear and definite reference in the designer's mind. Despite the clear dominance of digital technology on the production of today's architecture, it seems that the handcrafting still has a significant impact in determining the essence of the design concept. To sum up, for obtaining more accurate results on determining the effectiveness of both modeling techniques on the creation of design ideas, more experimental studies should be dedicated and conducted.

5.4. Concluding Remarks

In public domains, the issue of identifying the impacts of the models on visitors (public) as an absolute value that can be measured was one of the challenges faced this study. On the one hand, none of the acquired statistical data could determine a reasonable increase or decrease in the number of visitors by the representative models in miniaturk. However, it was only based on the interview survey results that the impacts of models on public became much more definable (from the most chosen models) than the statistics obtained from the ministry. From the frequency of selection and definite/indefinite plans to visit it becomes possible to determine the degree of certainty among the visitors who made their plans to visit the real building, after having seen the models.

Accordingly, such certainty is an indication of the extent to which the models encouraged the visitors to visit the real building. This degree of certainty can be regarded as a measurable value that can only be achieved by the physical representation of the building (product). Although the inquiry on public domain was based initially on qualitative data, it was possible to convert these into quantitative "measurable results". Therefore, it is not always true that value in design is hard to measure.

In education environment, this study came up with a method that explains how the performance of the students in design studio can be increased by relying on the principle of "learning by doing". This principle is based on designing directly with models for strengthening the physical interaction between the students and their ideas. Making such a direct interaction let the students comprehend all the design constraints that may impact their creativity/ideas. Furthermore, learning by doing lets the students learn from their mistakes and provides them the opportunity to preview and practically test their designs.

The aim of this study was to convert the performance of the students into measurable values, which can be evaluated statistically to test the hypothesis of the dissertation. One of the bases for measuring the performance of the students was the skills of the students in making their projects' models. To evaluate the students' modeling skills the instructors first defined appropriate criteria such as design Proposal(s) in terms of design principles, Ideation and concept improvement, Relationship with neighborhood, etc. These criteria helped to determine a measurable value that could be correlated to their previously obtained grades on studio design courses (practical) as well as building science courses (theoretical). Conducting an experimental design studio course based on designing with models helped to compare the performance of the students before and after taking the course through the assessment of their grades.

According to the result of the study when modeling skills of the students are correlated with their performance in design studio courses a significant correlation is achieved. In particular, it is noted that the performance of the students doubled after conducting the experimental studio course. Moreover, the modeling skills of the students had an obvious improvement after conducting the experimental studio course (Table 5.7.)

Table 5.7 The values of linear correlation (R) obtained for the universities grades.

Correlation	Linear correlation (R) Value		
	METU	BENGHAZI (AC311)	ELMERGIB (AR315/ AR417/AR518)
Design studio grades vs Building Science grades	0.5785	0.7734	0.6178
Modeling Skills vs Modeling course (AC162) & (AR214)		0.3803	0.1311
Modeling skills grades vs Building science grades (for selected samples)	0.5861	0.5829	0.3785
Modeling skills vs CGPA (for selected samples)	0.7932	0.4488	0.5517
Modeling skills grades vs Design studio GPA (for selected samples) Before conducting the experimental studio course]	0.8569	0.4258	0.5259
Modeling skills grades vs Design studio GPA (for selected samples) After conducting the experimental studio course]		0.4844	0.7021
Modeling skills vs the experimental design studio course		0.5171	0.8548

Running an Analysis of Variance test (Anova) between the average design grades of students before the model based experimental studio was conducted and the design grades for the experimental studio. We see that the calculated F-value is much greater than the critical F, hence the null hypothesis Ho i.e the students' performance was not impacted by the experimental treatment is rejected. Also since the P-value (0.000097) is much smaller than alpha 0.05 hence we can say with 95% confidence that there is a significant improvement in the students' performance after designing with models.

Table 5.8. Analysis of variance test (Anova) conducted for the students of Elmergib University

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
DesignGPA/Before	32	1940.881	60.65253	19.10211		
EXP-Studio Final grades	32	2322	72.5625	242.125		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2269.558	1	2269.558	17.37613	0.000097	3.995887
Within Groups	8098.04	62	130.6136			
Total	10367.6	63				

In professional domain, however, the impacts that were identified among professional architects were almost identical to those obtained in the public domain in how they are measured. Measuring the value-added to a design or a building in this domain is regarded as discrete and unique**.** Since there were very limited architects who participated in the interview, it was not possible to convert the information obtained into measurable data. However, value added as a result of the impacts of models in public and educational domains was an absolute value the can be measured accurately.

CHAPTER 6

CONCLUSION

Architectural models and model-making play an important and essential role in designing and creating an idea, especially when it is required to get a physical product. Architectural models are considered to be one of the strongest design tools through which architects are able to transfer their architectural thoughts and visions from the imaginative to the concrete state. They help to test the applicability of ideas to reality. These architectural models have several impacts not only as means of representation that carry an implicit meaning, but also other critical impacts that can be regarded as value that can be measured. Therefore, the study explored the impacts of model-making as value-added tool in three major domains namely; public, educational and professional domain.

The study started with several exploratory stages of the evolution and impact of architectural models through several transitions. First of all, a chronological overview was given on the development and implementation of architectural models and their major impacts on the designing and production of our physical environment ever since they first appeared. Through the historical overview provided in this study it is affirmed that architectural models have had a significant impact in the formation and existence of civilization since ancient times.

Then, the study shifted to investigates the epistemological approach of model making either as a thinking mechanism, means of creativity, or a way of learning in education (design studio). This claimed to look at the nature of design and thinking in the sense of how creative ideas are basically born, generated and realized. The interrelation between the design as “process” and the emergent idea as a “product” lead to another concern that claimed to be a fundamental issue in architectural design process, i.e. the relationship between creativity and architecture. Accordingly, it has been found that when the process of design involves physical interactions between designers and their ideas the outcomes (design product) are very creative, buildable and efficient products/building. Moreover, the physical interactions had its affirmative impacts in architectural education in particular. On the one hand, relying on “learning-by-doing” as a way of learning in academic environments reflected positively on the pedagogical and psychological aspects of the study. Incorporating the method of “learning-by-doing” in academic environments, especially those depending heavily on practical work, yielded several positive outcomes such as: encouragement and motivation, gaining self-confidence, increase in the degree of perception and imagination, improving competency and experience of the student, offering a cheerful and entertaining atmosphere, in addition it offers a participatory and cooperative learning environment(s). On the other hands, the changes brought about by the emergence of new technologies and their impact on the design process highlighted further impacts. As a result, relying on digital technology does indeed have many advantages either in education or in design practice. However, these tools (digital technology) have apparently impacted the way a designer represent his already created idea. Since the interaction between the designer and his idea is through a 2D projection (screen), issues regarding scale, zoom in/out, depth and intangibility were among the obvious drawbacks.

This lead to the necessity of classifying models according to their roles; functions; project progress stages; and techniques of construction and applications. Although the architectural models may take various classifications, but most of them fall into the following four categories: descriptive models, predictive models, evaluative models and explorative models.

Another issue of concern was the evaluation of architectural design projects since it is very subjective and based on individual assessment approach, which varies from one person to another and thus cannot be generalized. Moreover, the issue of evaluating architecture design projects in order to grade the course students had to be based on clear measurable values. Thus, it was necessary to comprehend what is the exact definition of the term "value" in general, and how it is consistent with the subject of this study in particular. Accordingly, the concept of “Value through Design” considering various definitions and forms of value were dwelt upon.

Similarly, the relationship between value and quality in design was further discussed as well as the measurement of value in design was questioned.

Since the measurement of the "value of design" is a problematic matter that also involves subjective judgments, the study contributes to the debate on how the value of design can be articulated and measured. To this end the focus of this study was based on the value that can be inferred from the impacts of architectural models in the three mentioned domains namely; public, educational and professional. These are elaborated upon in the following sections.

6.1. The Impacts of Models on Public Domain

Based on the field study, it is revealed that models do have a significant impact on the cultural heritage of societies. Visitors interviewed at the Minaturk Park were appreciative of the opportunity to see 3-D representations of important buildings that were located all over the country, in one place. These models had also made them realize how rich their culture was and how varied the architecture. Consequently, most of the visitors were "certain" of their plans to visit the real buildings after seeing the models and those who were "uncertain" declared the reason to be lack of time to make their visit. This data on the visitors' impressions and decisions effectively measures the "value" of models in the public domain. Accordingly, this value reflected a clear indication that architectural models do have a significant impact on increasing the motivation of public to decide and make their plans for visiting and appreciating their cultural legacy and heritage.

6.2. The Impacts of Models on Educational Domain

The face-to-face interviews made with the participants from the three universities included in this study helped to determine the nature of the online questionnaire so as to avoid bias. Accordingly, these informal interviews highlighted some basic concepts of students' design approach, modeling abilities and experiences. Generally, the procedure was carried out for almost all the students; whether in METU, University of Benghazi, or Elmergib University. Apparently, architectural models have an obvious impact in defining the workshop multiplicity in learning environment. On the one hand, the extensive use of physical models as a means of representation had positively helped to create cooperative and multiple learning environments. That is, the physical models were presented at the core of every student's jury that allows the members and audiences to follow what is being discussed and presented. At the same time, other students were preparing their projects' models and slides doing their final touches with help of their friends. This multiplicity in learning environments helped the students to learn from each other.

On the other hand, most of the students were not keen to use the hand modeling technique to create and develop their design ideas due to time constraints, limited availability of materials and the lack of experience to cope in making complicated shapes by hand. This drawback reflected the lack and negligence of incorporating model-making courses or training programs in their school. Hence, this led to touch upon how students think and express their design approach for transferring their design ideas from the unknown or invisible state into physical state. Defining the ideation progress for most of the students was very problematic; some students declared that what externalized from their minds did not correspond with what they thought due to the lack of their modeling skills, so most of the time their ideas were subject to change.

Other issues such as the sense of scale and modeling materials properties were also discussed during the interviews. A quick test was made for some of the interviewed students asking them to estimate some dimension of some randomly selected models to determine their sense of scale. Interestingly, based on the students' response toward the test as well as what came out of the questionnaire result, it seems that a great majority of the students do have a sense of scale. Similarly, the questionnaire results revealed that 61% of the participated students preferred to use handcrafted models rather than digital models for the creation of their ideas. As result, some students mentioned that the case is not related to which technique they would love to use, but it is related to which techniques they can master well. For this reason, most of the responses cited in the questionnaire concerning why students do not prefer using the handmade modeling techniques for creating their ideas, were dedicated to the weakness and inexperience of doing their models by hands. This emphasizes the urgent need to employ model-making courses as an integral part in the education program in the schools of architecture. It is noted that most of the above-mentioned impacts are subjective and difficult to treat as absolute values that can be measured, but remain as a qualitative indicator that can emphasize the importance of learning by doing.

However, since one of the major parts of this study is to find out the impacts of models on education and the learning environment, a correlation analysis was made between design studio grades, lecture (building science courses) grades, and student's modeling skill grades. Accordingly, the performance of the students that is identified by the modeling skills assessment cannot be correlated to that in building science courses as in these courses the interactions between the students and the course materials is "indirect". In other word, the courses are based on theoretical lectures in classrooms where the interaction between the students and the course subject is intangible (Table 6.1.).

Table 6.1. Students performance and type of interactions identified by correlating modeling skills with theoretical and practical based courses.

Correlation	Relationship	Tangibility	Type of interaction	Value
Performance identified by Modeling skills vs Building science courses	Weak	Intangible	Indirect interaction based on theoretical lecture	measurable
Performance identified by Modeling skills vs Design Studio courses	Strong	Tangible	Direct interaction based on practical lecture	measurable
Performance identified by Modeling skills vs Experimental design studio course	Strong	Tangible	Direct interaction based on practical lecture	measurable

On the other hand, in design studio course the impact of models is obviously noticed since these courses are "practical based" that the students dealt with what is being given to them tangibly. Therefore, when learning engages tangible interactions, particularly in architecture, it is revealed that learners became very motivated and their performance is improved. Hence, "learning by doing" should be considered as the basis of imparting knowledge to the students, which can also be achieved by the making of models (physically).

6.3. The Impacts of Models on Professional Domain

The impacts of models whether they are digitally or manually produced, are also seen in the professional domain of architecture. Both mediums imposed some sort of challenges between the way architects create, generate, improve, produce and test their ideas and buildings.

According to the results of this study, architectural model-making has obviously positive impacts and contributed to identify several critical facts such as:

- The architectural model is considered as a tool for generating ideas rather than just for representing purposes.
- The models are also contributed positively in project collaboration process.
- Utilization of modeling technique, whether handmade or by the use of digital technology is almost matched.
- Modeling skills do have an impact on the design approach and ideation progress for many architects.
- The most widely accepted techniques in starting a design idea are 2D sketching and making physical compositions, whereas the use digital tools almost dedicated for presentation stage.
- The rendered "image" obtained by using any graphical software is not regarded a 3D model, rather it is considered as a 2D representation of 3D object.
- Unlike in digital modeling, handmade modeling allows the designer to tangibly control his design components.
- Models do have an impact on increasing or decreasing the chance of getting a job.
- Architectural models have significant impacts on architectural marketing due to its capability to clarify ideas realistically that convince the clients.

As a result, the obtained impacts are more likely to be identical to those obtained in the public domain in how they are measured. In other word, the obtained results can be treated as value-added that can only be estimated subjectively since it is based on qualitative data. On the other hand, value-added as a result of impacts of model making on public domain is an absolute value that can be measured accurately, that is; it is based on quantitative data. Hence, it true that the measurement of the value of design is a problematic matter involving complex subjective judgments only if the design evaluation criteria relied on qualitative data. However, in architectural education the value of design when it is based on clearly defined and scaled evaluation criteria it becomes a measurable value.

6.4. Recommendations For Further Studies

Although the study was able to identify the impacts of models in the public domain as a measurable value, this domain is not limited (confined) only to Miniaturk. What has been discussed in this study was only one of the aspects that reflected the impacts of models and how they can be measured. There are many other aspects in the public domain that the physical models can play important roles in identifying the types of impacts on people. Because of the time constraints in this study, only certain types of value resulting from the impact of the models in the public domain has been defined. That is, increasing the motivation of public to decide and make their plans for visiting and appreciating their cultural legacy and heritage certainty in making plan visit. Therefore, it is advisable that further studies should be dedicated in this aspect to develop and determine more ways of how to measure the value-added as a result of the representation of architectural products (buildings).

In learning environment, where the issue of model making is almost neglected due to the domination of advanced technology, more studies should be devoted in the importance and impacts of model making in the development of educational process. One of the issues that have been reached in this study is that there is a weak relationship between modeling skills and Building Science courses in determining student performance.

If the model-making is employed as a major tool in the analysis of buildings and structures in the way that Antonio Gaudi used in his design approach, this would have a prominent role in avoiding many design failures. The devotion of model-making should not be limited only to the educational domain, but also professional ones. Models can be used also to teach materials science and structure courses in architecture, to establish a sort of direct interaction between the students and the subject.

This study approved that the models can be used as a tool that assists the evaluation and determining the design value, which was only measured subjectively. Thus, now it becomes possible to measure the value-added design by the use of models in various occasions. It is recommended that further investigations in this area are needed which would provide several solutions to various controversial issues, including how to deal with the issue of value-added in architecture design as an absolute value that can be measured objectively not subjectively.

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APPENDIX A

MINIATURK DATA

Table A1. Raw data on the number of foreign visitors to Miniatürk since 2003-2012 (Source: Miniatürk authority)

Date	Number of foreign visitors	Note
2003-2005	No recorded data	No accurate data recorded during this period
2006	10 000	
2007	16 000	Number of visitors increased by 60%
2008	23 000	Number of visitors increased by 43.75%
2009	35 000	Number of visitors increased by 52.17%
2010	61 000	Number of visitors increased by 74.29%
2011	111 000	Number of visitors increased by 81.97%
2012	168 000	Number of visitors increased by 51.35%

Table A2. Raw data on the number of Turkish citizens' visitors (to miniatürk) since 2003-2012. (Source: Miniatürk authority)

Date	Number of Turkish citizens visitors	Note
2003	700 000	
2004	750 000	Number of visitors increased by 7.14%
2005	500 000	Number of visitors decreased by 33.33%
2006	500 000	Number of visitors remains at Constant rate
2007	500 000	Number of visitors remains at Constant rate
2008	500 000	Number of visitors remains at Constant rate
2009	500 000	Number of visitors remains at Constant rate
2010	550 000	Number of visitors increased by 10%
2011	600 000	Number of visitors increased by 9.09%
2012	500 000	Number of visitors decreased by 16.67%

Table A3. Sample data obtained through Interviews with Miniatürk park visitors.

NO	NATIONALITY	Gender	AGE	NUMBER OF VISIT	SELECTED BUILDING	Planning to visit the real building	NOTES
1	CANADA	M	50	1st	Haghia Sophia	Yes	They are Canadian couple, they have already planned to visit both buildings
					The Blue Mosque (Sultan Ahmet)	Yes	
2	CANADA	F	46	1st	Haghia Sophia	Yes	
					The Blue Mosque (Sultan Ahmet)	Yes	
3	IRAG	M	26	1st	Haghia Sophia	Yes	Translation is highly appreciated
					The Blue Mosque (Sultan Ahmet)	Yes	
4	TURKEY	M	47	2nd	Yerebatan Cistern (SARNICI)	Yes	He has already visited most of the monuments (only) in Istanbul territory
5	TURKEY	F	40	1st	Yerebatan Cistern (SARNICI)	Yes	
6	IRAN	F	54	1st	Suleymaniye Mosque	Yes	These are Iranian family, Miniaturk was hard for them to reach, not well advertised for assisting visitors and tourists.
7	IRAN	F	50	1st	Suleymaniye Mosque	Yes	
8	IRAN	M	13	1st	Suleymaniye Mosque	Yes	
9	RUSSIA	M	24	1st	Haghia Sophia	Yes	Russian couple, they impressed by the "valuable" history offered by the models. They learned too much historical information for the 1st time. They decided to visit both building after miniaturk.
					The Blue Mosque (Sultan Ahmet)	Yes	
10	RUSSIA	F	22	1st	Haghia Sophia	Yes	
					The Blue Mosque (Sultan Ahmet)	Yes	
					Aspendos Amphitheatre	Depends on time	
					Fairy Chimneys (Cappadocia)	Yes	
					Suleymaniye Mosque	Yes	

Table A4. Distribution of Foreigners Arriving in Turkey by Years and Months (2010-2012). (Source: Turkish Ministry of culture and tourism, Source link: http://www.kultur.gov.tr/EN,36567/tourism-statistics.html)

DISTRIBUTION OF FOREIGNERS ARRIVING IN TURKEY BY YEARS AND MONTHS					
	YEARS			RATE OF CHANGE (%)	
MONTHS	2010	2011	2012*	2011/2010	2012/2011
JANUARY	809 974	975 723	981 611	20.46	0.60
FEBRUARY	953 848	1 079 505	997 571	13.17	-7.59
MARCH	1 414 616	1 617 782	1 460 563	14.36	-9.72
APRIL	1 744 628	2 290 722	2 168 715	31.30	-5.33
MAY	3 148 337	3 283 125		4.28	
JUNE	3 500 024	3 780 637		8.02	
JULY	4 358 275	4 597 475		5.49	
AUGUST	3 719 180	4 076 783		9.62	
SEPTEMBER	3 486 319	3 923 546		12.54	
OCTOBER	2 840 095	3 039 754		7.03	
NOVEMBER	1 491 005	1 596 295		7.06	
DECEMBER	1 165 903	1 194 729		2.47	
TOTAL	28 632 204	31 456 076		9.86	
4 Months Total	**4 923 066**	**5 963 732**	**5 608 460**	**21.14**	**-5.96**

Table A5. Distribution of foreigners arriving in Turkey by nationalities in 2010-2012 (*) April (Top Ten. (Source: Turkish Ministry of culture and tourism, Source link: http://www.kultur.gov.tr/EN,36567/tourism-statistics.html)

DISTRIBUTION OF FOREIGNERS ARRIVING IN TURKEY BY NATIONALITIES IN 2010-2012(*) APRIL (TOP TEN)						
Countries	2012*	SHARE %	2 011	SHARE %	2 010	SHARE %
Germany	347 567	16.03	392 873	17.15	254 364	14.58
Russian Fed.	152 198	7.02	171 282	7.48	104 672	6.00
Bulgaria	130 060	6.00	125 476	5.48	115 610	6.63
U.Kingdom	128 047	5.90	155 984	6.81	108 026	6.19
Netherlands	119 293	5.50	111 989	4.89	71 785	4.11
France	111 547	5.14	132 004	5.76	84 521	4.84
Georgia	108 256	4.99	77 396	3.38	79 750	4.57
Iran	66 468	3.06	126 878	5.54	136 979	7.85
Greece	64 215	2.96	70 339	3.07	64 709	3.71
Italy	50 514	2.33	50 039	2.18	50 180	2.88
Others	890 550	41.06	876 462	38.26	674 032	38.63
Total	**2 168 715**	**100.00**	**2 290 722**	**100.00**	**1 744 628**	**100.00**

Table A5. (Continued) Distribution of foreigners arriving in Turkey by nationalities in 2010-2012 (*) April (Top Ten). (Source: Turkish Ministry of culture and tourism, Source link: http://www.kultur.gov.tr/EN,36567/tourism-statistics.html)

DISTRIBUTION OF FOREIGNERS ARRIVING IN TURKEY BY NATIONALITIES IN 2010-2012(*) JANUARY- APRIL (TOP TEN)						
Countries	**2012***	**SHARE %**	**2011**	**SHARE %**	**2010**	**SHARE %**
Germany	869 985	15.51	929 890	15.59	779 881	15.84
Bulgaria	368 051	6.56	401 665	6.74	367 500	7.46
Georgia	349 571	6.23	285 833	4.79	263 216	5.35
Iran	349 479	6.23	605 567	10.15	577 568	11.73
Russian Fed.	317 505	5.66	350 521	5.88	224 367	4.56
U.Kingdom	242 468	4.32	261 339	4.38	211 364	4.29
France	220 509	3.93	263 166	4.41	170 887	3.47
Netherlands	198 996	3.55	199 978	3.35	146 438	2.97
Syria	186 716	3.33	273 672	4.59	230 209	4.68
Greece	186 032	3.32	199 390	3.34	176 520	3.59
Others	2 319 148	41.35	2 192 711	36.77	1 775 116	36.06
Total	**5 608 460**	**100.00**	**5 963 732**	**100.00**	**4 923 066**	**100.00**

Table A6. Comparison of foreigners arriving in Turkey by nationalities in 2010-2012(*) (January-April). (Source: Turkish Ministry of culture and tourism, Source link: http://www.kultur.gov.tr/EN,36567/tourism-statistics.html)

NATIONALITY	**YEARS**			**SHARE (%)**			**RATE OF CHANGE %**	
	2010	**2011**	**2012***	**2010**	**2011**	**2012**	**2011/2010**	**2012/2011**
Germany	779 881	929 890	869 985	15.84	15.59	15.5	19.23	-6.44
Austria	76 694	106 784	81 659	1.56	1.79	1.46	39.23	-23.53
Belgium	74 865	93 698	79 747	1.52	1.57	1.42	25.16	-14.89
Denmark	35 778	47 460	50 782	0.73	0.80	0.91	32.65	7.00
Finland	22 538	37 454	34 181	0.46	0.63	0.61	66.18	-8.74
France	170 887	263 166	220 509	3.47	4.41	3.93	54.00	-16.21
Netherlands	146 438	199 978	198 996	2.97	3.35	3.55	36.56	-0.49
U.Kingdom	211 364	261 339	242 468	4.29	4.38	4.32	23.64	-7.22
Ireland	10 084	11 219	10 451	0.20	0.19	0.19	11.26	-6.85
Spain	70 679	57 819	63 700	1.44	0.97	1.14	-18.19	10.17
Sweden	43 009	63 683	76 769	0.87	1.07	1.37	48.07	20.55
Switzerland	46 344	61 903	64 339	0.94	1.04	1.15	33.57	3.94
Italy	108 508	126 096	117 260	2.20	2.11	2.09	16.21	-7.01
Iceland	588	711	698	0.01	0.01	0.01	20.92	-1.83
Luxembourg	1 511	2 063	2 421	0.03	0.03	0.04	36.53	17.35
Portugal	9 853	10 629	9 624	0.20	0.18	0.17	7.88	-9.46
Greece	176 520	199 390	186 032	3.59	3.34	3.32	12.96	-6.70
Czech Rep.	14 951	17 979	16 028	0.30	0.30	0.29	20.25	-10.85
Poland	28 363	41 081	41 061	0.58	0.69	0.73	44.84	-0.05
Hungary	11 361	16 088	15 372	0.23	0.27	0.27	41.61	-4.45
Norway	28 662	47 370	50 308	0.58	0.79	0.90	65.27	6.20
Slovakia	6 016	8 332	7 780	0.12	0.14	0.14	38.50	-6.63
EUROPE OECD	**2 074 894**	**2 604 132**	**2 440 170**	**42.15**	**43.67**	**43.51**	**25.51**	**-6.30**

Table A6. (Continued)

U.S.A	100 950	130 924	122 736	2.05	2.20	2.19	29.69	-6.25
Australia	21 846	23 486	22 122	0.44	0.39	0.39	7.51	-5.81
Japan	56 494	58 228	59 609	1.15	0.98	1.06	3.07	2.37
Canada	21 921	28 588	24 267	0.45	0.48	0.43	30.41	-15.11
New Zealand	4 148	4 779	4 155	0.08	0.08	0.07	15.21	-13.06
Mexico	3 117	4 528	3 919	0.06	0.08	0.07	45.27	-13.45
Korea, Rep. of	39 697	47 021	49 781	0.81	0.79	0.89	18.45	5.87
TOTAL OECD	**2 323 067**	**2 901 686**	**2 726 759**	**47.19**	**48.6 6**	**48.62**	**24.91**	**-6.03**
Estonia	4 662	5 766	4 285	0.09	0.10	0.08	23.68	-25.69
Montenegro	2 819	3 577	4 614	0.06	0.06	0.08	26.89	28.99
Kosova	9 432	12 109	14 755	0.19	0.20	0.26	28.38	21.85
Malta	780	745	945	0.02	0.01	0.02	-4.49	26.85
Lithuania	9 215	10 426	9 589	0.19	0.17	0.17	13.14	-8.03
Greek Cypriot Administration	1 620	2 037	4 267	0.03	0.03	0.08	25.74	109.47
Latvia	4 659	6 896	6 678	0.09	0.12	0.12	48.01	-3.16
Bosnia Herzg	9 647	11 889	13 463	0.20	0.20	0.24	23.24	13.24
Croatia	7 939	10 512	13 751	0.16	0.18	0.25	32.41	30.81
Slovenia	6 884	7 990	9 167	0.14	0.13	0.16	16.07	14.73
Serbia	21 501	26 539	30 639	0.44	0.45	0.55	23.43	15.45
Rep.of, Macedonia	28 406	33 671	36 998	0.58	0.56	0.66	18.53	9.88
Albania	9 508	10 611	12 225	0.19	0.18	0.22	11.60	15.21
Bulgaria	367 500	401 665	368 051	7.46	6.74	6.56	9.30	-8.37
Romania	59 976	67 884	75 066	1.22	1.14	1.34	13.19	10.58
O. EUROPE COUNTRIES	436	532	506	0.01	0.01	0.01	22.02	-4.89
TOTAL EUROPE	**2 619 878**	**3 216 981**	**3 045 169**	**53.22**	**53.9 4**	**54.30**	**22.79**	**-5.34**
Azerbaijan	120 650	181 343	150 006	2.45	3.04	2.67	50.31	-17.28
Belarus	11 884	15 560	12 869	0.24	0.26	0.23	30.93	-17.29
Armenia	12 369	13 579	14 690	0.25	0.23	0.26	9.78	8.18
Georgia	263 216	285 833	349 571	5.35	4.79	6.23	8.59	22.30
Kazakhstan	28 736	35 647	46 471	0.58	0.60	0.83	24.05	30.36
Kyrgyzstan	9 346	12 811	13 020	0.19	0.21	0.23	37.07	1.63
Rep. Moldova	16 547	18 884	19 905	0.34	0.32	0.35	14.12	5.41
Uzbekistan	15 511	21 970	26 568	0.32	0.37	0.47	41.64	20.93
Russian Fed.	224 367	350 521	317 505	4.56	5.88	5.66	56.23	-9.42
Tajikistan	4 009	4 951	6 468	0.08	0.08	0.12	23.50	30.64
Turkmenistan	31 248	39 860	40 317	0.63	0.67	0.72	27.56	1.15
Ukraine	79 921	93 260	100 939	1.62	1.56	1.80	16.69	8.23
UIS	**817 804**	**1 074 219**	**1 098 329**	**16.61**	**18.0 1**	**19.58**	**31.35**	**2.24**

Table A7. Foreigners and Citizens Arriving in Turkey by Means of Transport in August (2010-2012*). (Source: Turkish Ministry of culture and tourism, Source link: http://www.kultur.gov.tr/EN,36567/tourism-statistics.html)

Foreigners and Citizens Arriving in Turkey by Means of Transport in April (2010-2012*)												
	TOTAL			Rate of Change %	FOREIGNERS			Rate of Change %	CITIZENS			Rate of Change %
	2010	2011	2012*		2010	2011	2012*		2010	2011	2012*	
Airway	1 585 595	2 184 955	2 187 645	0.12	1 104 894	1 600 051	1 583 816	-1.01	480 701	584 904	603 829	3.24
Roadway	833 005	915 255	792 329	-13.43	513 677	537 984	470 978	-12.46	319 328	377 271	321 351	-14.82
Railway	5 433	4 995	2 114	-57.68	4 554	4 098	1 730	-57.78	879	897	384	-57.19
Seaway	147 291	173 459	138 734	-20.02	121 503	148 589	112 191	-24.50	25 788	24 870	26 543	6.73
Total	2 571 324	3 278 664	3 120 822	-4.81	1 744 628	2 290 722	2 168 715	-5.33	826 696	987 942	952 107	-3.63
Excursionist	99 248	122 211	88 537		99 165	122 115	88 469		83	96	68	

Table A7. (Continued) Foreigners and Citizens Arriving in Turkey by Means of Transport in January-April (2010-2012*). (Source: Turkish Ministry of culture and tourism, Source link: http://www.kultur.gov.tr/EN,36567/tourism-statistics.html)

Foreigners and Citizens Arriving in Turkey by Means of Transport in January-April (2010-2012*)												
	TOTAL			Rate of Change %	FOREIGNERS			Rate of Change %	CITIZENS			Rate of Change %
	2010	2011	2012*		2010	2011	2012*		2010	2011	2012*	
Airway	4 593 721	5 733 416	6 043 847	5.41	2 998 849	3 795 262	3 909 380	3.01	1 594 872	1 938 154	2 134 467	10.13
Roadway	2 921 772	3 446 041	2 671 410	-22.48	1 722 087	1 896 194	1 521 119	-19.78	1 199 685	1 549 847	1 150 291	-25.78
Railway	16 852	18 061	10 214	-43.45	14 989	15 495	8 531	-44.94	1 863	2 566	1 683	-34.41
Seaway	273 980	347 744	255 217	-26.61	187 141	256 781	169 430	-34.02	86 839	90 963	85 787	-5.69
Total	7 806 325	9 545 262	8 980 688	-5.91	4 923 066	5 963 732	5 608 460	-5.96	2 883 259	3 581 530	3 372 228	-5.84
Excursionist	142 129	202 147	125 179		142 043	202 011	125 074		86	136	105	

Table A8. Distribution of foreigners arriving in Turkey by provinces of entry and means of transport-2012. (Source: Turkish Ministry of culture and tourism, Source link: http://www.kultur.gov.tr/EN,36567/tourism-statistics.html)

DISTRIBUTION OF FOREIGNERS ARRIVING IN TURKEY BY PROVINCES OF ENTRY AND MEANS OF TRANSPORT-2012						
JANUARY-SEPTEMBER						
		MEANS OF TRANSPORT				
PROVINCES	AIR	LAND	TRAIN	SEA	TOTAL	%SHARE
ADANA	81 592	-	-	908	**82 500**	0.32
AĞRI	-	307 942	-	-	**307 942**	1.20
ANKARA	269 927	-	-	-	**269 927**	1.05
ANTALYA	8 745 355	-	-	122 685	**8 868 040**	34.43
ARTVİN	622	1 143 254	-	29	**1 143 905**	4.44
AYDIN	-	-	-	466 573	**466 573**	1.81
BALIKESİR	-	-	-	11 732	**11 732**	0.05
BURSA	2 404	-	-	493	**2 897**	0.01
ÇANAKKALE	48	-	-	8 802	**8 850**	0.03
DENİZLİ	23	-	-	-	**23**	0.00
DİYARBAKIR	22	-	-	-	**22**	0.00
EDİRNE	-	2 098 069	10 470	-	**2 108 539**	8.19
ELAZIĞ	7 861	-	-	-	**7 861**	0.03
ERZURUM	2 714	-	-	-	**2 714**	0.01
ESKİŞEHİR	13 562	-	-	-	**13 562**	0.05
GAZİANTEP	29 962	57 925	1 373	-	**89 260**	0.35
GİRESUN	-	-	-	769	**769**	0.00
HAKKARİ	-	92 968	-	-	**92 968**	0.36
HATAY	10 333	229 420	-	1 289	**241 042**	0.94
ISPARTA	25 548	-	-	-	**25 548**	0.10
MERSİN	-	-	-	17 223	**17 223**	0.07
İSTANBUL	6 664 549	-	-	424 079	**7 088 628**	27.52
İZMİR	742 745	-	-	405 238	**1 147 983**	4.46
KARS	-	-	-	-	-	-
KASTAMONU	-	-	-	66	**66**	0.00
KAYSERİ	44 118	-	-	-	**44 118**	0.17
KIRKLARELİ	-	246 167	-	-	**246 167**	0.96
KOCAELİ	-	-	-	3 897	**3 897**	0.02
KONYA	13 941	-	-	-	**13 941**	0.05
MALATYA	3 592	-	-	-	**3 592**	0.01
MARDİN	-	-	-	-	-	0.00
MUĞLA	2 252 583	-	-	472 041	**2 724 624**	10.58
MUŞ	-	-	-	-	-	0.00
NEVŞEHİR	8 651	-	-	-	**8 651**	0.03
ORDU	-	-	-	58	**58**	0.00
RİZE	-	-	-	12	**12**	0.00
SAMSUN	13 266	-	-	13 577	**26 843**	0.10

Table A8. (Continued)

SİNOP	-	-	-	6 774	**6 774**	0.03
SİVAS	1 002	-	-	-	**1 002**	0.00
TEKİRDAG	2 023	-	-	15 281	**17 304**	0.07
TRABZON	14 227	-	-	7 747	**21 974**	0.09
ŞANLIURFA	-	47 647	-	-	**47 647**	0.18
UŞAK	-	-	-	-	**-**	0.00
VAN	-	24 547	12 263	-	**36 810**	-
ZONGULDAK	3 503	-	-	3 990	**7 493**	0.03
ŞIRNAK	-	243 065	-	-	**243 065**	0.94
BARTIN	-	-	-	60	**60**	0.00
ARDAHAN	-	26 211	-	-	**26 211**	0.10
IĞDIR	-	182 172	-	-	**182 172**	0.71
KİLİS	-	95 981	14	-	**95 995**	0.37
TOTAL	**18 954 173**	**4 795 368**	**24 120**	**1 983 323**	**25 756 984**	100.00
% SHARE	73.59	18.62	0.09	7.70	100.00	

APPENDIX B

MINIATURK MODELS

Figure B1: Ankara (1427-1429) Hacı Bayram mosque, Antalya (1230) the Chamfered Minaret Mosque, Monument to the Martyrs of Çanakkale (1960) Gallipoli, Amasya Yalıboyu Houses, Karabük (18.A.D.) Houses of Safranbolu, Zeynel Bey Külliyesi /Türbasi /HAMAMI, Şanlıurfa (1211-1212) The Halil-ür Rahman mosque and the Fishy Lake, Kırşehir (1322) The Tomb of Aşık Paşa, The Stone Bridge in Adana (2nd A.D.), Diyarbakir (1147) Malabadi Bridge.

Figure B2: The Temple of Artemis (Artemision), The Great mosque of Diyarbakir, Parliament Building (1939-1961), The Tomb of Ertuğrul Gazi, Bursa Grand Mosque, ismail Fakirullah HZ. Türbasi & Ibrahim Hakki HZ. Türbasi, Selçuk isa Bey camii, Darende Şeyh Hamid-i Veli (1412), çifte Minareli medrese,

Figure B3: konya Alaaddin Mosque (Konya), Manisa Muradiye Mosque (Manisa), Amasya Yaliboyu Houses (Amasya), Meryem Ana Kilisesi (Izmir), The Ruins of Mt. Nemrud (Adiyaman), The Civilization of Hitit (1650-1200), Karaman Hatuniye Medrese (Karaman), The Church of the Virgin Mary (Izmir), Rock Houses of Mardin (Mardin), Sumela Monatery (Trabzon)

Figure B4: The Celsus Library of Ephesus ((Izmir), Sivas Gök (sky) Medrese (Sivas), Zeus Altar (Izmir), Sivas Divriği Grand Mosque (Sivas), Konya Thin Minaret Medrese (Konya), Atatürk Olympic Stadium (Istanbul), Istanbul Metropolitan Municipality Building (Istanbul), Hacı Bektaş-I Veli Complex (Istanbul), Pamukkale, Aksaray Sultan Han (Aksaray)

Figure B5: The Tomb of Master Sinan (Istanbul), The Anatolian Fortress (Istanbul), The Maiden’s Tower (Istanbul), Eyüp Sultan Mosque, Kaymak Mustafa Paşa Masque (Istanbul), Kuleli Military College (Istanbul), Pertevniyal College (Istanbul), The Mosque of Valide Sultan (Istanbul).

Figure B6: Beylerbeyi Palace (Istanbul), Khedive’s Villa (Istanbul), Çırağan Palace (İstanbul), The Ecyad Castle (Mecca), Mehmet Ali Pasha Mosque (Cairo), Dolmabahçe Palace (Istanbul).

Figure B7: Damascus Station (Damascus), Sultan Süleyman Surlari sham Kapısı (Jerusalem), The Dome of the Rock (Jerusalem), Al Aqsa Mosque (Jerusalem), The Istanbul Ramparts and Yedikule (Istanbul), Gül Baba Tomb (Budapest), Ataturk's House (Thessalonki), The mostar Bridge (Mostar).

Figure B8: Bosphorus Bridge (Istanbul), The Istanbul Ramparts (Istanbul), Ataturk International Airport (Istanbul), Haseki Hurrem Turkish Bath (Istanbul), Sadullah Pasha Waterside Mansion (Istanbul), Örme Sütun & Burmali Sütun & The German Fountain & Egyptian Obelisk & Sultanahmet square (Istanbul), Haghia Sophia (Istanbul), The Blue Mosque "Sultanahmet moque" (Istanbul), Haghia Irini (Istanbul), Yerebatan Cistern (Istanbul).

Figure B9: Haghia Sophia, Istanbul (Built in 537).

Figure B10: The Blue Mosque (Sultan Ahmet), Istanbul (Built in 1609).

Figure B11: Suleymaniye Mosque, Istanbul (1550-1559).

Figure B12: Topkapı Palace, Istanbul (1461-1468).

APPENDIX C

I.ONLINE QUESTIONNAIRE SURVEY

MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / Building Science PhD program
Prepared by: HATEM HADIA
2013-2014 Academic year
Ankara/Turkey

Model-making practice / General Questionnaire

Name (optional)	....	Year of study (e.g. 1st, 2nd, 3rd, M.A.)	....
Age	....	Gender	....
Department & Institution	....	Country	....

---

1. General

1) Please list all the reasons you can think of why a designer should make a model? (You can choose more than one answer)

BECAUSE IT IS CONSIDERED AS:

- ☐ As a tool to work out ideas.
- ☐ A means of presenting/representing ideas/visualization.
- ☐ A means of integrating different design elements.
- ☐ A means of generating ideas that '*may not have been seen in the drawings*'.
- ☐ A means of design interpretation (facilitating the complication of rough sketches).
- ☐ A means of eliminating potential problem(s) during the construction process.
- ☐ Others? (Please specify)..

2. Materials and methods

1) If you consider yourself as a good model-maker, how do you rate yourself?

- ☐ Very bad
- ☐ Bad
- ☐ Fair
- ☐ Good
- ☐ Excellent

2) Which technique would you prefer to model your design?

- ☐ Hand-made (Manual techniques)
- ☐ digital technology (Rapid prototyping)

3) Are there any aspects of model-making you find particularly difficult, don't enjoy or resent having to do?

- ☐ Yes
- ☐ No

4) Does that difficulty (ies) limit(s) your imagination & creativity?

- ☐ Yes
- ☐ No
- ☐ If yes please specify

5) What materials do you habitually use for model-making (if you are free to choose?)
(Please give at least two choices)
a) 1st material.......................
b) 2nd material...........................

6) What other materials do you use occasionally?

(Answer)...

7) Which of the following may force you to change your decision-making in selecting the most appropriate material for your model? (you can select more than one)

- ☐ The availability of materials.
- ☐ Price.
- ☐ Properties
- ☐ standard dimensions (Size & thickness)
- ☐ If others please specify...

9) Do you use any form of plastic i.e. PVC, styrene, acetate, acrylic, Styrofoam?

- ☐ Yes
- ☐ No

10) What do you use it for? (If you do but don't know what it's called just describe it and say where you got it.)

(Answer)...

11) Have you ever done any casting (in plaster) for a model?

- ☐ Yes
- ☐ No

12) Have you ever considered casting (in plaster) but haven't in the end?

- ☐ Yes
- ☐ No

13) If your answer is (YES) give a reason?

(Answer)...

14) Have you ever used paints?

- ☐ YES
- ☐ NO

14) What paints do you normally use? (you can choose more than one).

- ☐ tube acrylic
- ☐ liquid acrylic
- ☐ tube or cake watercolour
- ☐ Spray paint
- ☐ *car spray*
- ☐ crayon
- ☐ enamel
- ☐ acrylic
- ☐ Other (specify)..

3. Relationship to design

1) If you are in a hurry, what medium would you choose to present your idea?

- ☐ Sketches
- ☐ 2D CAD drawings
- ☐ 3D Digital model
- ☐ Scale model

- ☐ Animation
- ☐ Other/s...

2) Is your design approach influenced by your modelling skills?

- ☐ Yes
- ☐ No

3) Has your lack of modelling skills or facilities restricted your design?

- ☐ Yes
- ☐ No

4) How do you start designing?

- ☐ 2D sketching (on sketch paper) then moves on.
- ☐ 2D sketching using CAD application software then moves on.
- ☐ 3D sketching using CAAD application software.
- ☐ Making composition models by hand.
- ☐ Using both methods (please specify which comes first)....................................
- ☐ Others (please specify)..

5) When do you start modelling or working in 3D?

- ☐ At the beginning of the design process.
- ☐ In the middle of the process.
- ☐ The last stage of the design process.
- ☐ If others, please specify...

6) Which modelling method do you usually choose and why?

- ☐ Using 3D software application..
- ☐ Using my hands skills/...
- ☐ Ask friend for help...
- ☐ If others please specify..

7) Which 3D software have you mastered?
(You can specify more than one)...

8) How well do you know the logic (algorithm) behind the software you use?

- ☐ Very well
- ☐ Enough
- ☐ A little
- ☐ Not at all

10) The model is useful in:

- Contributing to the design development.
- Just conveying the design intention.

Would it be possible for you to have a better grade if your model was good?

- Yes
- No

11) Have you ever used your model for design analysis? If YES please specify how? If “No” Why?

- Yes...
- No...

4. Practicalities

1) What scale do you usually make your model in? (you can choose more than one answer)

- I comply with the specified scale.
- Work without considering scale.
- It depends on the degree of details required.
- It depends on work space.
- 1:25
- 1:50
- 1:100
- 1:200
- Other (specify)..

2) When do you consider working in another/different scale?

- When I come up with the main idea.
- When I come to the presentation stage.
- At the detailing stage..
- At the stage of structural analysis.
- Never worked with several scales.

3) How good are you at estimating the time you need to finish the model in?

- İ mostly finish on time
- İ usually need more time
- İ usually finish in less time.

4) What is the ideal working environment you prefer during the modeling process?

- Listening to music.

- ☐ Talking to others or even watching the TV.
- ☐ Quietness is preferable.

5) Do you prefer doing your model at home rather than school?

- ☐ Always
- ☐ Usually
- ☐ Sometimes
- ☐ Never

6) Why would you prefer to work at home?

- ☐ There is no disturbance
- ☐ The availability of equipment
- ☐ The availability of materials
- ☐ Other (Specify)...

7) Why would you prefer to work at school rather than home?

- ☐ The is more space
- ☐ The space is more quiet
- ☐ The availability of equipment
- ☐ The availability of materials
- ☐ cooperative work
- ☐ Other (Specify)...

8) How often can you afford to pay for a model yourself?

- ☐ Always
- ☐ Most of the time
- ☐ Sometimes
- ☐ Never

9) At what point might you have to consider alternatives?

- ☐ When Cost of the material is high.
- ☐ When materials are not available.
- ☐ When Time is limited.

10) How much do you usually spend on your model?

- ☐ 10-15 Euro
- ☐ 20-40 Euro
- ☐ 50-100 Euro
- ☐ 100-500 Euro
- ☐ More than 500 Euro

11) Do you rely on finding free or cut-price materials? If so, what?

- ☐ No
- ☐ Yes

(Specify here please)..

12) What support does your college provide?

- ☐ Financial.
- ☐ materials
- ☐ Tools.
- ☐ workshop
- ☐ No support.

5. In collaboration

1) What is the contribution of your model in project collaboration process? i.e. in working with directors, classmates, instructors, and technical staff.

0%	25%	50%	75%	100%

2) Do you think directors/instructors have appreciated your models?

Never	**Sometimes**	**Often**	**Always**

3) How have your models been used?

- ☐ To open up a design discussion.
- ☐ For the final presentation.
- ☐ For Design Analysis.
- ☐ To test some technical issues before hand (like structural failure, technical errors, etc.)
- ☐ To reorganize the tasks between workers.
- ☐ To convince the designers to make the necessary adjustments to the entire design.
- ☐ Others (specify)...

4) What experience have you had with the way technical staff have recreated information provided by the model? Was any form of supporting information necessary? (*In terms of construction/ as a means of communication)*

- ☐ The information provided by the model was supported by drawings.
- ☐ Technical staff contribution was required to clarify the operational idea of the construction process.
- ☐ The model was necessary during the design discussions and sometimes led to improvements in the design.

- The model had to be supported by further verbal discussion.
- The model contributed to the determination of technical errors.
- Other (specify)…………………………………………………………………...

***5)* For how many of your projects have you made physical models for:**

- 100%
- 75%
- 50%
- 25%

6) Do you think that NOT having made a physical model lost you the chance of getting the job?

- Yes
- No

II.ONLINE QUESTIONNAIRE FOR EVALUATING THE EXPERIMENTAL STUDIO COURSE

MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / Building Science PhD program

Prepared by: HATEM HADIA

2014-2015 Academic year

Ankara/Turkey

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1. Please select your participation identity
   - ☐ 1st year student
   - ☐ 2nd year student
   - ☐ 3rd year student
   - ☐ 4th year student

2. Gender:
   - ☐ Male
   - ☐ Female

3. Course code:
   - ☐ AR315
   - ☐ AR417
   - ☐ AR518
   - ☐ AC311 (For Benghazi university)

4. University & Institution:
   - ☐ …………………………………………………………………………..
5. ID number:
   - ☐ …………………………………………………………………………..

6. Your Age?
   - ☐ ………….

7. Nationality:
   - ☐ ………….

8. Have you ever started your design by making a physical model (mass or conceptual) instead of making 2D sketches?
   - ☐ Yes
   - ☐ No

9. Please if your answer is "Yes" can you please specify when and course code or name of the course?
    - Please specify here…………………………………………………
10. Did you study (practiced) a model making course before?
    - Yes
    - No

11. Regarding the previous question, can you specify when did you take the model-making course? (the term Or year is required)
    - Please specify here…………………………………………………

12. Were there any difficulties you faced when you designed with models?
    - Yes
    - No

13. Regarding the previous question, whether your answer is "Yes" or "No" can you briefly explain?
    - Please specify here…………………………………………………

14. Does your continues improvements for your design concept through making several compositions and models contributed to get a better grades and evaluation?
    - Yes
    - No

15. Do you support the adaptation of this methodology in all architectural design studios, and why?
    - Yes
    - No

16. Concerning your previous answer, whether your answer was "Yes" or "No" can you please give a reason
    - Please specify here…………………………………………………

17. How do you evaluate this design methodology (design and generate ideas with models)
    - Bad
    - Good
    - Excellent

18. Concerning the proposed methodology in design studio (design with models), was it complicated or not?
    - Complicated
    - Easy

19. Concerning the previous question, can you briefly explain why and when did you think is "complicated" or "easy"?
    - Please specify here……………………………………………………

III. GRAPHICAL REPRESENTATION OF ONLINE QUESTIONNAIRE-II FOR EXPERIMENTAL COURSE EVALUATION

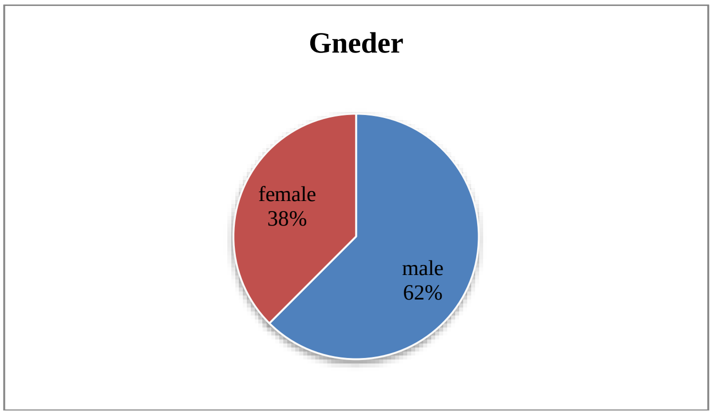


Figure C1. Gender of Participants

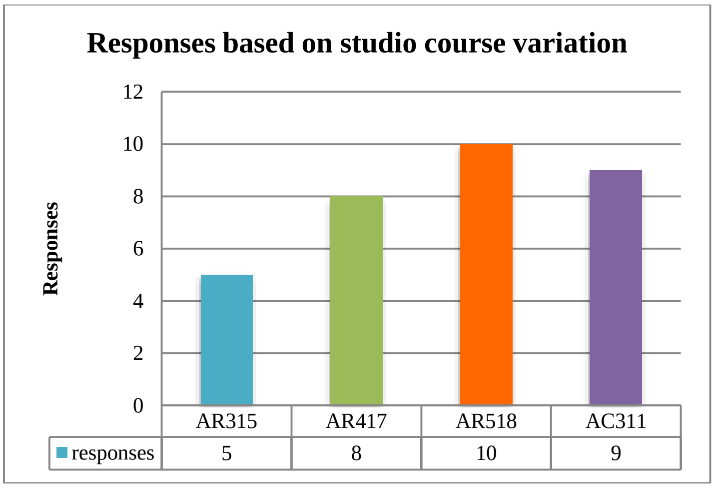


Figure C2. Responses based on studio course variation

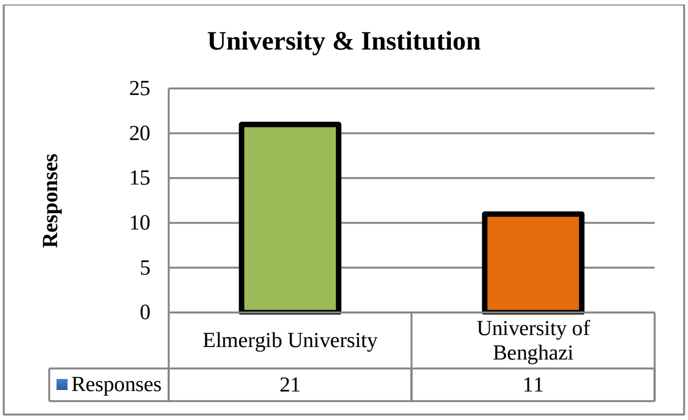


Figure C3. Participation according to universities and institutions.

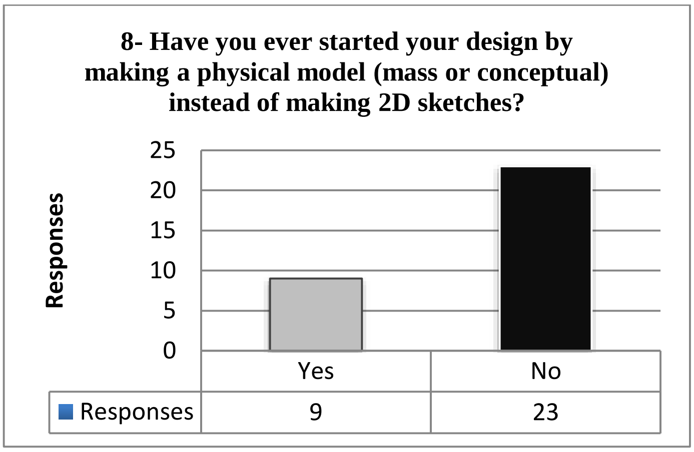


Figure C4. Question 8 for the online questionnaire-II

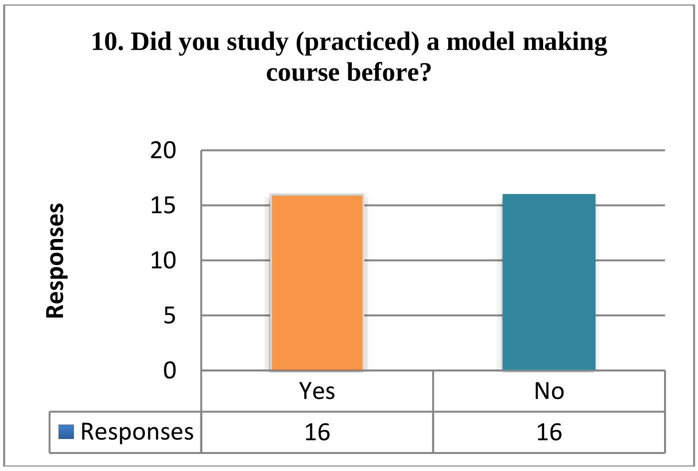


Figure C5. Question 10 for the online questionnaire-II

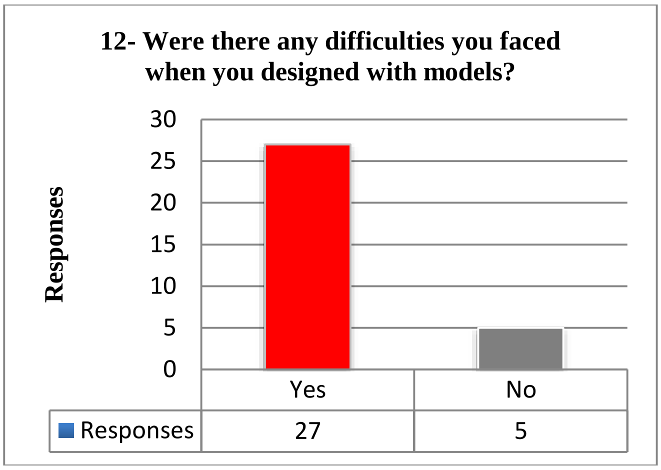


Figure C6. Question 12 for the online questionnaire-II

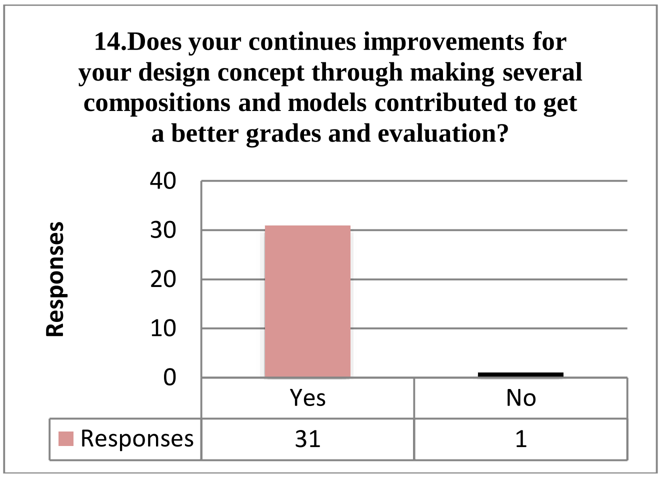


Figure C7. Question 14 for the online questionnaire-II

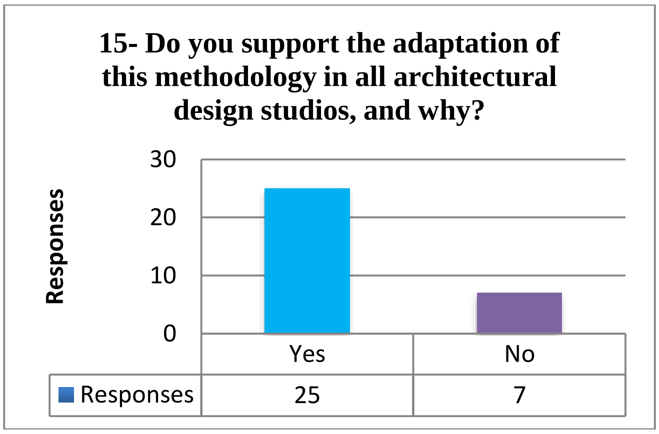


Figure C8. Question 15 for the online questionnaire-II

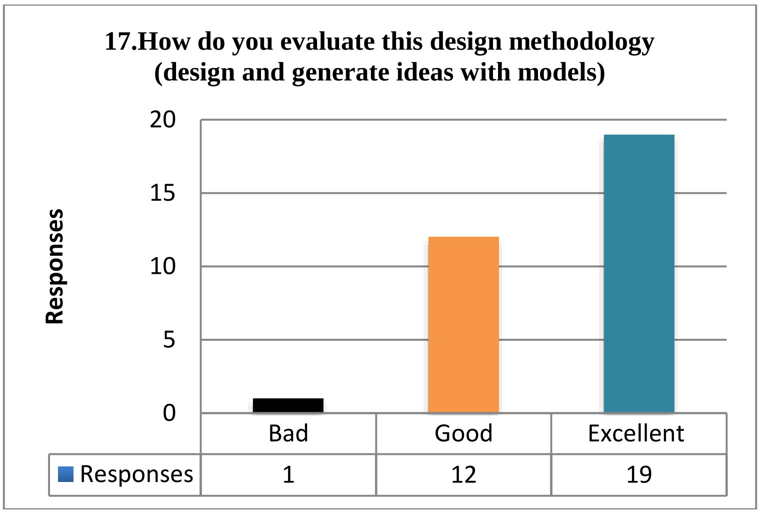


Figure C9. Question 17 for the online questionnaire-II

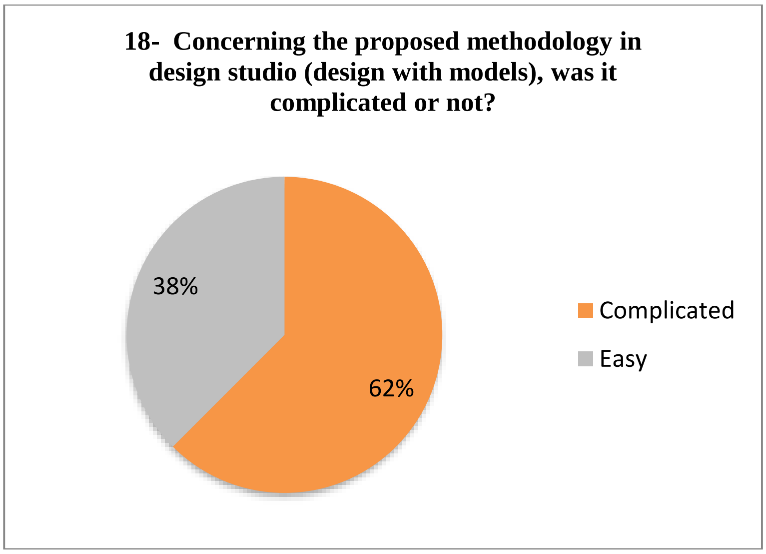


Figure C10. Question 18 for the online questionnaire-II

APPENDIX D

RAW DATA FOR MIDDLE EAST TECHNICAL UNIVERSITY

(COURSES THAT CONSIDERED IN THE STUDY ANALYSIS)

Table D1. METU Architectural Design Studio Courses with codes allocated in METU.

Architectural Design Studio Courses Included in the Analysis	
Course codes	**Course name**
Arch 101	Basic design
Arch 102	Introduction to architectural design
Arch 201	Architectural design I
Arch 202	Architectural design II
Arch 301	Architectural design III
Arch 302	Architectural design IV
Arch 401	Architectural design V
Arch 402	Architectural design VI

Table D2. METU Building Science Courses with codes allocated in METU.

Building Science Courses Included in the Analysis	
Course codes	**Course name**
Arch 231	Statics and strength of materials
Arch 232	Behavior and analysis of structures I
Arch 251	What buildings are made of
Arch 252	How buildings are made
Arch 282	Environmental design I
Arch 331	Structural design I
Arch 332	Behavior and analysis of structures II
Arch 351	What gets buildings made
Arch 381	Environmental design II
Arch 382	Environmental design III
Arch 452	Professional practice

Table D3. Collected data and grades for METU's students: the table presents the instructors comments and the followed grades for METU's students.

Cases **According to the sequence**	**Comments Of Instructors (Inst-1 & Inst-2)**	**Note**	**ST-codes**	**Gender**	**Nationality**	**Model**
1				1	1	
2				2	1	
3				2	2	
4				2	1	
5				1	2	
6				1	1	
7				2	1	
8				1	1	
9				1	1	
10				2	2	
11				1	1	
12				1	1	
13				1	1	
14				2	1	
15				1	1	
16				1	2	
17				1	1	
18				2	1	
19				1	1	

Table D3 Continued

20				2	1	
21				2	1	
22				1	1	
23				1	2	
24				2	1	
25				2	1	
26				2	1	
27				2	1	
28				1	1	
29		Cannot be found in METU system			2	
30				1	1	
31				1	1	
32				1	1	
33				1	1	
34				2	1	
35				1	1	
36				2	1	
37				1	1	
38				1	1	
39				2	1	

Table D3 Continued

40				2	1	
41				2	2	
42				1	1	
43				1	1	
44				1	1	
45				1	1	
46	talented and very skilled student	photographed	st-10	2	1	Physical
47				1	1	
48				1	1	
49				1	2	
50	below the average	photographed	st-1	1	1	Physical
51				2	1	
52				1	1	
54				2	1	
55				2	1	
57				1	1	
59				2	1	
60	below the average	photographed	st-4	2	1	Physical
61				1	1	
62				1	1	

Table D3 Continued

63				1	1	
64				1	1	
65				2	1	
66	perfect amazing	photographed	st-7	1	1	Physical
67				2	1	
68		photographed	st-6	1	1	Physical
69		photographed	st-8	1	2	Physical
70				2	1	
71	He needs to be guided… when he left freely not performing well			2	1	
73				2	1	
74		photographed	st-23	1	1	Physical
75		METU-catalog	st-25	2	1	digital & physical
76		METU-catalog	st-15	2	1	digital & physical
77				2	1	
78		METU-catalog	st-17	1	1	digital & physical
79				2	1	
80		METU-catalog	st-16	2	1	digital & physical
81	Talented but she needs to trust herself. She is good also in models			1	1	
82	ideal students every one wish to have	METU-catalog	st-26	1	1	digital & physical

Table D3 Continued

83	Hard working, comes with several proposals, but he is not skilled & talented (just working hard). He came from different educational system (Italian). Can be regarded as an acadimission not designer.	His grades are not sorted in the system (appears as special student)				
84	One of the best , never satisfied with what he achieved.			2	1	
85	Always thniking in details, thinking as a whole , rational mentalitiy			2	1	
86	She is so special, not like others, she has an artisitic atitude but not talented. but has problems with architectural overiew			1	1	
87				1	1	
88				2	1	
89				2	1	
90				1	1	
91	extremely talented, fast in producing and making…he has his own style.. Good with models and media he uses	METU-catalog	st-11	2	1	digital & physical
92				1	2	
93				2	1	
94	she is a real designer…talented in making forms and models (like Zaha hadid's style)	METU-catalog	st-12	1	1	physical
95				2	1	
98				1	1	
99	he is serious student but not spacial.			2	1	
100				1	1	

Table D3 Continued

101	excellent..hard working. Talented student.	photographed	st-5	2	1	physical
102				2	1	
103				1	1	
104	among the best	photographed	st-2	1	1	physical
107	Performing such an artist. Very well.			2	1	
109	steady student ideal student			2	1	
110				1	1	
111				2	1	
112				1	1	
113	normal & typical	METU-catalog	st-13	1	1	digital & physical
114				1	2	
115	very low and weak… below the normal level	METU-catalog	st-9	1	1	physical
116				1	1	
119	very low and weak student	METU-catalog	st-14	2	1	Physical
120				1	1	
121				1	1	
122				1	2	
123	she has no models published in the metu's catalog	photographed	st-3	1	1	Physical
124	she is perfect ..she has an intellectual depth in her mind..one of the best			1	1	
125				1	1	

Table D3 Continued						
126	above the average	photographed	st-21	2	1	Physical
128				1	1	
129	extreamly talented, very skilled.. Performaing well in studio.	METU-catalog	st-18	1	1	Physical
130	hard-working students. Good in making models.	photographed	st-19	1	2	Physical
131	serious student, but no special skills noticed.	METU-catalog	st-20	1	1	Physical
132	innovative and creative student	METU-catalog	st-22	1	1	Physical
133	very weak student.	METU-catalog	st-24	1	1	Physical

Table D3. (Continued) Design studio grades and building science grades for METU's students.

CASE	Design studio courses								Building Science courses										
	Arch 101	**Arch 102**	**Arch 201**	**Arch 202**	**Arch 301**	**Arch 302**	**Arch 401**	**Arch 402**	**Arch 231**	**Arch 232**	**Arch 251**	**Arch 252**	**Arch 282**	**Arch 331**	**Arch 332**	**Arch 351**	**Arch 381**	**Arch 382**	**Arch 452**
1	2	2.5	2.5	3	3.5				4	3	3	2	4	2.5		2	2		
2	2	2.5	3	2	2.5				4	3.5	4	4	4	4		3	4		
3	2.5	2.5	1.5						2										
4	3	2.5	4	4	3.5				3	3	4	4	4	**3.5**		3	2		
5	2	2	2	2.5					2		1.5	2	2						
6	2	2.5	3.5	2	2.5				3.5	4	1.5	3	2.5	3		1.5	1.5		
7	2.5	2.5	4	3	3.5						1.5	2.5	2	1.5		2.5	1.5		
8	2.5	3	3.5	3.5	4				1.5	4	1.5	2.5	3	4		3	2		
9	2	2	4	3.5	3.5				4	3	3.5	3	3.5	3		3	3		

10	3	3	3.5	4	2.5				1	2	4	4	3.5			3	3		
11	2	2	2	1.5					1		3.5	0	1						
12	2.5	3	3	3.5	3				2.5	2.5	4	3.5	4	4		3	1.5		
13	3	2	3	3	3				2.5	2	3.5	3	3.5	3.5		2.5	2		
14	2	2	3.5						2.5		1		1						
15	3	4	3	4	3				2	3.5	4	3.5	3.5	4		3.5	3..5		
16	1.5	2	2						0		1		W						
17	2	2	2.5	3	3.5				1.5	3	3	2	3.5	W		2	2		
18	2.5	3	4	4					2.5	3	2.5	2	3.5						
19	2	2.5	3.5	4	3.5				1	2	3.5	3	3.5	4		2.5	2		
20	1.5	1.5	2.5						1.5		2								
21	2.5	2	2.5	2	3				2	1	3	2.5	2	1		3	2		
22	2	2.5	3.5	2	2.5				3.5	4	1.5	3	2.5	3		1.5	1.5		
23	2	1.5	2	1.5	2.5				1		2	2	2.5			2	1.5		
24	2	2.5	3.5	2.5	3				2.5	3.5	1	2.5	2	2.5		2.5	1.5		
25	2.5	2	3.5	2	2				1	2.5	2	1.5	2	0		0.5	2		
26	2.5	2	3.5	2	3				1.5	1.5	4	3.5	3	0.5			0		
27	2	1.5	3						3		2		2						
28	3	3	3	2	3				3	1	2.5	3.2	3	1		2	W		
29																			
30	2	2	3	3	3				3.5	2	4	3	3.5	1.5		2.5	2		

31	2	2.5	3.5	3.5	3				3	3.5	3	3	3.5	2		2.5	0		
32	2.5	2.5	2.5	2.5	3				3	2	3	3	3.5	2.5		2.5	2.5		
33	2.5	2.5	3	3	2.5				4	4	3	2	3.5	4		3	1.5		
34	2.5	2.5	3.5	3.5	3				1.5	1	2	2.5	3	1		2.5	0.5		
35	1.5	2	3	2					2.5	2	4	4	3.5	1.5			1		
36	3	3.5	4	4	4				4	4	4	4	4	4		3.5	4		
37	2.5	3	3.5	4	3				3.5	4	4	4	4	4		4	4		
38	2.5	2.5	3	3.5	3				3	2.5	2.5	2.5	3.5	2.5		2.5	1.5		
39	2.5	3.5	4	4	3.5				4	4	3.5	2.5	3	2		2.5	2		
40	2	2	3.5	3.5	3.5	3	3		3.5	3.5	3.5	2.5	3.5	4	3	4	1		
41	2	2	3.5	3	3	3.5	3		1.5	1	2	2.5	2	2		3	3		1
42	3	4	4	4	3.5	4	4		1.5	1	3.5	2	3	1	1.5	1.5	2	2	
43	1.5	1.5	3.5	3.5	3	3.5	2.5		1.5	2	3	2	1.5	3.5	3	3	1.5	2.5	
44	3	3	2.5	2	3	2	3.5		1	1	2	1.5	2.5	1	2.5	2	1		
45	3	2.5	3	3	3	3	3.5		2	3.5	1	3.5	3	2.5	2.5	2.5	1	1	
46	3.5	3.5	4	4	4	3.5	4		2.5	3	3.5	4	4	3.5	2.5	4	2	3	
47	2	2	2.5	2.5	3	3	2.5		3	3	2	2	3	4		4	2.5		
48	1.5	1.5	3	3.5	3	3	2.5		2.5	3.5	4	4	4	4	4	3.5	2.5	3	
49	3	3.5	3	3.5	3	2.5	4		1	2	1	1	1.5	1	1.5	2.5	0.5		
50	1	2	2.5	2	3.5	2	3		2.5	2	3	2.5	2.5	2	0.5	3	1.5	1	
51	2.5	2	4	4	3.5	4	3		3	4	2.5	2	3	4	2.5	3	2		

52	2	2.5	3	4	4	4	3		3	2.5	3.5	3	4	2.5	4	3.5	2	1	
54	4	3.5	2.5	3.5	4	4	4	4	4	3	2.5	3.5	2	1.5	3	4	2.5	1	2.5
55	3	3	3.5	3.5	3	4	2	3	4	4	4	4	4	4	3.5	4	2	3.5	3.5
57	2.5	2	3	2.5	4	3	2.5	2	4	3	2.5	2.5	3.5	3	3	3	1.5	2	3.5
59	2.5	3.5	4	3.5	3	2.5	3	3	2	1	3.5	1	1	1	1	1	1	1	2.5
60	**3**	2	3	2.5	2.5	2.5	1	1.5	1	1	2.5	2.5	1	1.5	2	2.5	1	1.5	3
61	3	2.5	3	3.5	3.5	2	2.5	3	3.5	4	4	4	4	4	3	4	2	2	4
62	1.5	2	2.5	2.5	3	2	2	3	3	2	3	2.5	3	2	2	3	1	1	2.5
63	2	2.5	3	3	3	3	2.5	2.5	4	4	3	3.5	3.5	3.5	3	3.5	3	2	4
64	3	3	3	3.5	3.5	3.5		3	4	2	3.5	3.5	3	2.5	2	3.5	2	1.5	2
65	3	2	3	3	3	3.5	3	3	2	2	4	3.5	3	3	2.5	3.5	1	2	3
66	3	4	4	4	4	4	4	4	3.5	4	4	3.5	4	4	1	3.5	4	2.5	4
67	2.5	3	3.5	3.5	4	3.5	4	4	1.5	1	2.5	1.5	1.5	1	3	3.5	2.5	1	2
68	**2.5**	2.5	3	2.5	3.5	2.5	1.5	3	2.5	2	1.5	2.5	3	1.5	2.5	2	1.5	1.5	1
69	4	3.5	4	3.5	3	3.5	3.5	3.5	2	1.5	3	1	2	2	2	2	1	2.5	2.5
70	2.5	3.5	3.5	3	4	2.5	3	3	4	3.5	3	3.5	3	3	3	3.5	2	1.5	2
71	3	2.5	3.5	3	4	4	3	4	2.5	3	3	3	2.5	4	2	3.5	2	3	2.5
73	3	2	3.5	3.5	3.5	3.5	2.5	4	3.5	3.5	3	4	3.5	4	2.5	4	2.5	3	3.5
74	**2.5**	2.5	2.5	3	3	3	2.5	3	2.5	2	2.5	1.5	1.5	2	4	3.5	3.5	2	1
75	3.5	3.5	4	4	4	3.5	4	4	3.5	3.5	3	4	3.5	3.5	4	4	3	2	4
76	2.5	2	3	2.5	2.5	2	2.5	4	1	1	3	1.5	1.5	1	3	2.5	2	1	1

77	3	3	2.5	3	2.5	3	2.5	4	2	2	3.5	1.5	2.5	4	3.5	2.5	2	2	4
78	3	3.5	3	4	3.5	3.5	3.5	4	2	2	3.5	2.5	2.5	4	3.5	3	2	2	3
79	3	2	3.5	3.5	3.5	3.5	2.5	4	3.5	3.5	3	4	3.5	4	2.5	4	2.5	3	3.5
80	4	4	4	4	3.5	4	2.5	4	3.5	2	4	4	4	4	4	4	2.5	2	3.5
81	4	3.5	3	2.5	3.5	3	3	3.5	1.5	2	2.5	1	1.5	2	3.5	3	2	2	2
82	3.5	4	2.5	3	4	4	4	4	3	2.5	3	2.5	3	2	4	3.5	2.5	1.5	4
83																			
84	3	3.5	3.5	3	4	4	4	3.5	3.5	4	4	4	3.5	4	4	4	2.5	3	4
85	3.5	3.5	4	3	3.5		4	2	4	2.5	4	3.5	3.5	4	2	2.5	2	2.5	3.5
86	3	3	3	3			4	3.5	2.5	1	4	3	1.5	2.5	1		3	3	3.5
87	3	3.5	3	4	3.5	3.5	3.5	4	2	2	3.5	2.5	2.5	4	3.5	3	2	2	3
88	2.5	2.5	4	4	3.5	3.5	4	2.5	3.5	2	3	2	2	2.5	3	2	2.5	1	2.5
89	3	2.5	3.5	4	3.5	2.5	3.5	4	2.5	2	3	1	2	3	2.5	2.5	2.5	3	3
90	2	1.5	2.5	2.5	3.5	3.5	3.5	3.5	2.5	1.5	2.5	2.5	2	1	3	3	1.5	1	4
91	2.5	3	2.5	3	4	4	4	4	3	2.5	3	2.5	2.5	2	4	3.5	2	2	3
92	3	3.5	3.5	3.5	4	3.5	4	4	3.5	3	4	4	4	2.5	3	4	3	4	4
93	4	3.5	2.5	3.5	4	4	4	4	4	3	2.5	3.5	2	1.5	2.5	4	2.5	1	2.5
94	3	3.5	3.5	3.5	4	3.5	4	4	2	2	2	3.5	4	2	2	4	2	1.5	3
95	2.5	3	2.5	3	4	4	4	4	3	2.5	3	2.5	2.5	2	4	3.5	2	2	3
98	2.5	3	2.5	3	4	3.5		3.5	2.5	2	3.5	2	3.5	1.5	1	3.5	2	2	3.5
99	2.5	3.5	4	4	4	3.5	3.5	3.5	2.5	2	3	4	2.5	2.5	2	3.5	1.5	2	3.5

100	3	2.5	3.5	3	3.5	4	3	3.5	1.5	2	3	3	2.5	3	1	3	1	2	4
101	2.5	2	3.5	3.5	3.5	4	4	4	1.5	3	1	1.5	1	2	3.5	1.5	1.5	1.5	2.5
102	2	3	3	3	3.5	3.5	3	3	3	1.5	3	3	1	1	1.5	2.5	2	1	1
103	3	3	3	3.5	3.5	3.5		3	4	2	3.5	3.5	3	2.5	2	3.5	2	1.5	2
104	4	3.5	3	3	4	3	3	2.5	3.5	4	4	3	4	3	3	3.5	1.5	4	4
107	2	2.5	4	4	3.5	3.5	3	3.5	4	4	4	3.5	4	3	2	2	1.5	2.5	2
109	3	3.5	3.5	3.5	3.5	4	3.5	4	4	2.5	4	3.5	3.5	3	2	3.5	3	3.5	4
110	2	2	3	2	4	4	3.5		2.5	3	4	4	4	4	4	4	4		4
111	3	3	3.5	2.5	4	2	2.5		1.5	1	1.5	2.5	1	1		1	1		
112	1.5	2	3.5	3	4	3	3.5		3.5	2	3.5	3.5	3	2		3			
113	2	1.5	2.5	2	4	1.5	2	2	1.5	1	1.5	2	2	1.5	1	2	1	0.5	1
114	2.5	3	3.5	3.5	3	3	1.5	2.5	2.5	3	4	3	3	3.5	2.5	4	1.5	2	2
115	2.5	2.5	2.5	1	2.5	3	2	2.5	2	1.5	3.5	3	3	2	2	3.5	1	2	2.5
116	2	1	3	3	3	3	2.5	2	1	1	2.5	1	1.5	1.5	1	3	1.5	1.5	1
119	1	1	1.5	2	2.5	2.5	1	1.5	3	1.5	2.5	1	1	1	1.5	1.5	2.5	1	3
120	2.5	3	3	3	3	3	1	0	0	3.5	4	3.5	4	3.5	2.5	2.5	3.5	1.5	1.5
121	2.5	1.5	2.5	2.5	3	3	3.5	3.5	3	2.5	3	3.5	4	2.5	2.5	3.5	2.5	2	3.5
122	2.5	2.5	2.5	3	3	3	2.5		3	3	3.5	3.5	4	4	2.5	3.5	1.5	3	3
123	**1.5**	1.5	2	3	3.5	3.5	3	3.5	2.5	3	4	4	4	4	3	4	3.5	3	4
124	3.5	4	4	4	4	4	4		4	2	4	4	4	4	2.5	2.5	2.5	2	3.5
125	2	2	3	3	3.5	3.5	3		1	2	2.5	3	3	1	1	3	2	1.5	3.5

126	**2.5**	2.5	3	3.5	3.5	3	2.5	2.5	4	3	1.5	2.5	2	2	2.5	3	2	1	1
128	3.5	2	3	3	4	3.5	2.5		2	1	2.5	2.5	2.5	1.5	3	2.5	1	1.5	2.5
129	3.5	4	3	4	4	4	4	4	3.5	2.5	4	4	3.5	3.5	3	3.5	4	2	2.5
130	4	4	4	4	4	4			1	1	1.5	3	1			3	2	0.5	
131	3	2	4	4	3.5	4	2.5	3.5	3.5	3	3.5	4	4	4	3.5	3	3	1.5	4
132	3.5	2	4	3.5	4	3.5	3.5	4	3	4	2	1	2	3	2.5	2	3	3	3.5
133	**2**	2	2.5	1.5	1.5	2	1.5	2	1.5	1.5	2	1.5	2.5	1.5	1.5	2	1	1.5	2.5

Table D3. (Continued) GPA, CGPA and modeling skills for METU's students.

CASES	ST-codes	GPA (DS) Represents Design studio & (BS) Building Science			Modeling skills
		DS/GPA	BS/GPA	CGPA	
1		2.7	2.8125	2.76923077	
2		2.4	3.8125	3.26923077	
3		2.166666667	2	2.125	
4		3.4	3.3125	3.34615385	
5		2.125	1.875	2	
6		2.5	2.5625	2.53846154	
7		3.1	1.91666667	2.45454545	
8		3.3	2.6875	2.92307692	
9		3	3.25	3.15384615	
10		3.2	2.92857143	3.04166667	
11		1.875	1.375	1.625	
12		3	3.125	3.07692308	
13		2.8	2.8125	2.80769231	
14		2.5	1.5	2	
15		3.4	3.42857143	3.41666667	
16		1.833333333	0.5	1.3	
17		2.6	2.42857143	2.5	
18		3.375	2.7	3	

19		3.1	2.6875	2.84615385	
20		1.833333333	1.75	1.8	
21		2.4	2.0625	2.19230769	
22		2.5	2.5625	2.53846154	
23		1.9	1.83333333	1.86363636	
24		2.7	2.25	2.42307692	
25		2.4	1.4375	1.80769231	
26		2.6	2	2.25	
27		2.166666667	2.33333333	2.25	
28		2.8	2.24285714	2.475	
29		0	0	#DIV/0!	
30		2.6	2.75	2.69230769	
31		2.9	2.5625	2.69230769	
32		2.6	2.75	2.69230769	
33		2.7	3.125	2.96153846	
34		3	1.75	2.23076923	
35		2.125	2.64285714	2.45454545	
36		3.7	3.9375	3.84615385	
37		3.2	3.9375	3.65384615	
38		2.9	2.5625	2.69230769	
39		3.5	2.9375	3.15384615	

40		2.928571429	3.16666667	3.0625	
41		2.857142857	2	2.375	
42		3.785714286	1.9	2.67647059	
43		2.714285714	2.35	2.5	
44		2.714285714	1.61111111	2.09375	
45		3	2.25	2.55882353	
46	st-10	3.785714286	3.2	3.44117647	7.266666667
47		2.5	2.9375	2.73333333	
48		2.571428571	3.5	3.11764706	
49		3.214285714	1.33333333	2.15625	
50	st-1	2.285714286	2.05	2.14705882	4.25
51		3.285714286	2.88888889	3.0625	
52		3.214285714	2.9	3.02941176	
54		3.6875	2.68181818	3.10526316	
55		3.125	3.68181818	3.44736842	
57		2.6875	2.86363636	2.78947368	
59		3.125	1.45454545	2.15789474	
60	st-4	2.25	1.77272727	1.97368421	4.2
61		2.875	3.5	3.23684211	
62		2.3125	2.27272727	2.28947368	
63		2.6875	3.36363636	3.07894737	

64		3.214285714	2.68181818	2.88888889	
65		2.9375	2.68181818	2.78947368	
66	st-7	3.875	3.45454545	3.63157895	7.35
67		3.5	1.90909091	2.57894737	
68	st-6	2.625	1.95454545	2.23684211	3.966666667
69	st-8	3.5625	1.95454545	2.63157895	7.3
70		3.125	2.90909091	3	
71		3.375	2.81818182	3.05263158	
73		3.1875	3.36363636	3.28947368	
74	st-23	2.75	2.36363636	2.52631579	4.65
75	st-25	3.8125	3.45454545	3.60526316	
76	st-15	2.625	1.68181818	2.07894737	4.35
77		2.9375	2.68181818	2.78947368	
78	st-17	3.5	2.72727273	3.05263158	7.316666667
79		3.1875	3.36363636	3.28947368	
80	st-16	3.75	3.40909091	3.55263158	7.1
81		3.25	2.09090909	2.57894737	
82	st-26	3.625	2.86363636	3.18421053	
83		0	0		
84		3.5625	3.68181818	3.63157895	
85		3.25	3.09090909	3.19444444	

86		3.5	2.5	2.78125	
87		3.3125	2.72727273	3.05263158	
88		3.3125	2.36363636	2.76315789	
89		2.8125	2.45454545	2.81578947	
90		3.375	2.22727273	2.47368421	
91	st-11	3.625	2.72727273	3	7.116666667
92		3.6875	3.54545455	3.57894737	
93		3.625	2.63636364	3.07894737	
94	st-12	3.375	2.54545455	3	6.783333333
95		3.142857143	2.72727273	3	
98		3.5625	2.45454545	2.72222222	
99		3.25	2.63636364	3.02631579	
100		3.375	2.36363636	2.73684211	
101	st-5	3	1.86363636	2.5	4.916666667
102		3.214285714	1.86363636	2.34210526	
103		3.25	2.68181818	2.88888889	
104	st-2	3.25	3.40909091	3.34210526	6.866666667
107		3.5625	2.95454545	3.07894737	
109		2.928571429	3.31818182	3.42105263	
110		2.928571429	3.75	3.41176471	
111		2.928571429	1.3125	2.06666667	

112		2.928571429	2.92857143	2.92857143	
113	st-13	2.1875	1.36363636	1.71052632	4.1
114		2.8125	2.81818182	2.81578947	
115	st-9	2.3125	2.36363636	2.34210526	4.733333333
116		2.4375	1.5	1.89473684	
119	st-14	1.625	1.77272727	1.71052632	5
120		2.3125	2.72727273	2.55263158	
121		2.75	2.95454545	2.86842105	
122		2.714285714	3.13636364	2.97222222	
123	st-3	2.6875	3.54545455	3.18421053	4.783333333
124		3.928571429	3.18181818	3.47222222	
125		2.857142857	2.13636364	2.41666667	
126	st-21	2.875	2.22727273	2.5	4.016666667
128		3.071428571	2.04545455	2.44444444	
129	st-18	3.8125	3.27272727	3.5	7.333333333
130	st-19	4	1.625	2.64285714	7.516666667
131	st-20	4	3.36363636	3.34210526	7.016666667
132	st-22	3.5	2.63636364	3	7.3
133	st-24	1.875	1.72727273	1.78947368	4.3

Table D4. Modelling evaluation skills criteria for METU's students/ Instructor-A1's evaluation.

Model-code	composition & typology	Selection of materials	status of the model in the site	relationship with neighbourhood	Expression	Scale	precision & accuracy	fairness of workshop (finishing)	spatiality (sense of space)	structure stability	Average
ST-1	6	4	3	3	6	5	3	4	3	5	4.2
ST-2	8	8	7	7	5	7	6	7	8	4	6.7
ST-3	6	7	3	4	5	6	5	7	6	6	5.5
ST-4	6	6	4	3	3	4	4	4	3	4	4.1
ST-5	7	6	4	3	6	5	5	4	4	6	5
ST-6	4	4	5	5	3	4	3	4	4	4	4
ST-7	8	7	8	8	7	8	7	7	7	7	7.4
ST-8	7	8	7	7	7	8	7	7	8	7	7.3
ST-9	5	6	6	4	4	5	4.5	5	4	5	4.5
ST-10	8	8	7	6	8	8	7	7	7	6	7.2
ST-11	8	8	7	7	6	8	6	8	6	6	7
ST-12	8	7	7	7	6	6	7	7	5	7	6.7
ST-13	5	4	6	5	4.5	3	4	3	3.5	4	4.2
ST-14	6	6	5	6	5	4	5	4.5	5	5	5.2
ST-15	5	4	7	6	3.5	4	4	5	4	3	4.6
ST-16	7	8	8	6	7	7	7	6.5	7	7	7.1
ST-17	8	8	7	7	7	8	7	7	7	7	7.3
ST-18	8	8	7	6	8	7	8	7	6.5	7.5	7.3
ST-19	8	8	7	7	8	8	8	8	7	6.5	7.6
ST-20	8	7	7	6	8	6.5	6	6.5	7	7	6.9
ST-21	5	5	4	4	3.5	3	4	3	4	5	4.1
ST-22	8	8	7	5	7	8	7.5	7.5	8	7	7.3
ST-23	5	5	4.5	4	5	6	6	4	4	5	4.9
ST-24	5	5	3.5	4	4.5	4	5	4	4	5	4.4

Table D5. Modelling evaluation skills criteria for METU's students/ Instructor-A2's evaluation.

Model-code	composition & typology	Selection of materials	status of the model in the site	relationship with neighbourhood	Expression	Scale	precision & accuracy	fairness of workshop (finishing)	spatiality (sense of space)	structure stability	Average
ST-1	4	4	3	3	6	5	5	4	4	4	4.2
ST-2	7	8	8	7	6	6	6.5	7	8	5	6.85
ST-3	5	5	3	4	5	6	5	4	4	4	4.5
ST-4	8	6	4	3	3	4	4	4	3	4	4.3
ST-5	6	6	4	3	6	5	5	4	4	4.5	4.75
ST-6	4	4	5	5	3	3	3	5	4	3	3.9
ST-7	8	6	8	8	7	8	7	7	6	7	7.2
ST-8	8	7	7	7	8	7	7.5	7	8	6.5	7.3
ST-9	5	6	5	4	4	5	4.5	4.5	4	4	4.6
ST-10	8	7.5	7	6.5	8	8	7	7	7	7	7.3
ST-11	8.5	7.5	7	6.5	7	8.5	7.5	8	6.5	7	7.4
ST-12	8	8	7	7	6	7	7.5	6.5	6	6.5	6.95
ST-13	4	3	6	5	4	3.5	3	3	4	4	3.95
ST-14	6	5	5	4.5	5	4	5	3	4	5	4.65
ST-15	5	4	3	5	3	3	4	5	4	3	3.9
ST-16	8	7	7.5	6.5	7	8	7	7	6	7	7.1
ST-17	8.5	8	8	6.5	6.5	8	7	7.5	7	7	7.4
ST-18	8	8	7	6	7	8	8	7	8	7	7.4
ST-19	8	8	6.5	7	8	7.5	8.5	8	6.5	7	7.5
ST-20	7	8	7.5	7	8	7	6.5	7	7	7	7.2
ST-21	4	4	4.5	3	3	4	4.5	3.5	4	4.5	3.9
ST-22	7.5	8	7.5	5.5	7	8	7.5	7.5	8	6.5	7.3
ST-23	4	4	5	3	4.5	5	5	4.5	4	4	4.3
ST-24	4	5	4	5	4	4	4	5	3	4	4.2

Table D6. Modelling evaluation skills criteria for METU's students/ Instructor-A3 evaluation.

Model-code	composition & typology	Selection of materials	status of the model in the site	relationship with neighbourhood	Expression	Scale	precision & accuracy	fairness of workshop (finishing)	spatiality (sense of space)	structure stability	Average
ST-1	5	4	4	4	5	4	4	5.5	4	4	4.35
ST-2	8	8	7.5	7.5	6	8	6.5	7	7	5	7.05
ST-3	6	4	3	3	4	5	4.5	4.5	5	4.5	4.35
ST-4	8	5	4	3	3	4	4	4	3	4	4.2
ST-5	7	6	4	3	6	5	5	4	4	6	5
ST-6	4	4	5	5	3	4	3	4	4	4	4
ST-7	8	7.5	8	8	7	8	7	7	7	7	7.45
ST-8	7	7	7	8	7	8	7	7	8	7	7.3
ST-9	5	6	5	4	4	5	4.5	5	4	5	4.75
ST-10	8	8	7	6	8	8	8	7	7	6	7.3
ST-11	8	7.5	7	7	6	8	6	8	6	6	6.95
ST-12	8	7	7	7	6	6	7	7	5	7	6.7
ST-13	5	3.5	6	5	4.5	3	4	3	3.5	4	4.15
ST-14	6	6.5	5	6	5	4	5	4.5	5	5	5.2
ST-15	5	4.5	7	6	3.5	4	4	5	4	3	4.6
ST-16	7	7.5	8	6	7	7	7	8	7	7	7.15
ST-17	8	7.5	7	7	7	8	7	7	7	7	7.25
ST-18	8	8	7	6	8	7	8	7	6.5	7.5	7.3
ST-19	8	7.5	7	7	8	8	8	8	7	6.5	7.5
ST-20	8	7.5	7	6	8	6.5	6	6.5	7	7	6.95
ST-21	5	4.5	4	4	3.5	4	4	3	4	5	4.1
ST-22	7.5	8.5	7	5	7	8	7.5	7.5	8	7	7.3
ST-23	4.5	6	4.5	4	5	5	6	4	4	5	4.8
ST-24	4	5	3.5	4	4.5	4	5	4	4	5	4.3

MODELS PHOTOGRAPHS OF METU'S STUDENTS

Figure D7. Models photographs of METU's students (samples 1-4)

Figure D8. Models photographs of METU's students (samples 5-8)

Figure D9. Models photographs of METU's students (samples 9-12)

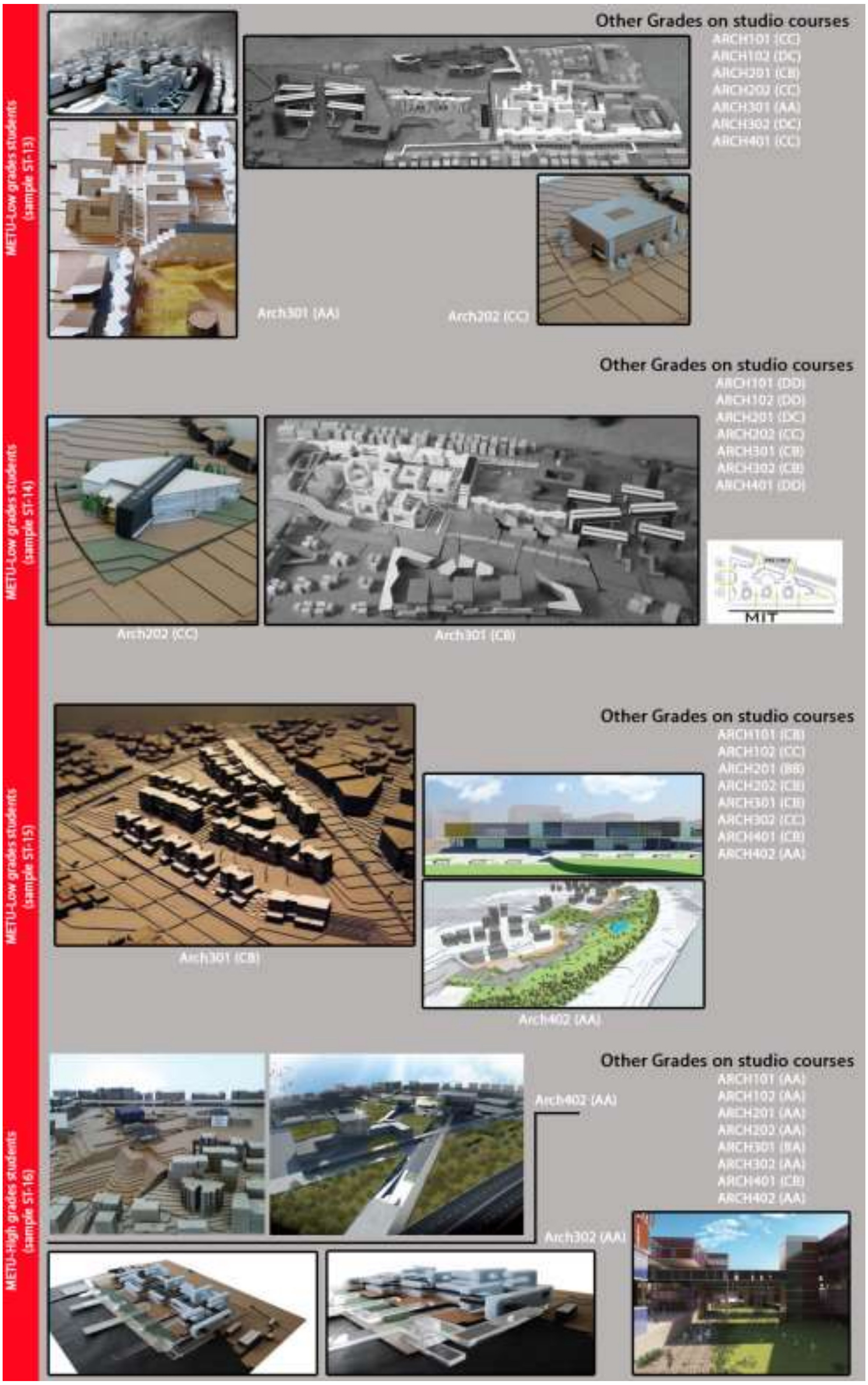


Figure D10. Models photographs of METU's students (sample 13-16)

Figure D11. Models photographs of METU's students (samples 17-19)

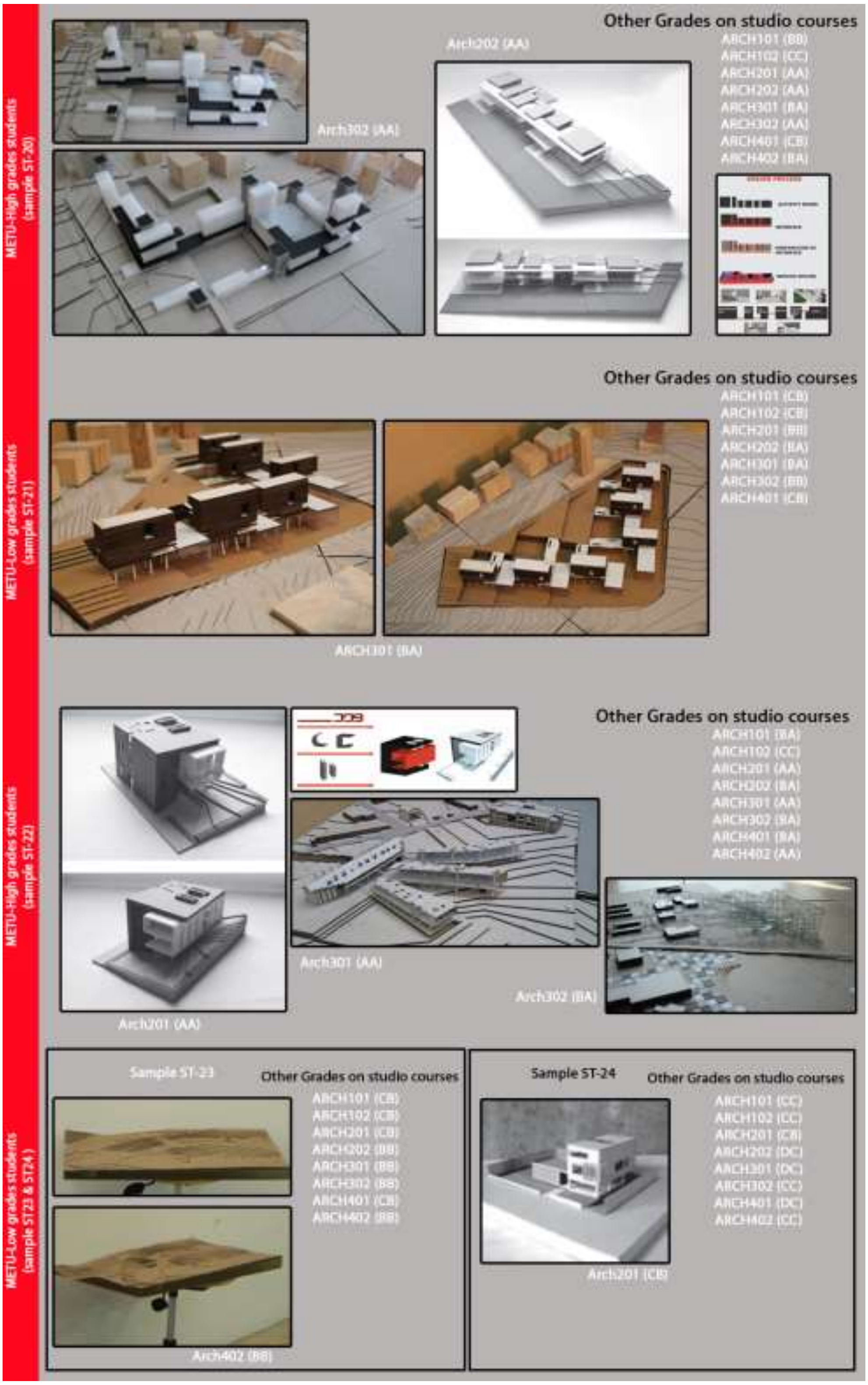


Figure D12. Models photographs of METU's students (samples 20-24)

SCATTER CHARTS USED FOR FURTHER CORRELATIONS ANALYSIS FOR METU'S STUDENTS

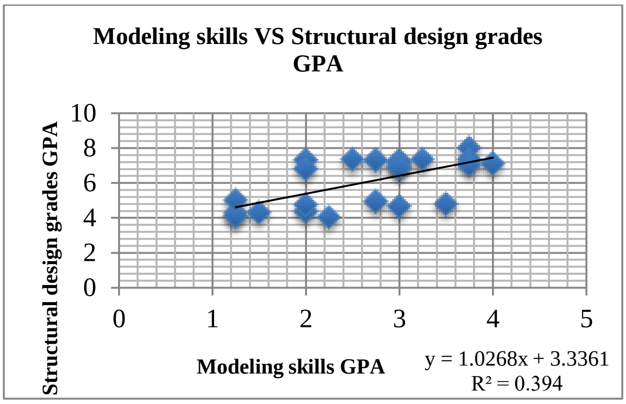


Figure D13. Correlation coefficient between modeling skills VS structural design grades GPA of METU's students.

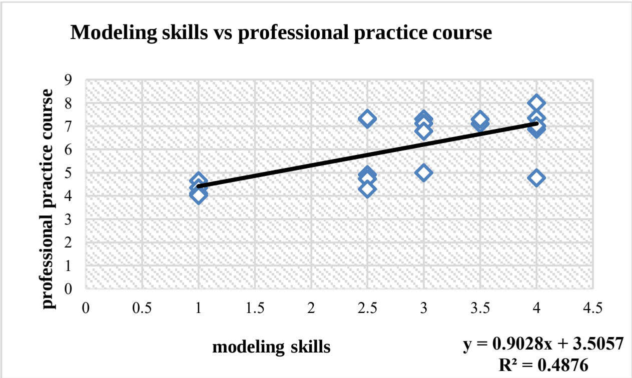


Figure D14. Correlation coefficient between modeling skills VS professional practice grades of METU's students.

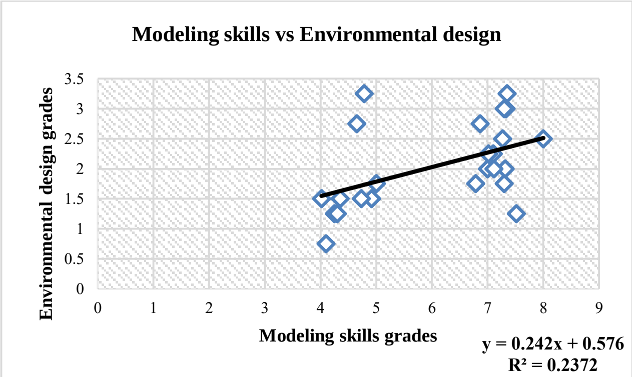


Figure D15. Correlation coefficient between modeling skills VS environmental design GPA of METU's students.

APPENDIX E

RAW DATA FOR UNIVERSITY OF BENGHAZI

(Courses that considered in the study analysis)

Table E1: Architectural Design Studio Courses codes allocated in University of Benghazi.

Architectural Design Studio Courses Included in the Analysis	
Course code	**Course name**
AC111	Bases of Design I
AC112	Architectural Design-II
AC211	Architectural Design-III
AC212	Architectural Design
AC311	Architectural Design
AC312	Architectural Design
AC411	Architectural Design
AC412	Architectural Design
AC511	Architectural Design
AC522	Final Project
AC162	Workshop & Photo

Table E2: Building science courses codes allocated in University of Benghazi

Building Science Courses Included in the Analysis	
Course codes	**Course name**
AC 131	Descriptive Geometry (I)
AC 132	Descriptive Geometry (II)
AC151	Properties of Materials (I)
AC 241	Architectural Expression (I)
AC 242	Architectural Expression (II)
AC 251	Building Technology (I)
AC 252	Building Technology (II)
AC 222	Domestic Architecture
AC 262	Acoustics
AC 272	Air- conditioning
AC 361	Environmental Control (I)
AC 362	Environmental Control (II)
AC 381	Computer Aided Design (AutoCAD)
AC 352	Implementation drawings
AC 382	Computer Aided Design (AutoCAD 3D)
AC 431	Quantities & specifications
AC 441	Architectural Expression Using Computer
AC 452	Building Restoration
AC 541	Steel Structures

Table E3. Collected data and instructors' comments for the students enrolled in the experimental studio course (AC311) in University of Benghazi accompanied with students modeling skills.

Cases ST-codes	Instructors comments (1 & 2)	Modeling skills
ST-16	Very weak student. She has a problem in 3D manipulations tasks. Weak in	**4.76**
ST-7	Intrepid Student, she is Very patient and hardworking.	**6.5**
ST-14	Hardworking student,	**5.55**
ST-6	Below the average	**6.28**
ST-4	Steady student.	**7.26**
ST-19	Below the average & Unstable student.	**5.18**
ST-5	Among the best students in school	**5.22**
ST-8	Talented student, she has a good design approach.. Good in creating hand-	**6.38**
ST-20	She is among the outstanding students, intrepid in expressing her design	**6.55**
ST-2	Below the average cannot be regarded as talented student.	**6.05**
ST-17	Very normal. Quite traditional, despite her hand skills	**4.94**
ST-1	Above the average. Skilled and Talented student.	**8.16**
ST-12	Among the best students in school. Talented & very skilled student, very	**7.7**
ST-3	Hard-working student, but he is considered among the average level.	**6.55**
ST-13	Creative student, but she needs to trust herself. Her hand-skills need to be	**6.27**
ST-10	She has a good vision of design, diligent and perseverance.	**6.24**
ST-15	below the average	**5.81**
ST-9	Weak student, lazy and she have a limited design vision.	**5.3**
ST-11	Normal student Lacks the Competitive spirit in design.	**6**
ST-18	Hard-working students, has the spirit of challenge to overcome design	**6.2**

Table E4. (Continued) Collected grades for design studio, modeling course, GPA and CGPA for the students enrolled in the experimental studio course in University of Benghazi.

ST-codes	Gender	Nationality	Model	CGPA	GPA	AC111	AC112	AC211	AC212	AC311	AC312	AC411	AC412	AC511	AC522	AC162
ST-16	F	IRAG	Photographed	1.92	1.86	1	2.5	1	3	0						1.5
ST-7	F	LIBYA	Photographed	3.17		3	3.5	2.5	3	3.5						W
ST-14	F	LIBYA	Photographed	2.7		3	3	3.5	3	4						4
ST-6	F	LIBYA	Photographed			3	2	3		3						2
ST-4	F	LIBYA	Photographed			3	3	3		3.5						4
ST-19	F	LIBYA	Photographed	2.22		3	2.5	3		3						4
ST-5	F	LIBYA	Photographed	3.73	3.96	3.5	4	4		4						4
ST-8	F	LIBYA	Photographed	3.06		3	3.5	3	4	4						3.5
ST-20	F	LIBYA	Photographed	2.92		2.5	3.5	3	3.5	4						4
ST-2	M	LIBYA	Photographed	1.89		3.5	2.5	2.5	2	3.5						2.5
ST-17	F	LIBYA	Photographed	2.55		3.5	3	3.5	3	4						4
ST-1	M	LIBYA	Photographed	3.5		3	4	3.5	4	4						4
ST-12	M	LIBYA	Photographed	3.9	3.96	4	4	4	4	4						4
ST-3	M	LIBYA	Photographed	3.01		3.5	3.5	4		4						4
ST-13	F	LIBYA	Photographed	2.27		2	2.5	3	1.5	3						3
ST-10	F	LIBYA	Photographed		2.2	1	2	2.5	2	4						3.5
ST-15	F	LIBYA	Photographed			2	2.5	1.5		3						3
ST-9	F	LIBYA	Photographed	1.83		2	2.5	2.5	2.5	0.5						1.5
ST-11	F	LIBYA	Photographed	2.21		2	2.5	2.5	2	2.5						
ST-18	F	LIBYA	Photographed							2						

Table E5. (Continued) Collected grades for building science courses for the students enrolled in the experimental studio course in University of Benghazi.

ST-CODES	AC 131	AC 132	AC 141	AC 142	AC 151	AC 241	AC 242	AC 251	AC 252	AC 351	AC 222	AC 262	AC 271	AC 272	AC 341	AC 342	AC 361	AC 362	AC 381	AC 322	AC 351	AC 352	AC 382	AC 441
ST-16																								
ST-7	3	3.5	2.5	3	3.5	3	4	4	3		2	3.5	1.5	2.5					3.5					4
ST-14	1.5	0.5	0.5	3	1.5	2.5	3.5	3	3		2	1.5	1						3					3.5
ST-6																								
ST-4																								
ST-19	2	2	1.5	2.5	2.5	1.5		3					0.5											
ST-5	4	0.5	3.5	3.5	4	3.5	4	3.5	4		3.5	4	4	4										4
ST-8	3	3.5	2.5	3	2	3	4	3	3		3.5	3.5	3	3										4
ST-20	2	3.5	2	2	3.5	2	4	2.5	3.5			2.5	4	3										3.5
ST-2	0.5	3	2	1.5	0.5			2																
ST-17	1.5	3	4	3.5	1.5	3.5	3.5	2	1.5			2.5	1.5											
ST-1	1.5	4	2	4	4	3.5	4	3.5	4		3.5		3.5	3.5					4					
ST-12	4	4	3	3.5	4	4	4	4	4			4	4	4										4
ST-3	2	2	3	3	3	2.5		1.5	3															
ST-13	2	1	4	2.5	2.5	3.5	4	2.5	2		2	0.5	0.5						2					
ST-10																								
ST-15																								
ST-9	0.5	4	3.5	1.5	0.5	2	3	1.5	2			0.5	1											
ST-11	1.5	3	0.5	3	0.5	3.5		3.5	2				2											
ST-18																								

Table E6. Modelling evaluation skills criteria for the students of Benghazi University (Instructor-B1 evaluation)

NO	Model-code	composition & typology	Selection of materials	Status of the model in the site	Expression	Scale	precision & accuracy	fairness of workshop (finishing)	spatiality (sense of space)	structure stability	Average
1	**ST-1**	6	7	5	8	8	8	7	7	8	7.11
2	**ST-2**	8	7	6	6	7	7	8	6	5	6.67
3	**ST-3**	6	7	5	6	7	6	7	7	6	6.33
4	**ST-4**	8	9	7.5	8.5	7	7	7	8	7	7.67
5	**ST-5**	5	8	6	5	6	4.5	6	5	5	
6	**ST-6**	6	7	6	6	7	6.5	8	6	7	6.61
7	**ST-7**	8	7	6	7	6	6	7	6	5.5	6.50
8	**ST-8**	7	7	7	7.5	7	6	5	6	6.5	6.56
9	**ST-9**	4	6	5	4	6	5	5	6	6.5	5.28
10	**ST-10**	8	8	7	6	6	5	7	7	6	6.67
11	**ST-11**	6	7	5	6	6	4	7	8	5	6
12	**ST-12**	8	8	8	9	7	9	7	8	8	8
13	**ST-13**	6	7	7	6	7	4.5	6	5	6	6.06
14	**ST-14**	6	6	6	6	7	5	6	6	6	6
15	**ST-15**	6.5	7	6	5	7	6	6	6.5	7	6.33
16	**ST-16**	5	7	5	5	3	4	6	4	4	4.78
17	**ST-17**	5	6	5	6	3	5	7	5	5	5.22
18	**ST-18**	6	8	8	5	7	4	7	5	6	6.22
19	**ST-19**	5	7	6	6	6	4	5	6	5	5.56
20	**ST-20**	8	8	7	7	6	6	7	7	7	7

Table E7. Modelling evaluation skills criteria for the students of Benghazi University (Instructor-B2 evaluation)

NO	Model-code	composition & typology	Selection of materials	Status of the model in the site	Expression	Scale	precision & accuracy	fairness of workshop (finishing)	spatiality (sense of space)	structure stability	Average
1	**ST-1**	5	5	6	7	7	7	6	7	7	6.33
2	**ST-2**	5	6	5	4	6	8	6	5	7	5.78
3	**ST-3**	6	6	7	7	7	7	6	7	7	6.67
4	**ST-4**	8	8	6	8	7	6	7	7	6	7
5	**ST-5**	6	5	4	5	5	3	4	5	6	4.78
6	**ST-6**	6	5	6	6	6	5	6	7	7	6
7	**ST-7**	8	7	6	6	5	6	7	6	7	6.44
8	**ST-8**	7	5	6	7	6	6	6	7	6	6.22
9	**ST-9**	5	4	4	4	5	4	4	6	6	4.67
10	**ST-10**	7	6	6	5.5	6	5	5	7	7	6.06
11	**ST-11**	8	5	5	6	4	6	5	8	5	5.78
12	**ST-12**	8	6	8	9	8	7	9	8.5	8	7.94
13	**ST-13**	6	7	6	6.5	5	7	8	6	8	6.61
14	**ST-14**	6	5	5	5.5	5	7	5	5.5	6	5.56
15	**ST-15**	5	6	6	6	6.5	4	6	6	8	5.94
16	**ST-16**	4	6	5	4	3	5	6	4	8	5
17	**ST-17**	5	5	4	4	6	4	6	6	5	5
18	**ST-18**	6.5	7	5	6	6.5	5	6	5.5	5	5.83
19	**ST-19**	5.5	5	5	4	5.5	4	5	6	6	5.11
20	**ST-20**	7	7	6.5	7	6	6.5	7	7	7	6.78

Table E8. Modelling evaluation skills criteria for the students of Benghazi University (Instructor-B3 evaluation)

NO	Model-code	composition & typology	Selection of materials	Status of the model in the site	Expression	Scale	precision & accuracy	fairness of workshop (finishing)	spatiality (sense of space)	structure stability	Average
1	**ST-1**	6	6	6	7	6.5	5.5	6	6.5	6.5	6.22
2	**ST-2**	5	6	5	5.5	6	6	6	5.5	6.5	5.72
3	**ST-3**	6.5	7	6.5	7	7	6	6.5	7	6.5	6.67
4	**ST-4**	8	7.5	7	8	6.5	6	6.5	7.5	7	7.11
5	**ST-5**	5.5	7	5	4.5	4	6	5	5	5.5	5.28
6	**ST-6**	7	7	6	5.5	5.5	7	6	6	6	6.22
7	**ST-7**	6.5	6	5.5	6.5	5	5.5	6	6	6	5.89
8	**ST-8**	6.5	6.5	6	6.5	7	6	5.5	7	6.5	6.39
9	**ST-9**	4	5.5	4.5	4	5	6	5	4.5	5	4.83
10	**ST-10**	6	6	5.5	6.5	6	5.5	5	7	6.5	6
11	**ST-11**	6	6	4.5	5	5	5.5	5	5.5	5	5.28
12	**ST-12**	8	6.5	7	8	7.5	6.5	6	7	8	7.17
13	**ST-13**	6.5	6.5	6	7	6	6	5	6	6.5	6.17
14	**ST-14**	4	5	5.5	5	5.5	5	5.5	5	5.5	5.11
15	**ST-15**	5	6.5	5	5.5	6	4	3.5	5.5	5.5	5.17
16	**ST-16**	3.5	4	4.5	4	5	5	5	5	4.5	4.5
17	**ST-17**	4	5	4.5	4	5	4.5	5	5	4.5	4.61
18	**ST-18**	6	7	5.5	6	6	6	4.5	5	5.5	5.72
19	**ST-19**	5.5	5	5	5.5	5	4	4	5	5	4.89
20	**ST-20**	6.5	6.5	6	6.5	6	4.5	4.5	6.5	6	5.89

Table E9. Modeling skills evaluation average for the students of Benghazi University

CASES Model-code	Average (Inst-B1)	Average (Inst-B2)	Average (Inst-B3)	Overall (AVERAGE)
ST-1	7.11	6.33	11.05	**8.16**
ST-2	6.66	5.77	5.72	**6.05**
ST-3	6.33	6.66	6.66	**6.55**
ST-4	7.66	7	7.11	**7.26**
ST-5	5.61	4.77	5.27	5.22
ST-6	6.61	6	6.22	**6.28**
ST-7	6.5	6.44	5.88	**6.278**
ST-8	6.55	6.22	6.38	**6.388**
ST-9	5.27	4.66	4.83	4.92
ST-10	6.66	6.05	6	**6.24**
ST-11	6	5.77	5.27	5.68
ST-12	8	7.94	7.16	**7.7**
ST-13	6.05	6.61	6.16	**6.27**
ST-14	6	5.55	5.11	5.55
ST-15	6.33	5.94	5.16	5.81
ST-16	4.77	5	4.5	4.76
ST-17	5.22	5	4.61	4.94
ST-18	6.22	5.83	5.72	5.92
ST-19	5.55	5.11	4.88	5.18
ST-20	7	6.77	5.88	**6.55**

MODELS PHOTOGRAPHS OF UNİVERSİTY OF BENGHAZİ STUDENTS

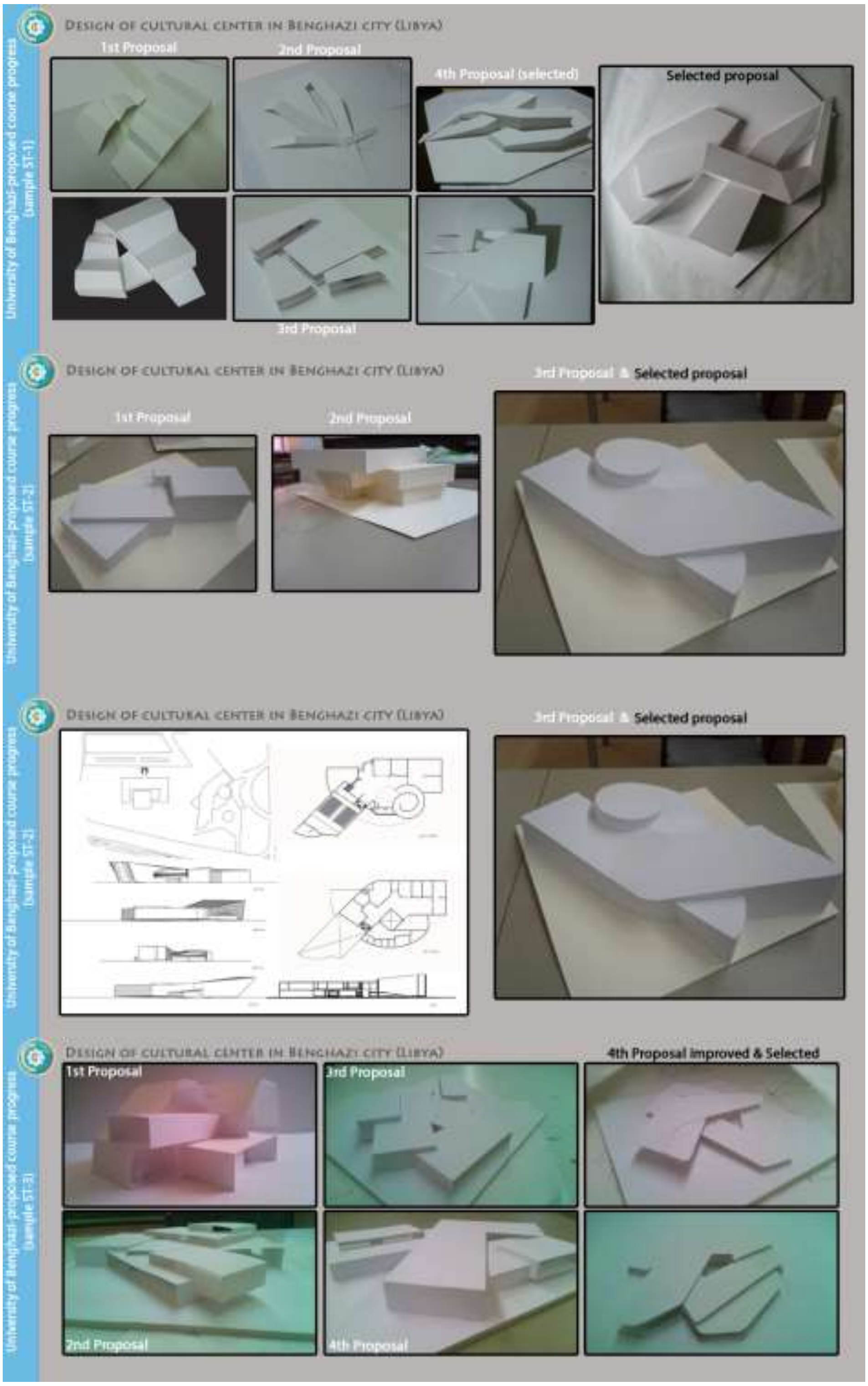


Figure E10. Models photographs of the University of Benghazi's students (samples 1-3)

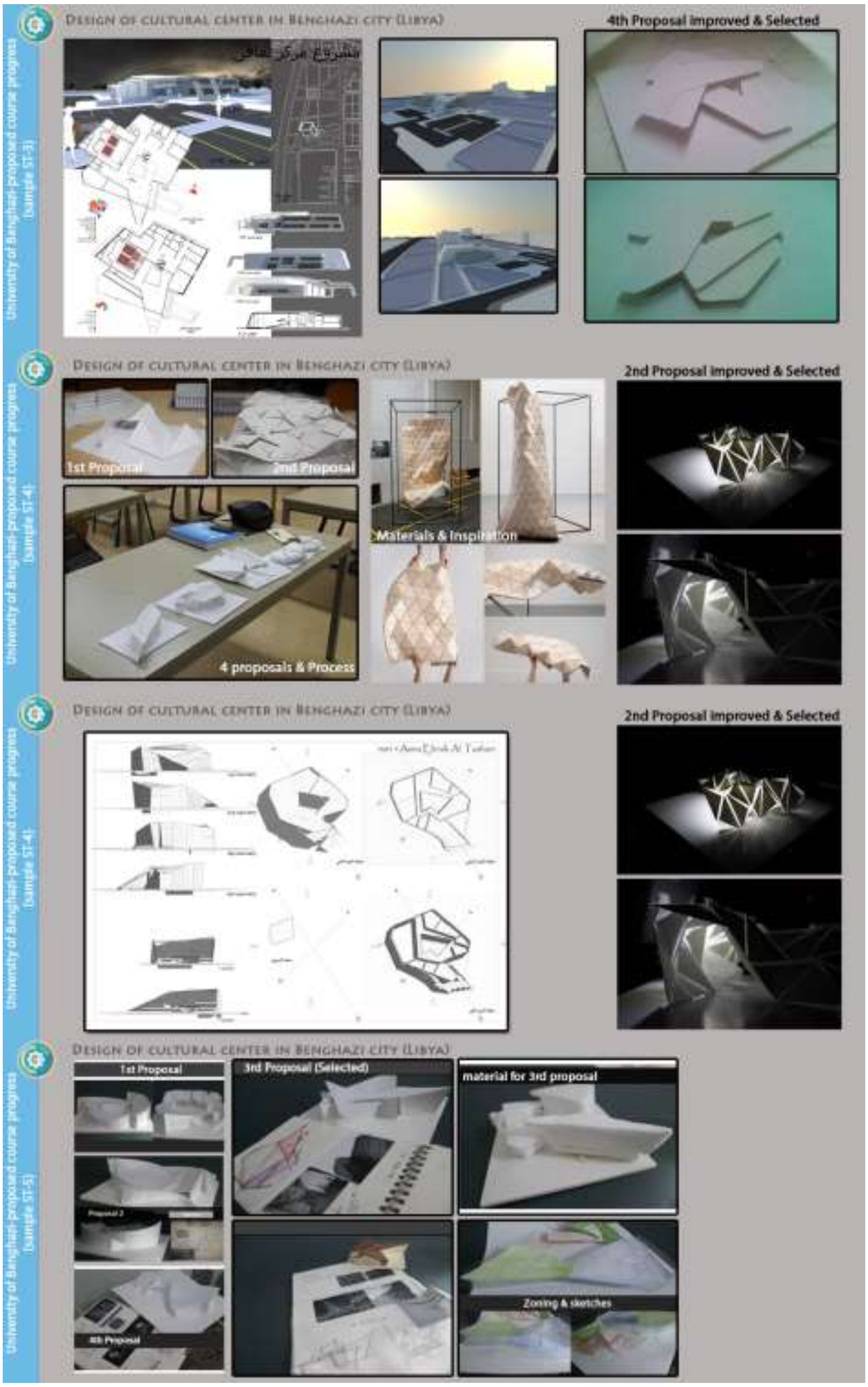


Figure E11. Models photographs of the University of Benghazi's students (samples 3-5)

Figure E12. Models photographs of the University of Benghazi's students (samples 5-7)

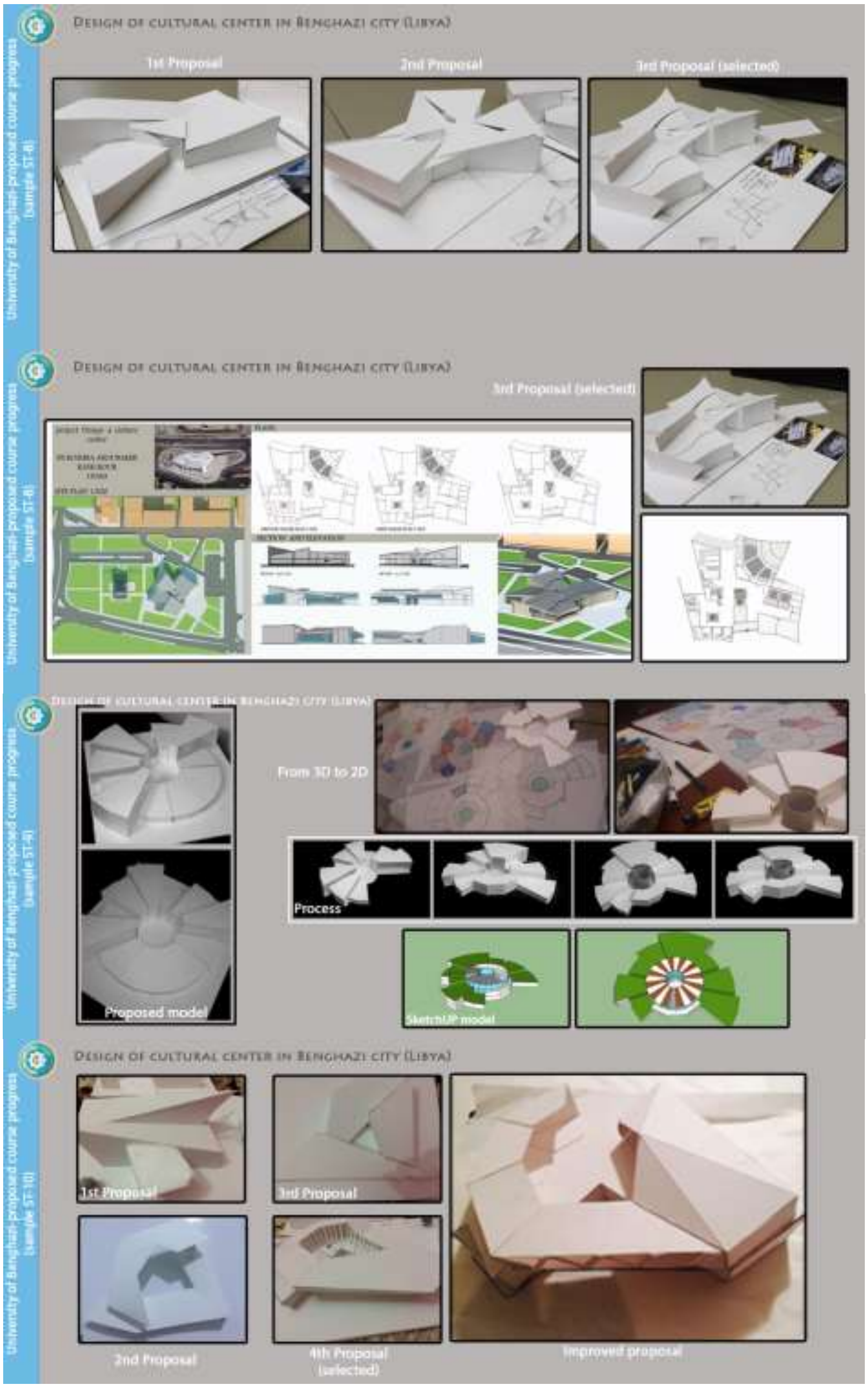


Figure E13. Models photographs of the University of Benghazi's students (samples 8-10)

Figure E14. Models photographs of the University of Benghazi's students (samples 11-13)

Figure E15. Models photographs of the University of Benghazi's students (samples 14-16)

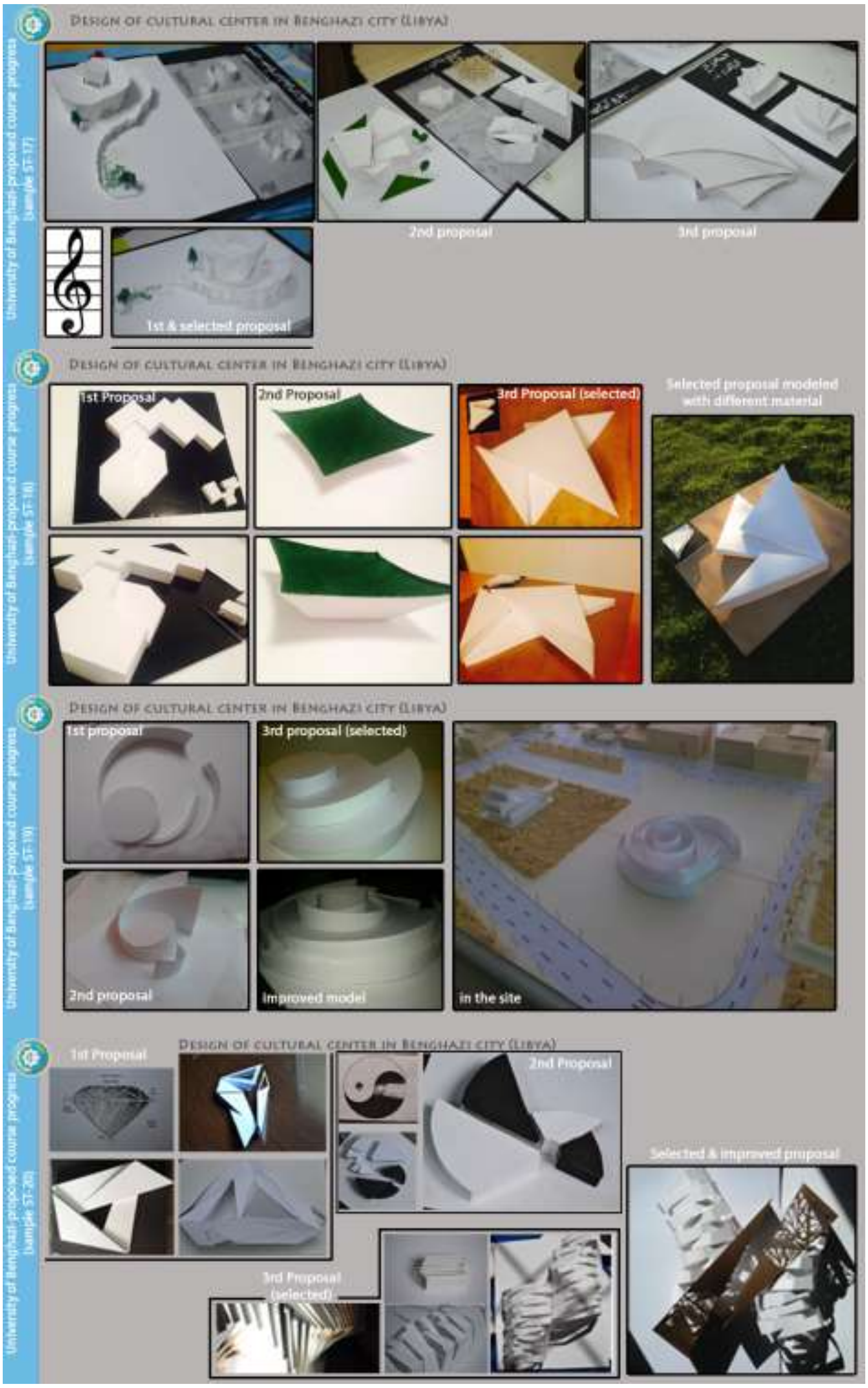


Figure E16. Models photographs of the University of Benghazi's students (samples 17-20)

RAW DATA USED FOR THE CORRELATION ANALYSIS FOR THE UNIVESITY OF BENGHAZI'S STUDENTS

Table E10. Raw data for design studio GPA and building science courses GPA for the students of Benghazi University

Sample-codes	Design Courses GPA	Building Science GPA
ST-7	3.1	3.1
ST-14	3.3	2.14
ST-19	2.88	1.95
ST-5	3.88	3.57
ST-8	3.5	3.14
ST-20	3.3	2.92
ST-2	2.8	1.58
ST-17	3.4	2.55
ST-1	3.7	3.46
ST-12	4	3.88
ST-3	3.75	2.5
ST-13	2.4	2.23
ST-9	2	1.82
ST-11	2.3	2.17

Table E11. Raw data for design studio GPA (DSGPA), building science GPA (BSGPA and modeling skills grade GPA that used in the correlation analysis for the students of Benghazi students.

ST-codes	DSGPA	BSGPA	modeling skills
ST-7	3	3.29166667	**6.5**
ST-14	3.125	2.31818182	**5.5533333**
ST-19	2.83333333	2.2	**5.18**
ST-5	3.83333333	3.54545455	**5.2166667**
ST-8	3.375	3.22727273	**6.3833333**
ST-20	3.125	3	**6.55**
ST-2	2.625	1.5	**6.05**
ST-17	3.25	2.375	**4.9433333**
ST-1	3.625	3.55	**8.1633333**
ST-12	4	4	**7.7**
ST-3	3.66666667	2.33333333	**6.55**
ST-13	2.25	2.2	**6.2733333**
ST-9	2.375	1.75	**5.3**
ST-11	2.25	2.33333333	**6**

Table E12. Raw data used for the correlation analysis between design studio courses GPA before and after the conduction of experimental studio along with modeling skills GPA.

Modeling Skills Grades VS Design Studio GPA				
NO	**Sample code**	**Modeling skills**	**Design Studio GPA/Before**	**Design Studio GPA/After**
1.	ST-16	4.756666667	1.88	1.5
2.	ST-7	6.5	3	3.1
3.	ST-14	5.553333333	3.13	3.3
4.	ST-6	6.276666667	2.67	2.75
5.	ST-4	7.256666667	3	3.125
6.	ST-19	5.18	2.83	2.875
7.	ST-5	5.216666667	3.83	3.875
8.	ST-8	6.383333333	3.38	3.5
9.	ST-20	6.55	3.13	3.3
10.	ST-2	6.05	2.63	2.8
11.	ST-17	4.943333333	3.25	3.4
12.	ST-1	8.163333333	3.63	3.7
13.	ST-12	7.7	4	4
14.	ST-3	6.55	3.67	3.75
15.	ST-13	6.273333333	2.25	2.4
16.	ST-10	6.236666667	1.88	2.3
17.	ST-15	5.81	2	2.25
18.	ST-9	5.3	2.38	2
19.	ST-11	6	2.25	2.3
20.	ST-18	6.2	-	-

Table E13. Raw data used for the correlation analysis between modeling skills grades and the experimental studio course grades (AC311).

The 20 students enrolled in design studio AC311					
NO	Sample code	Course code	Modeling skills	AC311/ decimal	AC311 grades
1	ST-16	AC311	4.76	2.86	0
2	ST-7	AC311	6.5	8.71	3.5
3	ST-14	AC311	5.55	9.43	4
4	ST-6	AC311	6.28	8.43	3
5	ST-4	AC311	7.26	8.71	3.5
6	ST-19	AC311	5.18	8.29	3
7	ST-5	AC311	5.22	9.29	4
8	ST-8	AC311	6.38	9.14	4
9	ST-20	AC311	6.55	9.57	4
10	ST-2	AC311	6.05	8.71	3.5
11	ST-17	AC311	4.94	9.14	4
12	ST-1	AC311	8.16	9.71	4
13	ST-12	AC311	7.7	9.57	4
14	ST-3	AC311	6.55	9.57	4
15	ST-13	AC311	6.27	8	3
16	ST-10	AC311	6.24	9.29	4
17	ST-15	AC311	5.81	8.14	3
18	ST-9	AC311	5.3	5.3	0.5
19	ST-11	AC311	6	7.86	2.5
20	ST-18	AC311	6.2	7.33	2

Table E14. Raw data used for the correlation analysis between modeling skills grades and workshop & photo course grades.

Modeling Skills VS Modeling course (AC162)			
No	Sample code	Modeling skills	Modeling course (AC162)
1	ST-16	4.76	1.5
2	ST-14	5.55	4
3	ST-6	6.28	2
4	ST-4	7.26	4
5	ST-19	5.18	4
6	ST-5	5.22	4
7	ST-8	6.38	3.5
8	ST-20	6.55	4
9	ST-2	6.05	2.5
10	ST-17	4.94	4
11	ST-1	8.16	4
12	ST-12	7.7	4
13	ST-3	6.55	4
14	ST-13	6.27	3
15	ST-10	6.24	3.5
16	ST-15	5.81	3
17	ST-9	5.3	1.5

Table E15. Design courses GPA & Building science GPA for University of Benghazi's students.

NO	Student/Sample codes	Design courses GPA	Building science GPA
1.	**ST-7**	3.1	3.1
2.	**ST-14**	3.3	2.14
3.	**ST-19**	2.88	1.95
4.	**ST-5**	3.88	3.57
5.	**ST-8**	3.5	3.14
6.	**ST-20**	3.3	2.92
7.	**ST-2**	2.8	1.58
8.	**ST-17**	3.4	2.55
9.	**ST-1**	3.7	3.46
10.	**ST-12**	4	3.88
11.	**ST-3**	3.75	2.5
12.	**ST-13**	2.4	2.23
13.	**ST-9**	2	1.82
14.	**ST-11**	2.3	2.17

Table E16. Students grades for Architectural Expression I, II and their modeling skills.

No	Student/Sample codes	Architectural Expression I	Architectural Expression II	Grades Average	Modelling skills
1.	**ST-7**	3	4	**3.5**	**6.5**
2.	**ST-14**	2.5	3.5	**3**	**5.55**
3.	**ST-5**	3.5	4	**3.75**	**5.22**
4.	**ST-8**	3	4	**3.5**	**6.38**
5.	**ST-20**	2	4	**3**	**6.55**
6.	**ST-17**	3.5	3.5	**3.5**	**4.94**
7.	**ST-1**	3.5	4	**3.75**	**8.16**
8.	**ST-12**	4	4	**4**	**7.7**
9.	**ST-13**	3.5	4	**3.75**	**6.27**
10.	**ST-9**	2	3	**2.5**	**5.3**

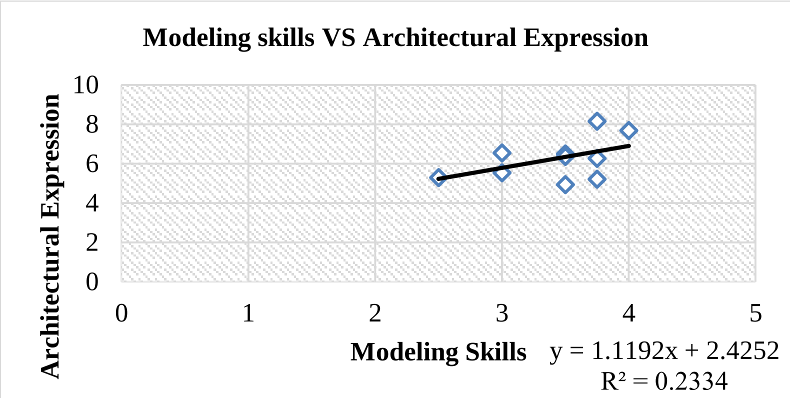


Figure E17. Correlation coefficient between modeling skills GPA VS architectural expression GPA for the students of Benghazi University.

Table E17. Sorted grades of the 18 students whose modelling skills are evaluated and taken the properties of materials I for the students of Benghazi University.

Modeling skills grades VS Properties of Materials I (AC151)			
NO	**Sample code**	**Modeling skills**	**Properties of Materials I (AC151)**
1	**ST-16**	4.756666667	-
2	**ST-7**	6.5	3.5
3	**ST-14**	5.553333333	1.5
4	**ST-6**	6.276666667	-
5	**ST-4**	7.256666667	-
6	**ST-19**	5.18	2.5
7	**ST-5**	5.216666667	4
8	**ST-8**	6.383333333	2
9	**ST-20**	6.55	3.5
10	**ST-2**	6.05	0.5
11	**ST-17**	4.943333333	1.5
12	**ST-1**	8.163333333	4
13	**ST-12**	7.7	4
14	**ST-3**	6.55	3
15	**ST-13**	6.273333333	2.5
16	**ST-10**	6.236666667	-
17	**ST-15**	5.81	-
18	**ST-9**	5.3	0.5
19	**ST-11**	**6**	**0.5**
20	**ST-18**	**6.2**	-

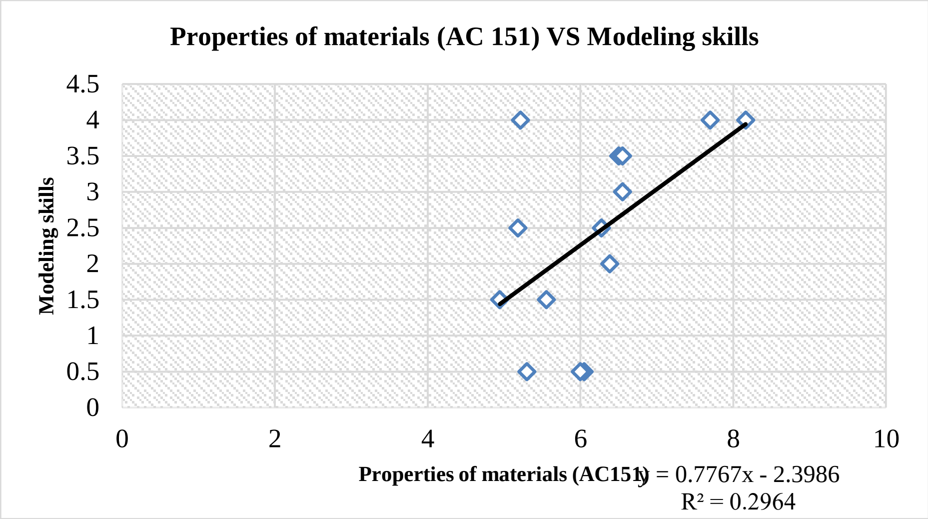


Figure E18. Correlation coefficient between modeling skills grades VS properties of materials I for the students of Benghazi University.

APPENDIX F

RAW DATA FOR ELMERGIB UNIVERSITY.

(Course that considered in the study analysis)

Table F1. Architectural Design Studio Courses codes allocated in Elmergib University.

Architectural Design Studio Courses Included in the Analysis	
Course code	**Course name**
AR111	Basic design I
AR212	Basic design II
AR213	Arch-Design studio I
AR314	Arch-Design studio II
AR315	Arch-Design studio III
AR416	Arch-Design studio IV
AR417	Arch-Design studio V
AR518	Arch-Design studio VI
AR214	Basic of model-making
AR213-M	Model-making

Table F2. Building Science Courses codes allocated in Elmergib University.

Building Science Courses Included in the Analysis	
Course code	**Course name**
GE121	Geometric drawing
AR141	Arch-drawing
AR224	Building materials
AR221	Building construction-I
AR213ML	Computer Aided Design (AutoCAD)
AR261	Geometric shadow
AR222	Building construction-II
AR262	Perspective
CE211	Properties of materials
AR323	Building construction-III
CE371	Sanitary
CE309	Strength of materials
AR324	Building construction-IV
AR335	Local Architecture
AR425	Implementation drawings-I
EE400	Lighting & Acoustics
CE422	Steel structures
AR426	Implementation drawings-II
AR401	Quantity & Specifications
ME521	Air-conditioning
AR490	Environmental control

Table F3. Collected data and grades for Elmergib University's students: the table presents the instructors comments and the followed grades for the selected students.

CASE According to the sequence	Instructors comments (3 instructors)	Note	ST-codes	Gender	Nationality	Model
1					Libyan	
2					Libyan	
3					Libyan	
4					Libyan	
5					Libyan	
6					Libyan	
7					Libyan	
8					Libyan	
9					Sudan	
10					Libyan	
11					Libyan	
12					Libyan	
13					Libyan	
14					Mauritania	
15					Libyan	
16					Libyan	
17					Libyan	
18					Libyan	
19					Egypt	
20					Libyan	
21					Libyan	
22					Libyan	
23					Sudan	
24					Libyan	
25					Libyan	
26					Libyan	
27					Libyan	
28	Too lazy student. Careless, needs a special follow-up	**enrolled in AR518**	**ST-5**	M	Libyan	Physical
29					Libyan	

30					Iraq	
31					Libyan	
32	She is a hard-working student, but was not good in modeling techniques.	**enrolled in AR417**	**ST-1**	F	Libyan	Physical
33	Extremely talented, ideal and the best among her group.	**enrolled in AR417**	**ST-5**	F	Libyan	Physical
34					Libyan	
35	Very weak student, careless.	**enrolled in AR417**	**ST-3**	M	Libyan	Physical
36				M	Libyan	
37				M	Libyan	
37	Talented student, fearless, she has acceptable hand-skills.	**enrolled in AR417**	**ST-4**	F	Libyan	Physical
38	Very weak, lazy and careless student.	**enrolled in AR417**	**ST-7**	M	Libyan	Physical
39	Serious student, but he doe not offer many design options.	**enrolled in AR417**	**ST-2**	M	Libyan	Physical
40	Above the average	**enrolled in AR417**	**ST-6**	F	Libyan	Physical
41					Libyan	
42					Libyan	
43					Libyan	
44					Libyan	
45					Iraq	
46					Libyan	
47					Libyan	
48					egypt	
49					Libyan	
50					Libyan	
51					Libyan	
52					Libyan	
53					Libyan	
54					Libyan	
55					Sudan	
56	Below the average.	**enrolled in AR518**	**ST-**	M	Libyan	Physical
57	Very careless student needs to be pushed hard.	**enrolled in AR518**	**ST-**	M	Libyan	Physical
58	He is very weak, he has very poor hand skills in drawing and modeling.	**enrolled in AR518**	**ST-16**	M	Libyan	Physical

59	Below the average.	**enrolled in AR518**	**ST-6**	M	Libyan	Physical
61	A unique student, never satisfied with what he achieved, always thinks in details.	**enrolled in AR518**	**ST-4**	M	Libyan	Physical
62	Below the normal level, needs to improve his hand-skills. Very bad in model making.	**enrolled in AR518**	**ST-2**	M	Libyan	Physical
63				F	Libyan	Physical
64	Normal student, very typical student.	**enrolled in AR518**	**ST-7**	M	Libyan	Physical
65	Ambitious student but missing concentration	**enrolled in AR518**	**ST-3**	M	Libyan	Physical
66	Too typical. Can be classified as normal student.	**enrolled in AR518**	**ST-**	M	Libyan	Physical
67	Normal student. He never submitted a model for his projects.	**enrolled in AR518**	**ST-9**	M	Libyan	Physical
68	one of the best students, very hard working	**enrolled in AR518**	**ST-1**	M	Libyan	Physical
69	Normal student, lazy, despite his hand skills in modeling.	**enrolled in AR518**	**ST-13**	M	Libyan	Physical
70	average student	**enrolled in AR518**	**ST-**	M	Libyan	Physical
71				M	Sudan	
72	She has the tendency to overcome the design difficulties. She also has a good skill in making physical models.	**enrolled in AR518**	**ST-11**	F	Libyan	Physical
73	Student relatively active, trying to prove himself.	**enrolled in AR518**	**ST-8**	M	Libyan	Physical
74	Disciplined student, but he needs to trust himself. Trying to learn the modeling skills.	**enrolled in AR315**	**ST-5**	M	Libyan	Physical
75	Hard-working student, always looking for innovation	**enrolled in AR315**	**ST-6**	M	Libyan	Physical
76	Creative student but he lacks some modeling techniques to	**enrolled in AR315**	**ST-8**	M	Libyan	Physical
77	He is the best among the group, very skilled, talented and creative. He is different from the group.	**enrolled in AR315**	**ST-7**	M	Libyan	Physical
78	He has different design approach, never satisfied with what he achieve. However, need to improve his modeling skills.	**enrolled in AR315**	**ST-9**	M	Libyan	Physical
79	very weak student.	**enrolled in AR315**	**ST-1**	M	Libyan	Physical
80	Among the best student in the group, creative and busy student, but he lacks presentation techniques.	**enrolled in AR315**	**ST-2**	M	Libyan	Physical
81	normal student	**enrolled in AR315**	**ST-3**	M	Libyan	Physical
82	Very serious student, planned and hard-working.	**enrolled in AR315**	**ST-4**	M	Libyan	Physical
74					Libyan	
75					Libyan	

76					Libyan	
77					Iraq	
78					Libyan	
79					Libyan	
80					Libyan	
81					Libyan	
82					Libyan	
83					Libyan	
84					Libyan	
85					Libyan	
86					Egypt	
87					Libyan	
88					Libyan	
89					Libyan	
90					Libyan	
91					Libyan	
92					Libyan	
93					Libyan	
94					Iraq	
95					Libyan	
96					Libyan	
97					Libyan	
98					Mauritania	
99					Libyan	
100					Libyan	
101					Libyan	
102					Libyan	
103					Libyan	
104					Egypt	
105					Libyan	
106					Libyan	
107					Libyan	
108					Libyan	
109					Libyan	
110					Libyan	
111					Libyan	

112					Sudan	
113					Libyan	
114					Libyan	
115					Libyan	
116					Libyan	
117					Iraq	
118					Libyan	
119					Egypt	
120					Libyan	
121					Libyan	
122					Libyan	
123					Libyan	
124					Libyan	
125					Sudan	
126					Libyan	
127					Libyan	
128					Libyan	
129					Mauritania	
130					Libyan	
131					Libyan	
132					Libyan	
133					Libyan	
134					Libyan	
135					Egypt	
136					Libyan	
137					Libyan	
138					Libyan	
139					Libyan	
140					Libyan	
141					Libyan	
142					Libyan	
143					Libyan	

Table F4. (Continued) Design studio grades and model making course grades

CASE	Design studio								
	AR111	AR212	AR213	AR314	**AR315**	AR416	**AR417**	**AR518**	AR214
1	56		54	50	62		55	56	
2	56	50	53	67	68		55	75	
3			42						
4	60	60	38	50	62	66	67	55	
5	58	50	62	50	57		60	76	
6	55	64	67	80		67	74	58	
7	50	50	57	51	62		57	53	
8	50	50	51	59	68				
9	38	50	50	70		55	70	50	
10	51	50	65	73		61	60	54	
11	50	54	71	84		76	68	56	
12	61	50	70	77		56	63	67	
13	61	50	67	72		54	64	51	
14	53	62	53		53	60	65	71	
15	50	60	50		58	0			
16	65	71	50		51	70	64	68	
17	51	74	61		62	67	60	65	
18	76	71	51		61	66	75	71	
19	63	60	50		54	69	70	74	
20	66	83	70		66	76	83	71	
21	50	55	61		58	62	55	72	70
22	52	51	54		50	50	58	51	
23	50	56	52		52	60	50	62	
24	50	58	54		50	52	53	62	
25	52	50	51		50	54	61	69	
26	50	50	57		64	74	81	65	
27	52	73	52						
28	50	69	60	58	50	53	52	**78**	

29	54	69	54		51	69	65	69	
30	56	60	56		57	61	50	54	56
31	51	56	53		50	67	64	66	
32	50	55	62	67	68	50	**81**		
33	58	68	61	50	51	50	**91**		50
34	55	59	60	50	54	61	58		57
35	50	57	53	50	51	54	**0**		
36	70	66	69						
37	60	58	52	60	57	52			
37	78	71	62	68	82	64	**83**		55
38	68	62	52	50	52	50	**66**		57
39	60	67	65	60	81	50	**81**		
40	63	70	61	50	59	62	**76**		50
41				66	58			57	70
42			52	50	50	53		50	
43			60	62	64	50		50	
44			50	50	50	54		53	
45			55	64	55	55		60	
46		50	55	55	50	50		50	
47		75	59	58	53	30	50	55	
48		87	65	75	66	70		58	
49		55		50	50	53	50	50	
50	56	65		57	70	64	61	65	
51		56		70	62	57	50	52	55
52	50	60		53	59	65	66	60	
53	53			50	55	60	58	63	
54		50		64	60	70		65	60
55	50		57	55	50	56	54	60	55
56	52	60	60	52	62	57	55	**63**	
57	73	67	55	62	52	50	54	**65**	
58	62	56	65	64	50	58	52	**61**	
59	67	57	55	62	50	57	58	**69**	
61	61	76	60	73	62	59	77	**93**	60
62	57	72	60	59	58	60	66	**67**	

63	64	61	62	63	50	55	15		
64	60	69	65	66	51	60	67	**74**	
65	67	71	63	73	54	51	78	**73**	
66	60	65	50	67	50	65	55	**61**	
67	58	50	58	60	55	59	62	**76**	
68	67	72	59	61	75	74	80	**87**	
69	62	61	55	63	66	58	67	**68**	
70	64	73	58	56	56	54	63	**76**	
71	54	59	65	70	53	50	50		
72	64	71	66	68	50	69	77	**79**	55
73	66	51	60	67	53	57	70	**79**	
74	50	71	69	60	**77**				59
75	58	69	69	72	**77**				65
76	50	56	68	50	**78**				73
77	59	68	66	50	**82**				70
78	55	71	59	51	**73**				50
79	50	59	58	52	**64**				70
80	51	68	67	69	**77**				58
81	50	73	67	51	**73**				
82	52	54	64	64	**77**				60
74									51
75									
76			65	66		50			
77			50	54	66	50	53		
78			51	50	50	53	50		
79			60	50	50	51		50	
80				51	55	50	51	56	
81			51	57	55	50	71		
82					50		52	29	
83				50	56	50	50		
84	50	52	70		56	64	50	56	56
85				50	55	51	50		
86			50	52	50	50	50		
87			50	50	53	51	50		

88			60	55	65	50	56		
89			50	50	62	51	52		
90	66	58	56	61	50	56	56	62	
91									
92	53	55	61	64	50	57	58	55	
93				57	55	56	60	70	
94				65	50	65	67	62	
95				50	51	50	55	56	
96				60	63	50	62		
97					50	53	50		
98				50	53	51	50	50	
99					50	50	50	22	
100						58	50		
101					62	56	50	68	
102						50	50	53	
103				52	50	50	63		
104					56	50		52	
105					73	63	66	91	
106				50	51	54	50	52	
107	55	60	50	72		61	50	51	
108	52	53	65	61	57	61	58	55	58
109	55	50	68	73	54	67	65	64	
110	61	50	70	77	60	56	63	65	
111	61	50	67	72	59	54	64	62	
112	53	62	53		53	60	65	56	
113	50	60	50		58	0			
114	65	71	50		51	70	64	58	
115	51	74	61		62	67	60	60	
116	76	71	51		61	66	75	68	
117	55	60	50		54	63	68	70	
118	66	79	69		66	76	73	58	
119	54	55	58		58	60	50	70	70
120	53	51	55		50	50	56	53	
121	50	60	66		52	59	50	67	

122	55	55	57		50	56	50	50	
123	52	53	53		53	54	55	54	
124	56	53	54		62	71	74	62	
125	53	77	62		55	66	56	50	
126	52	50	57	50	50	60	63	53	
127	61	52	56	52	50	67	53	52	
128	50	56	65	56	50	65	54	52	
129	29	50	50	50	50	50	69	54	
130	50	62	50	62	55	52	50	50	
131	70	65	53	65	65	63	38		
132	52	60	51		65	55	50		
133	50	58	50	58	50	65	50		
134	29	65	58	65	44	58	6	56	
135	90	56	56	56	50	57		59	
136	62	50	50	50	50	71	69	50	
137	58		50	50	54	58	67	61	
138	56	62	50	50	66	63	41	56	
139	66	56	63	56	56		78	54	
140	50	52	54	52	55	60	62		
141	68	63	61	54	64	66	52		
142	74	55	61	66	54	66	10	66	
143	66	65	67	50	60	58	52		

Table F5. (Continued) Building science grades that used in the correlation analysis.

NO	BS-Courses Grades																						
	GE121	AR141	AR224	AR221	AR213 ML	AR261	AR222	AR262	CE211	AR323	CE371	CE309	AR324	AR335	AR318P	AR425	AR418	EE400	CE422	AR426	AR401	ME521	AR490
1	A	58	42	70		75	51	83	5	62	93	50	50	63		53	56	50		52		41	50
2		51		50	52	71	65	60	8	63	83	39		74	66	59	56	69	52	50	62	86	71
3			51			58	52	34		0													
4		63		62		80	53	63	62	64	78		58	89	87	73	82		54	70		85	91
5		50		51		51	52	54	39	55	85	38	57	72	76	58	65		61	69	50	71	79
6		50		63		57	70	50	56	59	79	61	39	77	73	50	80	60	58	0	54	72	67
7		54		55		50	50	71	58	65	71	50	61	72	80	73	62	69	73	71		70	50
8	0	50		55	50	60	50	50		50	83						50					81	
9		55	64	50		58	58	66	54		76	53	51		90	50	50		50	56	60	65	
10		53	54	52		50	51	51	71	60	97	51	38	55	83	53	66	64	50	55	58	75	
11		68	67	54		81	52	52	50	50	72	64		66	64	55			50	64	55	61	
12	52	52	70	51		58	55	63	38	50	80	59		80	83	57	70	72	75	54	80	70	76
13		54	50	51		50	50	55	50	34	66	51	51	75	50	50		64	75	60		69	75
14		73		67	50	68	54	65	50		78	55	56	60	85	60	56		42	73	60	71	
15		55		60		74	65	58	6		80		50		54	0							
16		58		55		66	66	57	75		73	50	50	60	53	63				69		95	
17		45		51		80	50	71	69	53	73	57	60	64			58		55	56	61	72	51
18	60	53		52		79	61	58	67		79	58	67	57	65	61	85			78	80	60	
19	83	52		55		71	64	63	41	65	53	65		73	91	58				67	77	92	
20	78			65		78	69	75	78	64	77	28	78	60	50	86	85	69		85	67	60	50
21	74	65				62	55	60	62	51	73	69	58	75			72	65	66	62	70	80	67
22		57		50		56	53	66	52	53		52	61	50	52	53							
23		61		55		73	52	66	10	61	50		55	61	50	67					50	63	
24		50	72	50		61	52	58	52		66	53	59	67		52			32	52	50	59	
25		53	39	50		51	54	50	50	50	51	41		69	61	53				52		58	
26		50	50	51		79	50	50	66	58	70	50	51	75	58			52	82	71	69	57	59
27		51		50		64	54								72								
28	51	50	54	51		67	51	63	43	50	72	33	66	60			57	58				57	

29		32		55		75	67	50	57	56	80	58	61	65	51	77		63	50	79	50	78	78
30		53		35		66	56	52	55	68	65	59	64	50	51	63		45	50	68	56	70	58
31		38		50		57	59	52	50		55	50	51	50	57	59			51	62	60	78	
32		66	68	50		86	50	66		51	50			68	67		58	69				82	
33		59	55	56		71	61	50	56	50	50		54	55	56	51	59	63		52		54	31
34		63	62	60		68	56	50	40	70	55		56	60	74	61	50	52		25		50	55
35	50	50		50		59	54	58	54	50	81			52	55		59					53	51
36	50	60	59	58			26																
37	70	73	65	59		66	50	70	36	66			67			55				56			
37	78	53	90	68		73	66	68	80	73	80	59	86	89	97	66	69					87	
38	62	61	61	55		67	77	57	60		57			62	65			53				78	
39	56	61		67		78	88		26	71	74		82	67	96							83	
40	78	56	78	69		85	50	67	56	51	55	52	68	66	87	74		78				85	55
41				31		66	50	53	3	53			57				52			61		67	62
42			60			70	55	50	36	50	57		55	56		15	55			50	0		
43						70	50	60	56	68	73	50	50	63		60	50	55	50	57	74	50	
44		50	26	59		54	53	50	75	50	69	50			63	50	60	58	51	50	36	60	
45		54	70			55	50	50	25	50		53	58	59		50	50		50		52	50	
46		60				70	55	66	0	50	65		53	50	50		55	50	50				65
47			55	55		80	59	50	0	50	91	50	50		65	55	55	50	50	50	50	93	67
48			80				64	70	70	51	70	50	50	50	69	75	65		70	75	77	70	50
49		55	50	55		53	50	50	50	50	50	50	65	50	65	30	63					50	50
50		50		50		69	55	60	62	60	73	68	57	79	89		87	77	79	50	50	90	88
51	62	70	63	62			63	55	66		50	52	53	66	64		70		65		68	74	62
52		65	75	55		65	80	60	50	55	75	50	60	75	88	50		64	73		53	92	63
53		50		50		61	55	50	69	57	69	57	50	55	65		66	65	50	68	50	72	25
54	50	66	50	56			63	62	62	55	70	50	67	60	53	50	60	50	66	50	55	65	78
55	63	55	61	54		53		50	58	63		60	53	54	61	65		63	70	55	60	50	60
56	50	51	67	50		66	60	65	50	58	66	37	61	71	68	60				62	65	68	
57	50	53	53	50		61	56	60	16	50	75		62		67	50					20		
58	84	54	52	53		63	51	66	71	58	55		60		90	62				53		70	71
59	50	50	55	50		50	50	56		69	61		59	65	68	58							
61	62	76	62	51		68	71		73	64	50		74	52	68	80						81	50
62			51					63	50	59			56			55	54			0			
63	61	51	64	50		77	57	50	50	50	80	50	51	72	73	54		52		53	29	50	69
64	78	71	69	63		74	51	68	50	62	55	51	65	51	69	62	58	58	42	57	51	65	67
65	60	73	55	63		80	51	65	42	61	69		63		70	75	65	65		73			
66	65	50	56	58		53	53	50	59	69	71		64		68	51		55		65	10	89	25
67	50	50	66	50		66	58	50	50	51	68		76	65	55	54	74	69	26	51		76	81

68	50	70	62	62		65	51		70	78	96		82	73	95	79		73				94	
69	53	50	65	53		69	52	50	53	57	77	52	50	61	51	59	64	70	56	67	38	57	62
70	58	81	64	50		71	54	67	15	69	87	12	50	59	91	57	65	68		53	73	87	31
71	60	66	59	54		63	51	71	57	59	95		50	40	50	51						50	
72	62	51	52	59		58	64	69	58	50	86	22	65	69	60	74				65	53	63	77
73		59	76	65		65	56	58	53	50	58	50	60	55	67	68	54	65				65	53
74	50	69	70	64		53	68	66		69	90				95			74					73
75	72	66	77	73		69	65	71	68	73	85	59		69	95			75					78
76	84	67	66	53		82	67	69	50	56	91	50			62			67				89	
77	95	63	77	56		70	50	70	50	52	72			57	65			54					59
78	52	67	52	50		57	53		59	42	60				66			50				50	
79	56	63	55	35		60		59			61											54	
80	50	68	74	50		59	54	61		61	86	50						63					69
81	56	69	71	54		67	66	69	50	53	85	52		61	90			62	56			65	
82	50	58	51	60		59	55	63	81	40	75				84								
74							31																
75							67	50	28								50						
76								69	40	52	74				51	50	55	57	73			52	
77								78	33	52	91	52	67	51		50	53	50	60	50	50	61	
78			51			93	50	60	51	55	65	55		50	52	50	50	65			28	50	
79			50							51	70	52	50		50	50						29	
80							38	57	59	50		22	78		68	55	80			56		50	
81									50			53	51			65	53	55	55	50		70	
82									50			34			52	65	60			50		52	
83								50					52			50	50		52	54	50	50	
84		53		54		59	50	52	55	63	65	59	60	50	51	44		45	50	50	56	29	
85							50	56	53	57	76	37			50	50				50	50	90	
86						50	41	50	54	50		52	50	50	73	50	52		74	19	92	62	50
87			50				50	62	56	50	67		50	53	50	32	50		52	23	50	58	
88								65	50	65	91	50	55		70	78	50	72	79		63	56	
89			61			50	51	60	50	50		57	53		61		52	50	65	50		66	
90	53	50	56	52		51	50	58		67	60		57	66	66	56							
91				50			52	65	51				50				55						
92	50	53	55	61		50	50	56		70	59		59	65	66	58	54						
93								50	51			50	60			50	60		92	66		70	65
94								72	74	63		53	50	64	90	55	58		79			69	65
95								62	50	50		55	51	60	53	61	60		63	65	74	64	
96								56	60	50		60		50	52	70	50	65	60		55	64	50
97		63		56			54		52			50	70			52	50			50			

98			72				50	65	50	55			50		65	50	55		55	50		77	
99								63	50			35			68	53	50		28	56	52	57	
10												50							19		50		
10									50			37			69	64	59		53	64	60		
10				50				75	50										66	51			
10								50	38				62		70	50	50					53	50
10								75	21				60		75	50	50		92	63	41	70	56
10							73	60	63	67		54	78			50	87		57	78	90		
10								67	53	59		50	63	58	73	50	50		50			63	69
10		50	60	52		56	53	65	54		76	50	60		80	50	50		50	56	59	62	
10		50	55	52		50	60	50	69	60	80	50	39	55	79	53	66	64	50	55	60	73	
10		68	67	54		81	52	52	50	50	72	64		66	64	55			50	64	55	61	
11	52	52	70	51		58	55	63	38	50	80	59		80	83	57	70	72	75	54	80	70	76
11		54	50	51		50	50	55	50	34	66	51	51	75	50	50		64	75	60		69	75
11		73		67	51	68	54	65	50		78	55	56	60	85	60	56		42	73	60	71	
11		55		60		74	65	58	6		80		50		54	0							
11		58		55		66	66	57	75		73	50	50	60	53	63				69		95	
11		45		51		80	50	71	69	53	73	57	60	64			58		55	56	61	72	51
11	60	53		52		79	61	58	67		79	58	67	57	65	61	85			78	80	60	
11	83	52		55		71	64	63	41	65	53	65		73	91	58				67	77	92	
11	78			65		78	69	75	78	64	77	28	78	60	50	86	85	69		85	67	60	50
11	74	65				62	55	60	62	51	73	69	58	75			72	65	66	62	70	80	67
12		57		50		56	53	66	52	53		52	61	50	52	53							
12		61		55		73	52	66	10	61	50		55	61	50	67					50	63	
12		50	72	50		61	52	58	52		66	53	59	67		52			32	52	50	59	
12		53	39	50		51	54	50	50	50	51	41		69	61	53				52		58	
12		50	50	51		79	50	50	66	58	70	50	51	75	58			52	82	71	69	57	59
12	65	51		50		64	54		54	62	66	54	58	67	72				69				
12	68	82	64	83		55	78	53	90	68		73	66	68	80	73	80	59	86	89	97	66	69
12	50	52	50	66		57	62	61	61	55		67	77	57	60		57			62	65		
12	60	81	50	81			56	61		67		78	88		26	71	74		82	67	96		
12	50	59	62	76		50	78	56	78	69		85	50	67	56	51	55	52	68	66	87	74	
13	66	58			57	70				31		66	50	53	3	53			57				52
13	53		54		59	50	52	55	63	65	59	60	50	51	44		45	50	50	56	29	73	50
13						50	56	53	57	76	37			50	50				50	50	90	73	57
13					50	41	50	54	50		52	50	50	73	50	52		74	19	92	62	79	58
13		50				50	62	56	50	67		50	53	50	32	50		52	23	50	58	53	65
13							65	50	65	91	50	55		70	78	50	72	79		63	56	77	28
13		61			50	51	60	50	50		57	53		61		52	50	65	50		66	73	69

13	71	65	60	8	63	83	39		74	66	59	56	69	52	50	62	86	71	50	50	57		52
13	58	52	34		0														50	50	51	50	
13	80	53	63	62	64	78		58	89	87	73	82		54	70		85	91	38	50	50	66	53
14	51	52	54	39	55	85	38	57	72	76	58	65		61	69	50	71	79	51	50	65	51	41
14	57	70	50	56	59	79	61	39	77	73	50	80	60	58	0	54	72	67	50	54	71	70	50
14	50	50	71	58	65	71	50	61	72	80	73	62	69	73	71		70	50	61	50	70	66	54
14	60	50	50		50	83						50					81		65	50	65	67	62

MODE SKILLS EVALUATION FACTORS AND CRITERIA

Table F6. Modeling skills evaluation criteria for design studio group (AR315) by Instructor C1 (the dress-rehearsal stage).

NO	Sample Code	Model evaluation									
		Site						Mass & Conception			
		Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	scale (10)	accuracy (10)	sense of space (10)
1	**ST-4**	20	7	3	7	4	7	15	6	7	7
2	**ST-3**	13	7	3	2	3	7	17	7	6	7
3	**ST-2**	22	7	3	3	4	7	17	8	7	8
4	**ST-1**	17	7	4	7	4	7	0	0	0	0
5	**ST-9**	20	8	4	7	4	7	16	7	7	7
6	**ST-7**	22	8	3	0	2	6	18	7	6	8
7	**ST-8**	23	7	3	2	3	7	7	8	8	8
8	**ST-6**	22	7	3	4	3	7	12	7	6	8
9	**ST-5**	17	8	3	7	3	7	13	7	5	6

Table F6. (Continued) design project evaluation criteria for design studio group (AR315) by Instructor C1 (the dress-rehearsal stage).

Sample Code	Plans Evaluation							Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)		100%
ST-4	6	12	8	10	10	7	8	144	**72**
ST-3	9	13	6	4	12	8	8	132	**66**
ST-2	8	12	7	6	12	8	7	146	**73**
ST-1	7	12	0	10	10	**0**	7	92	**46**
ST-9	9	13	8	8	13	**0**	13	151	**75.5**
ST-7	8	13	7	10	12	7	8	145	**72.5**
ST-8	8	12	8	7	14	8	7	140	**70**
ST-6	8	13	8	10	13	9	12	152	**76**
ST-5	7	14	7	7	12	7	10	140	**70**

Table F7. Modeling skills evaluation criteria for design studio group (AR315) by Instructor C2 (the dress-rehearsal stage).

NO	Sample Code	Model evaluation									
		Site						Mass & Conception			
		Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	scale (10)	accuracy (10)	sense of space (10)
1	**ST-4**	20	7	3.5	5	3.5	4	14.5	5	5.5	6.5
2	**ST-3**	16	4	3.5	6	3.5	7	13.5	3	3.5	6
3	**ST-2**	22	6	3.5	6	4	6.5	17	8.5	8.5	8.5
4	**ST-1**	18	6	3	6	3	6	0	0	0	0
5	**ST-9**	20	9	4	4.5	4.5	5	17.5	8	6	7.5
6	**ST-7**	23	9	4	4.5	3.5	4.5	18.5	8.5	8.5	9
7	**ST-8**	23	8.5	4	6.5	3.5	7	16	8.5	7.5	8
8	**ST-6**	23	7	3.5	4	3.5	7	15	8	5.5	6.5
9	**ST-5**	21	6	3.5	5	2.5	7	13	7	6.5	5.5

Table F7. (Continued) design project evaluation criteria for design studio group (AR315) by Instructor C2 (the dress-rehearsal stage).

Sample Code	Plans Evaluation							Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)		100%
ST-4	7	10	7	7	12.5	8	12	138	**69**
ST-3	6.5	13	6.5	5	13	7	11	128	**64**
ST-2	9.5	12	7	7	13	8	13	160	**80**
ST-1	6.5	6.5	6	8.5	8.5	0	8	86	**43**
ST-9	5	13	7.5	7	12.5	0	9	140	**70**
ST-7	9.5	14.5	8	9	12.5	7.5	13	167	**83.5**
ST-8	8	13	7	7	12.5	8	13	161	**80.5**
ST-6	9.5	13	6.5	7.5	12.5	8	13	153	**76.5**
ST-5	6	10	6	7	9.5	6.5	10	132	**66**

Table F8. Modeling skills evaluation criteria for design studio group (AR315) by Instructor C1 (final stage)

NO	Sample Code	Model evaluation									
		Site						Mass & Conception			
		Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	scale (10)	accuracy (10)	sense of space (10)
1	**ST-4**	19	7	2	7	4	7	17	7	7	6
2	**ST-3**	19	7	4	6	3	6	16	7	6	6
3	**ST-2**	19	7	4	3	2	6	17	7	7	5
4	**ST-1**	19	6	3	5	2	5	17	5	5	7
5	**ST-9**	19	9	2	7	5	4	18	8	5	7
6	**ST-7**	19	8	4	7	4	7	17	8	7	8
7	**ST-8**	19	7	3	6	3	7	16	7	6	7
8	**ST-6**	19	7	3	6	3	5	17	7	7	6
9	**ST-5**	19	8	3	7	2	6	19	6	8	7

Table F8. (Continued) design project evaluation criteria for design studio group (AR315) by Instructor C2 (final stage).

Sample Code	Plans Evaluation								Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	relationship indoor & outdoor (10)	orientation (10)	circulation (15)	interior design (10)	Arch-Drawings (15)	Presentation (10)		**100%**
ST-4	7	12	7	6	10	7	12	6	150	**75**
ST-3	6	13	7	8	12	6	12	6	150	**75**
ST-2	7	12	6	8	12	7	12	7	148	**74**
ST-1	7	10	6	4	10	**6**	10	5	132	**66**
ST-9	7	13	7	5	10	**8**	13	6	153	**76.5**
ST-7	7	13	7	8	13	8	13	8	166	**83**
ST-8	7	13	7	9	13	8	12	6	156	**78**
ST-6	7	12	6	7	12	7	12	7	150	**75**
ST-5	8	12	7	6	12	7	13	7	157	**78.5**

Table F9. The dress-rehearsal stage evaluation averages for the design group (AR315)

NO	Sample Code	(INST A+ INST B)/2 FINAL GRADES AVERAGE 100
1	ST-4	71
2	ST-3	65
3	ST-2	77
4	ST-1	45
5	ST-9	73
6	ST-7	78
7	ST-8	76
8	ST-6	77
9	ST-5	68

Table F10. The final stage evaluation average for the design group (AR315)

NO	Sample Code	(INST A+ INST B)/2 FINAL GRADES AVERAGE 100
1	ST-4	77
2	ST-3	73
3	ST-2	77
4	ST-1	64
5	ST-9	73
6	ST-7	82
7	ST-8	78
8	ST-6	77
9	ST-5	77

Table F11. Modeling skills evaluation criteria for design studio group (AR417) by Instructor C3 (the dress-rehearsal stage).

Sample Code	Model evaluation									
	Site						Mass & Conception			
	Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	Scale (10)	accuracy (10)	sense of space (10)
ST-2	20	3	2.5	2.5	3	3	12	4	2.5	4
ST-3	0	0	0	0	0	0	0	0	0	0
ST-4	20	5	2.5	6	2	3	12	4.5	4	4
ST-1	25	5	2	5	2	3	10	4.5	4.5	4
ST-5	20	5	3	7	2.5	3	16	3	7	6
ST-7	20	5	2.5	6	2	2.5	10	4.5	5	4
ST-6	20	3	2.5	6	2	2	10	4	3	3

Table F11. (Continued) design project evaluation criteria for design studio group (AR417) by Instructor C3 (the dress-rehearsal stage)

Sample Code	Plans Evaluation							Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	relationship indoor & outdoor (10)	orientation (10)	circulation (15)	interior design (10)	Arch-Drawings		100%
ST-2	5	9	4.5	5	7.5	4	4.5	96	48
ST-3	0	0	0	0	0	0	0	0	0
ST-4	6	9	7	5	7.5	4	7.5	109	54.5
ST-1	6	9	5	5	7	4	8.5	109.5	54.75
ST-5	7	10.5	7	4	7.5	4	10.5	123	61.5
ST-7	5	9	5	5.5	9	6	8.5	109.5	54.75
ST-6	5	7.5	6	4	6	3	6.5	93.5	46.75

Table F12. Modeling skills evaluation criteria for design studio group (AR417) by Instructor C4 (the dress-rehearsal stage).

Sample Code	Model evaluation									
	Site						Mass & Conception			
	Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	Scale (10)	Accuracy (10)	Sense of space (10)
ST-2	20	3	2.5	2.5	3	3	12	4	2.5	4
ST-3	0	0	0	0	0	0	0	0	0	0
ST-4	20	5	2.5	6	2	3	12	4.5	4	4
ST-1	25	5	2	5	2	3	10	4.5	4.5	4
ST-5	20	5	3	7	2.5	3	16	3	7	6
ST-7	20	5	2.5	6	2	2.5	10	4.5	5	4
ST-6	20	3	2.5	6	2	2	10	4	3	3

Table F12. (Continued) design project evaluation criteria for design studio group (AR417) by Instructor C4 (the dress-rehearsal stage)

Sample Code	Plans Evaluation							Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	relationship indoor & outdoor (10)	orientation (10)	circulation (15)	interior design (10)	Arch-Drawings (15)		100%
ST-2	4.5	9.75	5.5	6.5	10.5	6.5	9.75	122.5	61.5
ST-3	0	0	0	0	0	0	0	0	0
ST-4	7	10.5	6.5	6.5	9	4	8.5	126.5	63.5
ST-1	5	10.5	8	6.5	9	4.5	9.5	140	70
ST-5	5	10.5	6	5.5	12	6	12	132	66
ST-7	4.5	7.5	6	6.5	8.5	5	7.5	109	54.5
ST-6	4	7.5	5	5	8.5	4.5	7.5	109	54.5

Table F13. Modeling skills evaluation criteria for design studio group (AR417) by Instructor C3 (final stage)

NO	Sample Code	Model evaluation									
		Site						Mass & Conception			
		Site model workshop (25)	Context (10)	Roads (5)	parking (10)	Entrances (5)	Landscaping (10)	Design logic (20)	Scale (10)	Accuracy (10)	Sense of space (10)
1	**ST-2**	24	7	4	9	4.5	8	18	8	5	7
2	**ST-3**	0	0	0	0	0	0	0	0	0	0
3	**ST-4**	24	8	4	8	3.5	7.5	17.5	6.5	6	7.5
4	**ST-1**	24	7.5	4.5	7.5	4	7.5	18	8	6	8
5	**ST-5**	24	7.5	3.5	8.5	4.5	5	19	10	10	10
6	**ST-7**	24	6.5	2.5	6.5	3	5	13.5	4	5	5
7	**ST-6**	24	7	3.5	7.5	3.5	6.5	16.5	8	6.5	7

Table F13. (Continued) design project evaluation criteria for design studio group (AR417) by Instructor C3 (final stage).

Sample Code	Plans Evaluation								Overall Grades 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)	Presentation (10)		**100%**
ST-2	8	13	8	8	13	8	12	7	171.5	85.75
ST-3	0	0	0	0	0	0	0	0	0	0
ST-4	7	13	8	7.5	12	6	10	7.5	163.5	81.75
ST-1	8	12	8	7.5	14	7	9	7.5	168	84
ST-5	9	14	9	8.5	14	10	11	9	186.5	93.25
ST-7	6	10	6	6	9	5	8.5	6	131.5	65.75
ST-6	7	13	7.5	7.5	11	6.5	11.5	7.5	161.5	80.75

Table F14. Modeling skills evaluation criteria for design studio group (AR417) by Instructor C4 (final stage)

NO	Sample Code	Model evaluation									
		Site						Mass & Conception			
		Site model workshop (25)	Context (10)	Roads (5)	Parking (10)	Entrances (5)	Landscaping (10)	Design logic (20)	Scale (10)	Accuracy (10)	Sense of space (10)
1	**ST-2**	24	7.5	3	6	4	4	10	8	5	7
2	**ST-3**	0	0	0	0	0	0	0	0	0	0
3	**ST-4**	24	7.5	3	7	4	6	15	9	8	9
4	**ST-1**	24	6	4	7	4	4	15	9	8	8
5	**ST-5**	24	7	4	8	4	4	18	10	10	10
6	**ST-7**	24	6	3	6	3	4	15	8	6	6
7	**ST-6**	24	7	4	8	4	5	10	9	8	7

Table F14. (Continued) design project evaluation criteria for design studio group (AR417) by Instructor C4 (final stage).

Sample Code	Plans Evaluation								Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)	Presentation (10)		100%
ST-2	8	13	8	8	12	7	10	7	151.5	75.75
ST-3	0	0	0	0	0	0	0	0	0	0
ST-4	8	13	8	8	13	4	13	8	167.5	83.75
ST-1	8	12	6	7	11	5	12	6	156	78
ST-5	8	13	9	8	12	9	12	9	179	89.5
ST-7	6	10	5	6	9	4	8	5	134	67
ST-6	7	11	4	6	12	4	9	5	144	72

Table F15. The dress-rehearsal stage evaluation averages for the design group (AR417)

NO	Sample Code	FINAL GRADES AVERAGE
1	ST-2	55
2	ST-3	0
3	ST-4	59
4	ST-1	63
5	ST-5	64
6	ST-7	55
7	ST-6	51

Table15. The final stage evaluation average for the design group (417)

NO	Sample Code	(INST C+ INST D)/2 FINAL GRADES AVERAGE
1	ST-2	81
2	ST-3	0
3	ST-4	83
4	ST-1	81
5	ST-5	91
6	ST-7	66
7	ST-6	76

Table F16. Modeling skills evaluation criteria for design studio group (AR518) by Instructor C5 (the dress-rehearsal stage).

NO	Sample Code	Model evaluation									
		Site						Mass & Conception			
		Site model workshop (25)	Context (10)	Roads (5)	Parking (10)	Entrances (5)	Landscaping (10)	Design logic (20)	Scale (10)	Accuracy (10)	Sense of space (10)
1	ST-6	25	7	4	4	4	4.5	10	6.5	6	5.5
2	ST-3	25	7	3	5	2	6	15	5	5.5	4.5
3	ST-12	25	9.5	4	8.5	3.5	5	13	6.5	6	5.5
4	ST-1	25	7	4.5	7	4	7	17	7.5	8	8
5	ST-5	25	6	3	4.5	3	5	14	6	5.5	4
6	ST-7	25	7	3.5	5.5	3	6	14	6.5	5	5
7	ST-4	25	9.5	4	5	4	5	19	9	8.5	7
8	ST-11	25	7.5	3	3	3	6	16	8	5.5	6.5
9	ST-13	25	8	3.5	7	3.5	3	15.5	5.5	6	7
10	ST-9	25	4	2.5	5	2	4.5	10	6.5	5.5	4.5
11	ST-8	25	6.5	2.5	5	2.5	4.5	11.5	5	5.5	7
12	ST-16	25	5	1.5	0	2	0	10	4	3	5
13	ST-2	25	5	2.5	6	2	4	14	6.5	4	5
14	ST-15	25	6.5	1.5	4.5	2	4	14.5	4.5	5	7
15	ST-10	25	3	2.5	4	2	6	8	3.5	3	3
16	ST-14	25	7.5	3	3	2	6	16.5	6	6	7.5

Table F16. (Continued) design project evaluation criteria for design studio group (AR518) by Instructor C5 (the dress-rehearsal stage)

Sample Code	Plans Evaluation							Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)		100%
ST-6	5	7.5	4	6	8	4	8.5	119.5	59.75
ST-3	6.5	8.5	5	7	9	5	10	129	64.5
ST-12	6.5	9.5	5	5	8.5	4	9	134	67
ST-1	8	12.5	8	7	12	6.5	13	162	81
ST-5	6.5	6	4	4	8	5	8	117.5	58.75
ST-7	8.5	12	4.5	5.5	11.5	4.5	11	138	69
ST-4	8.5	13	5	7	12	7.5	12	161	80.5
ST-11	7	13	7	7	12	8	12	149.5	74.75
ST-13	2	8	4	6.5	8	5	7.5	125	62.5
ST-9	2	7	4.5	4.5	8	7	7.5	110	55
ST-8	3.5	6	7	6.5	10	5	9.5	122.5	61.25
ST-16	5.5	9.5	4	5.5	10.5	4	10.5	105	52.5
ST-2	0	10	8	5	12	5	10	124	62
ST-15	5	8.5	4.5	5	9.5	5	8.5	120.5	60.25
ST-10	0	9	5	5.5	12	5	7.5	104	52
ST-14	5	11	5	7	9	6.5	7.5	133.5	66.75

Table F17. Modeling skills evaluation criteria for design studio group (AR518) by Instructor C6 (the dress-rehearsal stage).

NO	Sample Code	Model evaluation									
		Site						Mass & Conception			
		Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	scale (10)	accuracy (10)	sense of space (10)
1	ST-6	25	6	1	3	2	3	10	7	6	6
2	ST-3	25	8	3	6	3.5	6	15	5.5	6	6
3	ST-12	25	7	2	5	3	1	12	6	2	4
4	ST-1	25	7	4	8	4	6	17	7	9	8
5	ST-5	25	5	2	4	3	4	12	6	5	6
6	ST-7	25	7	3.5	5.5	2.5	6	13	6.5	5	5.5
7	ST-4	25	9.5	4	6	5	5	19	9	8.5	9.5
8	ST-11	25	6	2	7	4	3	15	7.5	7	8
9	ST-13	25	7	3	5	3	4	13	5.5	6	6
10	ST-9	25	5	2	2	2	4	10	6	7	5
11	ST-8	25	5	3	4	3	4	11	5	5	5.5
12	ST-16	25	7	2	6	3	0	12	6	2	5
13	ST-2	25	5	3	6	3	5	12	8	5	5
14	ST-15	25	7	1	2.5	1	4	10	5	5	2
15	ST-10	25	3	2.5	4	2	6	8	3.5	3	3
16	ST-14	25	7	1	6	3	6	14	6	4	5

Table F17. (Continued) design project evaluation criteria for design studio group (AR518) by Instructor C6 (the dress-rehearsal stage)

Sample Code	Plans Evaluation							Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)		100%
ST-6	7	9	6	6	12	4	10	123	61.5
ST-3	6.5	10	5	7	10	6	12	140.5	70.25
ST-12	5	7	5	5.5	8.5	4	7.5	109.5	54.75
ST-1	8	10	7	6.5	12	8	12	158.5	79.25
ST-5	6.5	10	5	5	8.5	5	7.5	119.5	59.75
ST-7	8.5	11	5	6	11	5	12	138	69
ST-4	8.5	12	4	7.5	10.5	8	12	163	81.5
ST-11	7	10	5	7	10.5	6	10	140	70
ST-13	5	7	4	6	9	5	8	121.5	60.75
ST-9	3	7	5	4	8	7	5	107	53.5
ST-8	6	7	5	7	9	4	5	113.5	56.75
ST-16	3	6	4	6	7	4	5	103	51.5
ST-2	3	10	5	5.5	8.5	4	10	123	61.5
ST-15	5	7.5	5	5	6	5	5	101	50.5
ST-10	0	9	5	5.5	12	5	7.5	104	52
ST-14	5	7	5	6	5	5	7	117	58.5

Table F18. Modeling skills evaluation criteria for design studio group (AR518) by Instructor C5 (final stage)

Sample Code	Model evaluation									
	Site						Mass & Conception			
	Site model workshop (25)	context (10)	roads (5)	parking (10)	entrances (5)	Landscaping (10)	Design logic (20)	scale (10)	accuracy (10)	sense of space (10)
ST-6	19	7	4	5	6	4.5	13	7	7	6.5
ST-3	19	7	3	5	2.5	6.5	12.5	6	5.5	5
ST-12	19	7	4	8.5	3.5	5	13	6.5	6	5.5
ST-1	19	7.5	4.5	7.5	4	8.5	17.5	7.5	8	8
ST-5	19	6.5	3.5	6.5	3	6.5	15	6	5.5	5
ST-7	19	7	3.5	7	3	6	14	6.5	5	6
ST-4	19	9.5	4.5	9	4.5	8	19	9.5	9.5	9.5
ST-11	19	7.5	3.5	5.5	3.5	6.5	16	8	8	6.5
ST-13	19	8	3.5	7	3.5	5	16	6	5.5	7
ST-9	19	5	2.5	6.5	4	6.5	12	6.5	5.5	6.5
ST-8	19	7.5	4	6.5	4	6	16.5	6.5	6	7.5
ST-16	19	5	1.5	6	2.5	3	11.5	4	3	6
ST-2	19	5.5	3	7	3.5	5	14	6.5	4	5
ST-15	19	6.5	2	6	2.5	5.5	15	4.5	5	7
ST-10	19	5	3	6	3	6	11.5	4.5	4.5	4.5
ST-14	19	8	3.5	6	3	6.5	16.5	6	6	7.5

Table F18. (Continued) design project evaluation criteria for design studio group (AR518) by Instructor C5 (final stage).

Sample Code	Plans Evaluation								Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)	Presentatio n (10)		100%
ST-6	7.5	11	4	6	10	5.5	11.5	7.5	142	71
ST-3	7	9.5	6	7	9	5.5	11.5	7	134.5	67.25
ST-12	7	12.5	6	6	12	7.5	12	7.5	148.5	74.25
ST-1	9	13	8	7	12	8	13	9	171	85.5
ST-5	7	13	6.5	6.5	12	7.5	13	8.5	150.5	75.25
ST-7	7.5	12	6.5	7	11.5	5	11	6	143.5	67.25
ST-4	8.5	14	8.5	8	14	8.5	13.5	8.5	185.5	92.75
ST-11	7	13.5	7	7	12.5	8	12.5	8.5	160	80
ST-13	2.5	11	6.5	6.5	11	6	8	5.5	137.5	68.75
ST-9	4.5	12	6	6	11.5	7	12	6	139	69.5
ST-8	7	12.5	7	6.5	12.5	5	12	6	152	76
ST-16	5	10.5	4	5.5	10	4.5	11	5	117	58.5
ST-2	2.5	9.5	8	6	13.5	5.5	11	5.5	134	67
ST-15	6.5	8.5	4.5	5.5	12	7	8.5	7	132.5	66.25
ST-10	2.5	12.5	5.5	6	12	5	7.5	6	124	62
ST-14	7.5	13	6	8	12.5	6.5	11.5	7	154	77

Table F19. Modeling skills evaluation criteria for design studio group (AR518) by Instructor C6 (final stage)

Sample Code	Model evaluation									
	Site						Mass & Conception			
	Site model workshop (25)	Context (10)	Roads (5)	Parking (10)	Entrances (5)	Landscaping (10)	Design logic (20)	Scale (10)	Accuracy (10)	Sense of space (10)
ST-6	20	6	1	3	2	3	10	7	6	6
ST-3	20	8	3	6	3.5	8	15	6	7	6
ST-12	20	7	3	5	3	2.5	12	6	2	4
ST-1	20	8	4.5	8	4	9	17	7	9	8
ST-5	20	7	4	7.5	3.5	8	16	6	5	6
ST-7	20	7.5	4	8	4	6	16	7	6	7.5
ST-4	20	9.5	4.5	8	5	9	19	9	8.5	10
ST-11	20	6	3.5	7	4	6.5	15	8	8.5	8
ST-13	20	7	3	5	3	4	13	5.5	6	6
ST-9	20	7.5	5	8	4	8.5	14.5	7.5	8.5	7
ST-8	20	8	4	7.5	4	7.5	17	7.5	6.5	8
ST-16	20	7	2	6	3	0	12	6	2	5
ST-2	20	5	3	6	3	5	12	8	5	5
ST-15	20	7	1	2.5	1	4	10	5	5	2
ST-10	20	3	2.5	4	2	6	8	3.5	3	3
ST-14	20	7	1	6	3	6	14	6	4	5

Table F19. (Continued) design project evaluation criteria for design studio group (AR518) by Instructor C6 (final stage).

Sample Code	Plans Evaluation								Overall Grade 200	Final Grade (200)/2
	Design program (10)	Activities & function (15)	Relationship indoor & outdoor (10)	Orientation (10)	Circulation (15)	Interior design (10)	Arch-Drawings (15)	Presentation (10)		100%
ST-6	9	9	6	7	12	5	12	8	132	66
ST-3	9	10	7	9	10	7	12	9	155.5	77.75
ST-12	5	7	5	5.5	8.5	4	7.5	5	112	56
ST-1	9	13	7.5	7	12	10	13	10	176	88
ST-5	9	13	7	8	12	8	12	9.5	161.5	80.75
ST-7	9	12	8	7	12	5	12	9	160	80
ST-4	9	15	8	9	14	8	12.5	9	187	93.5
ST-11	7	10	6	7	13	7	10	9.5	156	78
ST-13	5	10	7	6	10	7	8	7	132.5	66.25
ST-9	6	11	7.5	7	12	9	12	9	164	82
ST-8	9	13	8.5	7	12	5	11	9	164.5	82.25
ST-16	3	8	4	6	7	5	10	6	112	56
ST-2	3	10	7	6	12	6	10	6	132	66
ST-15	9	7.5	5	6	10	8	7	8	118	59
ST-10	2	12	7	5.5	12	5	10	12	120.5	60.25
ST-14	8	12	6	7	12	8	12	10	147	73.5

Table F20. The dress-rehearsal stage evaluation averages for the design group 518)

NO	Sample Code	2nd evaluation grades 100%
1	ST-6	60
2	ST-3	67
3	ST-12	60
4	ST-1	80
5	ST-5	59
6	ST-7	69
7	ST-4	81
8	ST-11	72
9	ST-13	61
10	ST-9	54
11	ST-8	59
12	ST-16	52
13	ST-2	62
14	ST-15	55
15	ST-10	52
16	ST-14	62

Table F21. The final stage evaluation average for the design group (518)

Sample Code	(INST E+ INST F)/2 Final grades
ST-6	69
ST-3	73
ST-12	65
ST-1	87
ST-5	78
ST-7	74
ST-4	93
ST-11	79
ST-13	68
ST-9	76
ST-8	79
ST-16	58
ST-2	67
ST-15	63
ST-10	61
ST-14	76

MODELS PHOTOGRAPHS OF ELMERGIB UNIVERSITY STUDENTS

Figure F1. Models photographs of AR315 design group at Elmergib University's students (Sample 1)

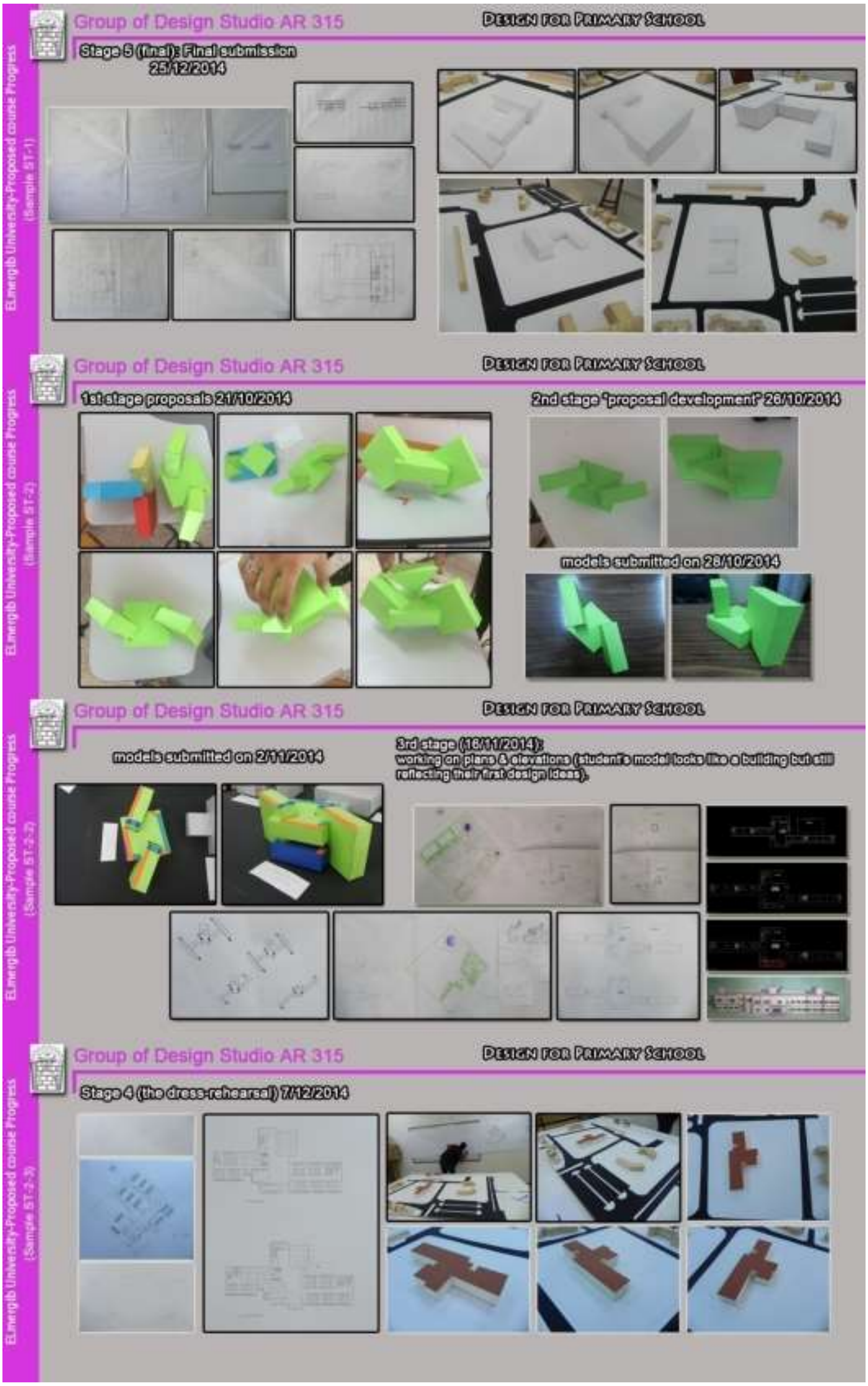


Figure F2. Models photographs of AR315 design group at Elmergib University's students (Samples 1-2)

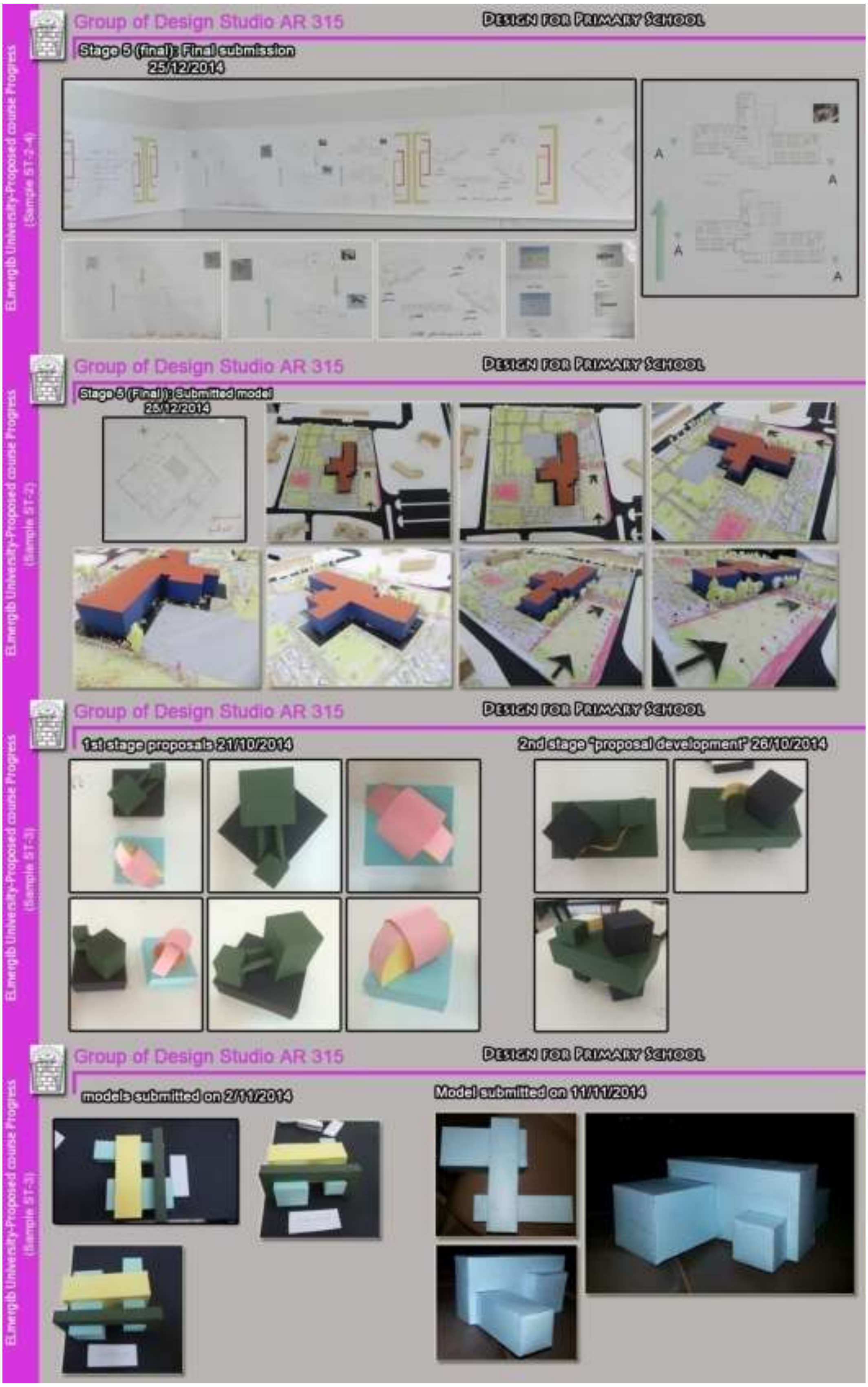


Figure F3. Models photographs of AR315 design group at Elmergib University's students (Samples 2-3)

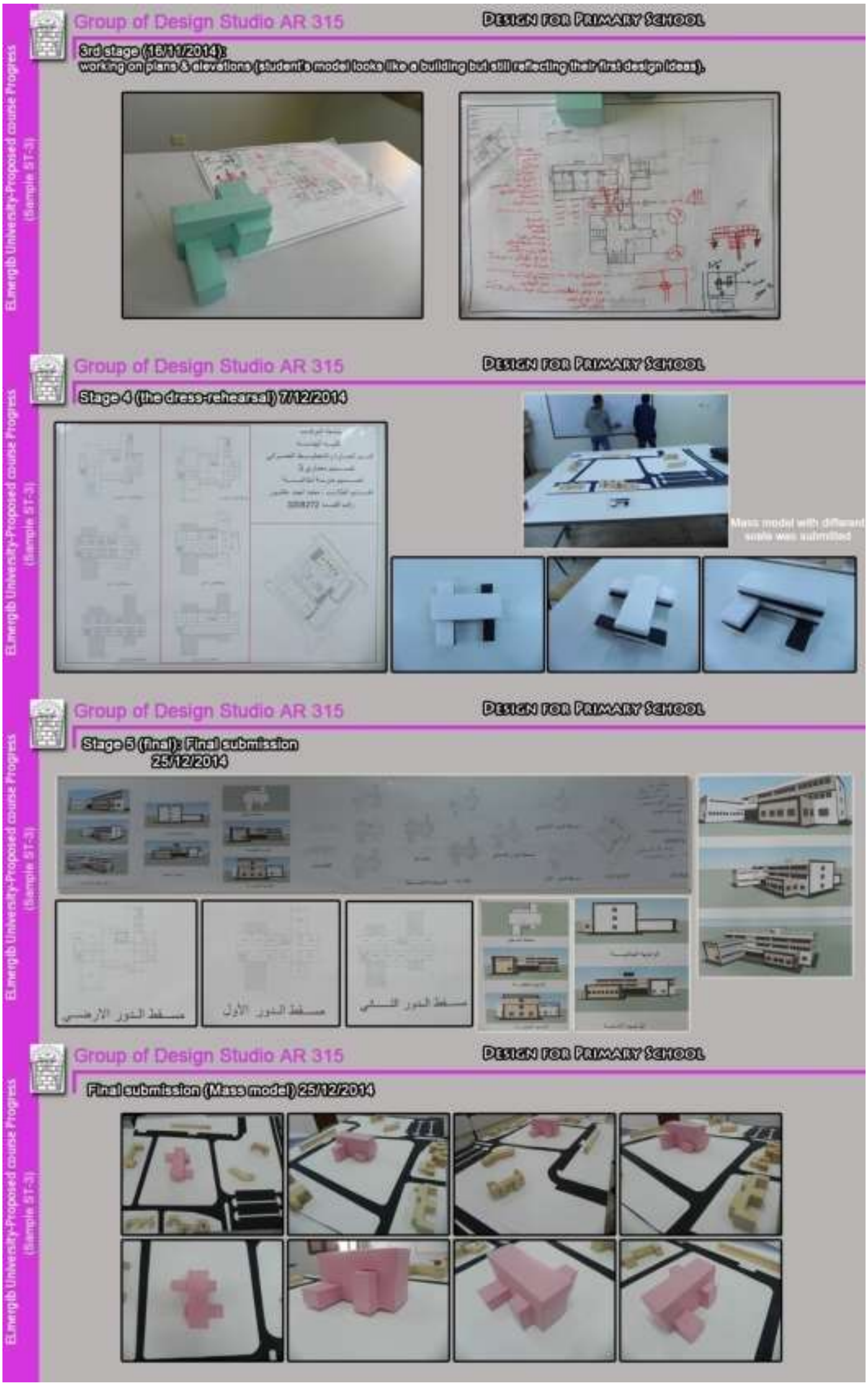


Figure F4. Models photographs of AR315 design group at Elmergib University's students (Sample 3)

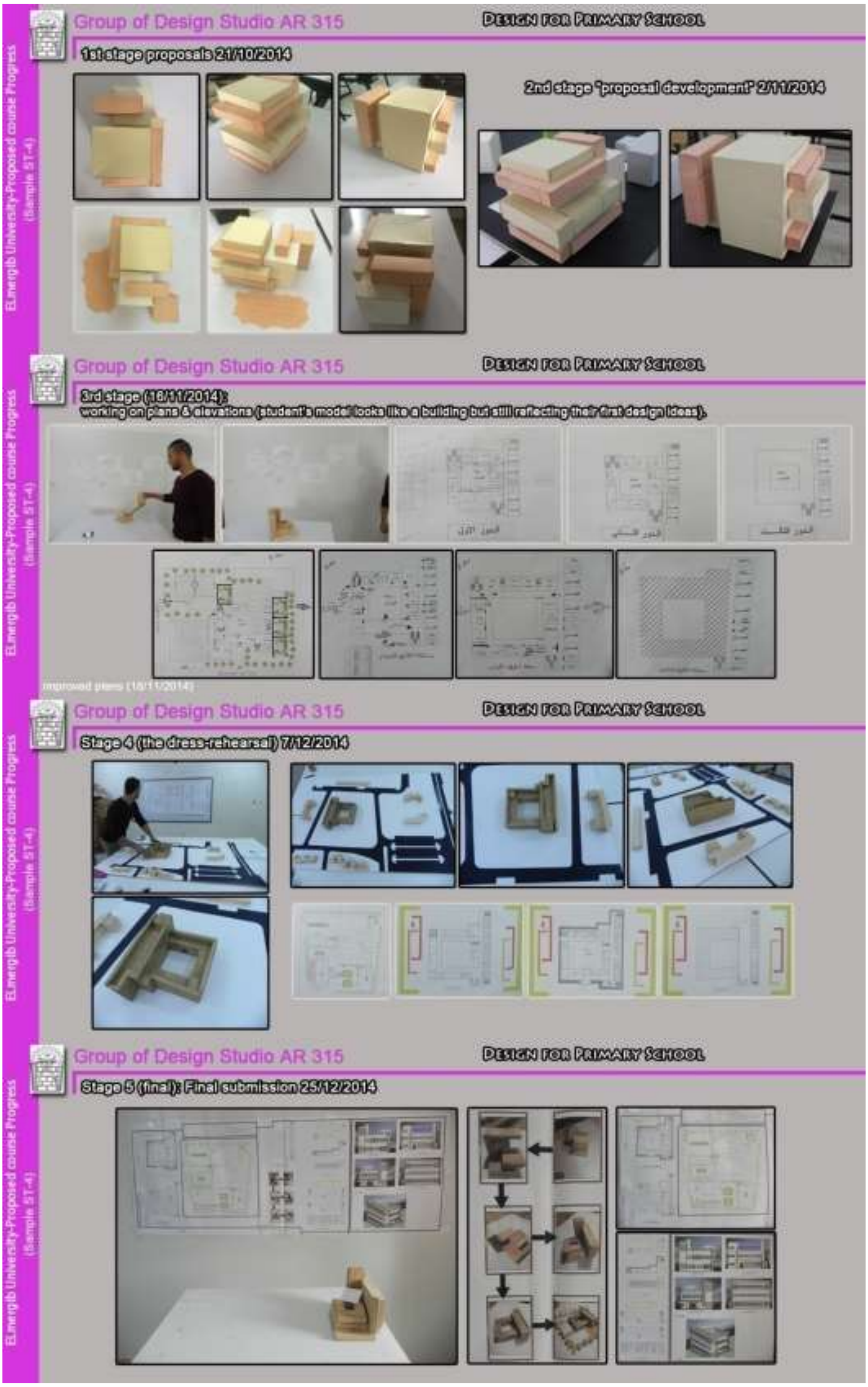


Figure F5. Models photographs of AR315 design group at Elmergib University's students (Sample 4)

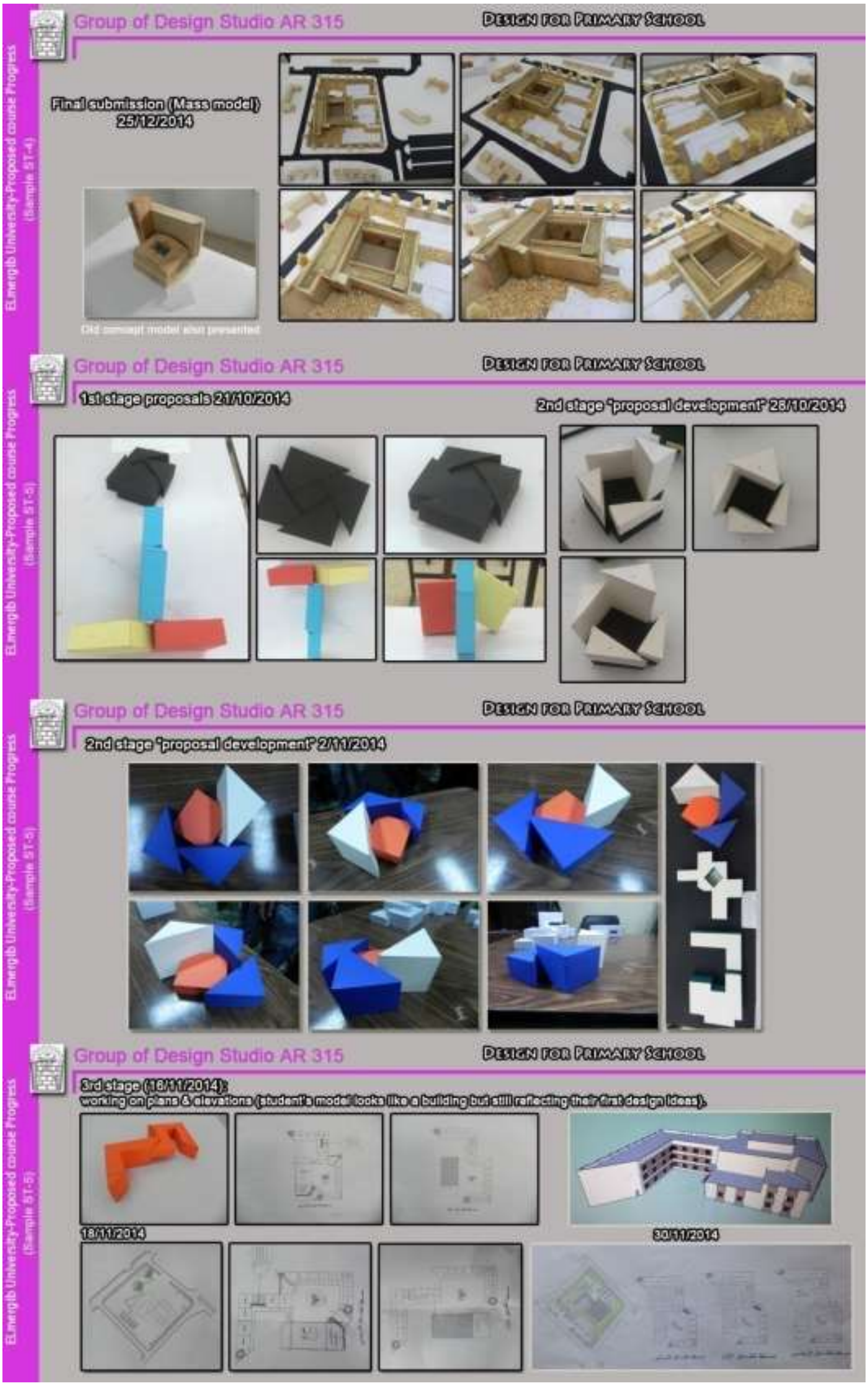


Figure F6. Models photographs of AR315 design group at Elmergib University's students (Samples 4-5)

Figure F7. Models photographs of AR315 design group at Elmergib University's students (Samples 5-6)

Figure F8. Models photographs of AR315 design group at Elmergib University's students (Sample 6)

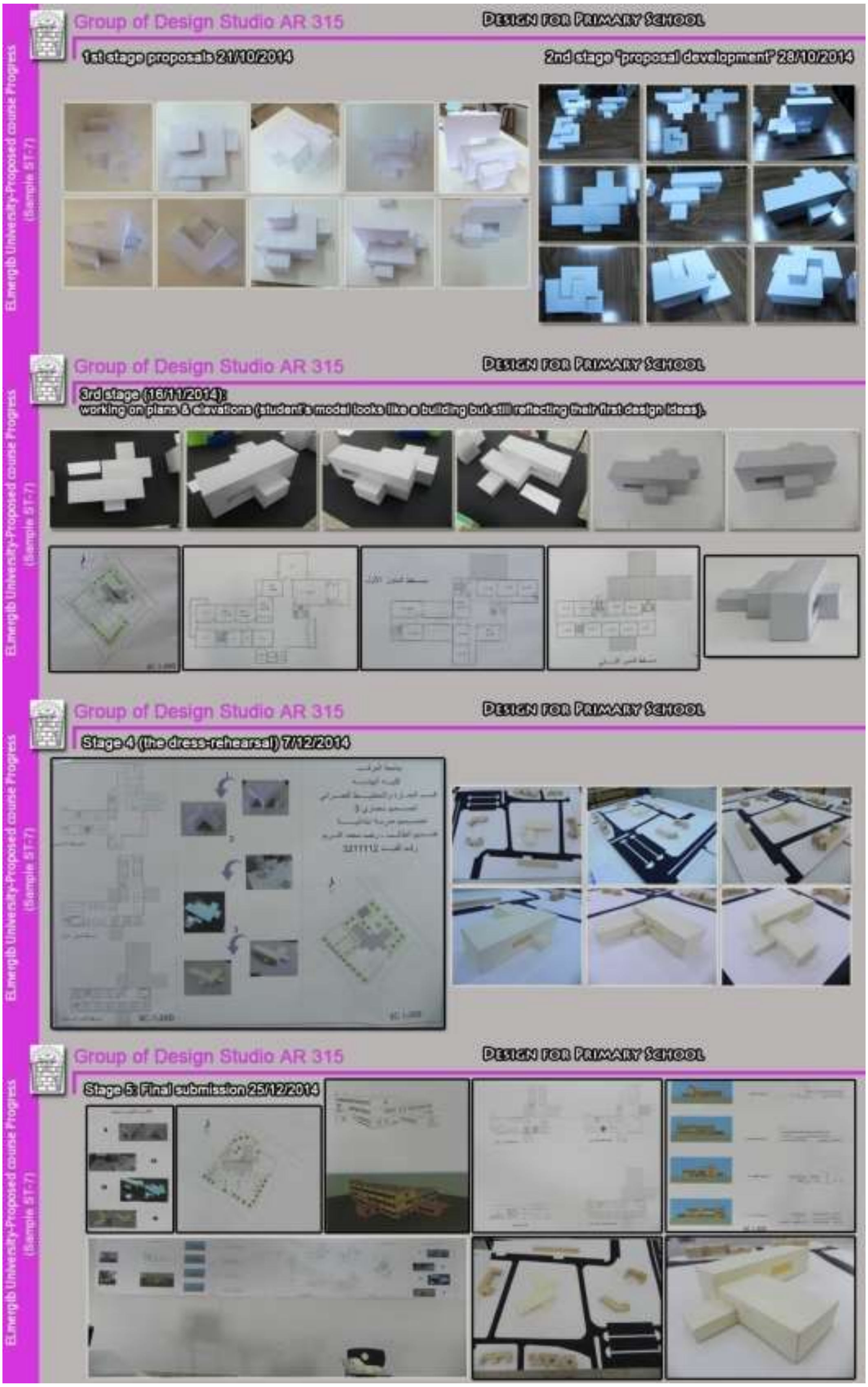


Figure F9. Models photographs of AR315 design group at Elmergib University's students (Sample 7)

Figure F10. Models photographs of AR315 design group at Elmergib University's students (Samples 7-8)

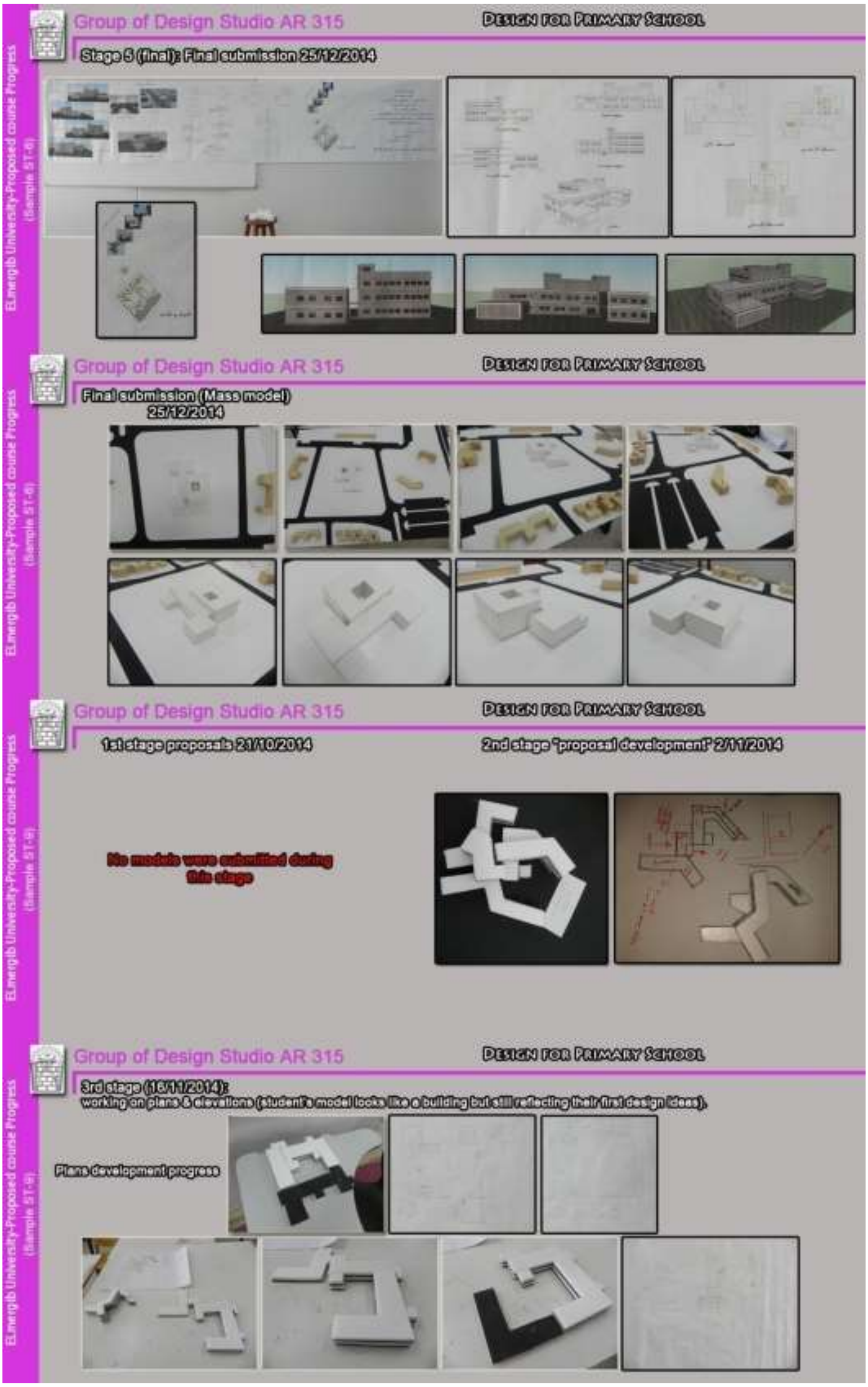


Figure F11. Models photographs of AR315 design group at Elmergib University's students (Samples 8-9)

Figure F12. Models photographs of AR315 design group at Elmergib University's students (Sample 9)

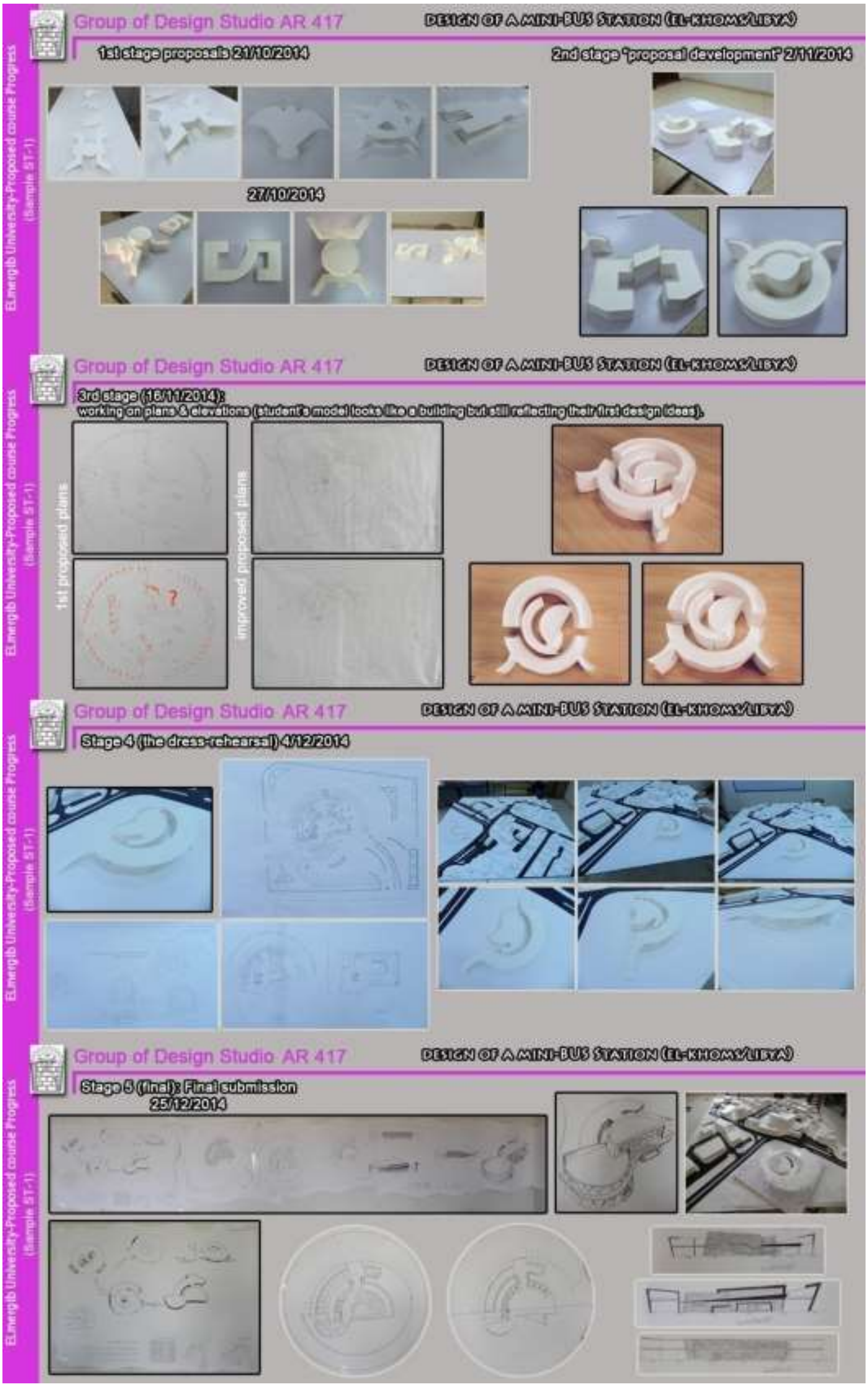


Figure F13. Models photographs of AR417 design group at Elmergib University's students (Sample 1)

Figure F14. Models photographs of AR417 design group at Elmergib University's students (Samples 1-2)

Figure F15. Models photographs of AR417 design group at Elmergib University's students (Samples 2-3)

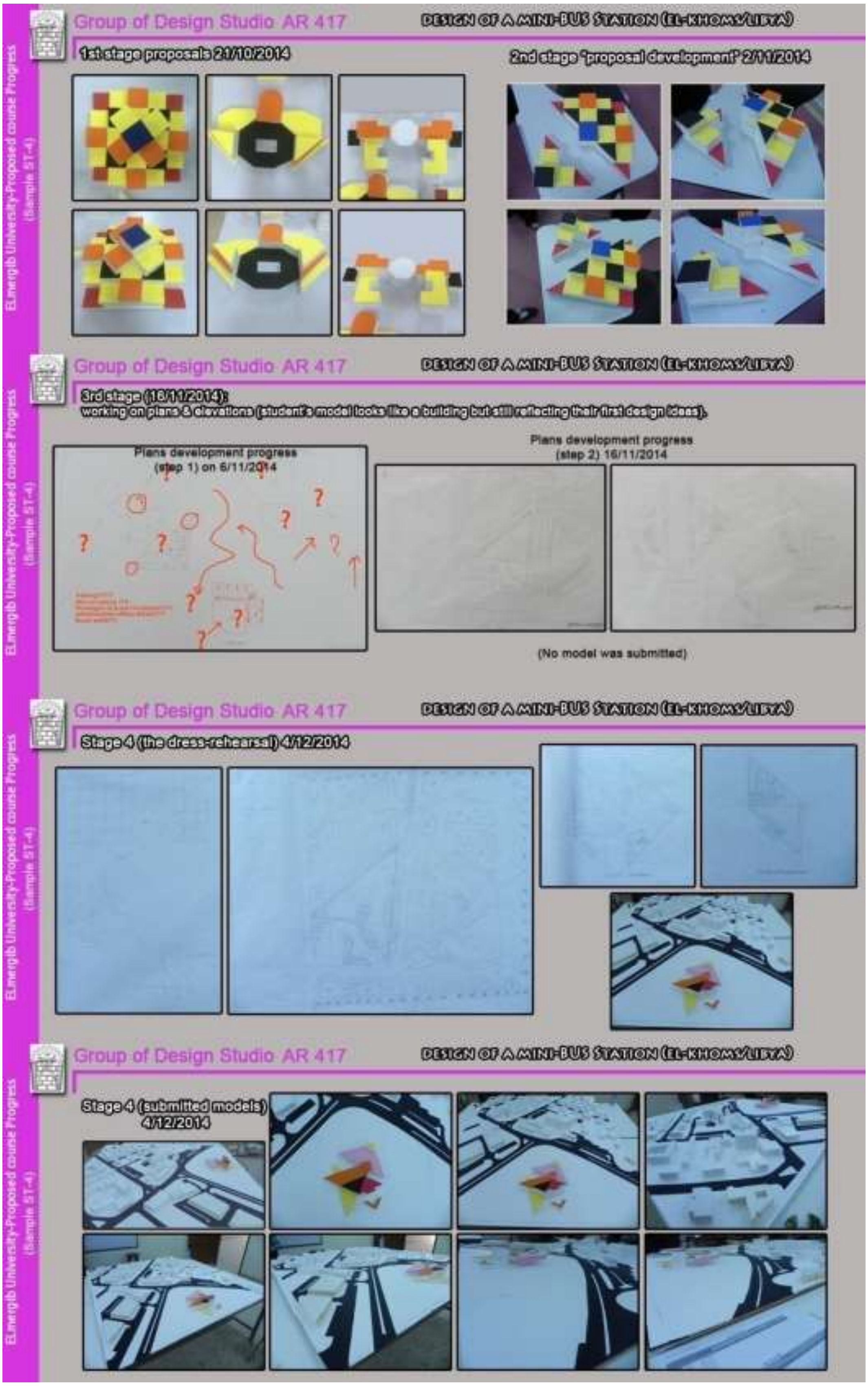


Figure F16. Models photographs of AR417 design group at Elmergib University's students (Sample 4)

Figure F17. Models photographs of AR417 design group at Elmergib University's students (Samples 4-5)

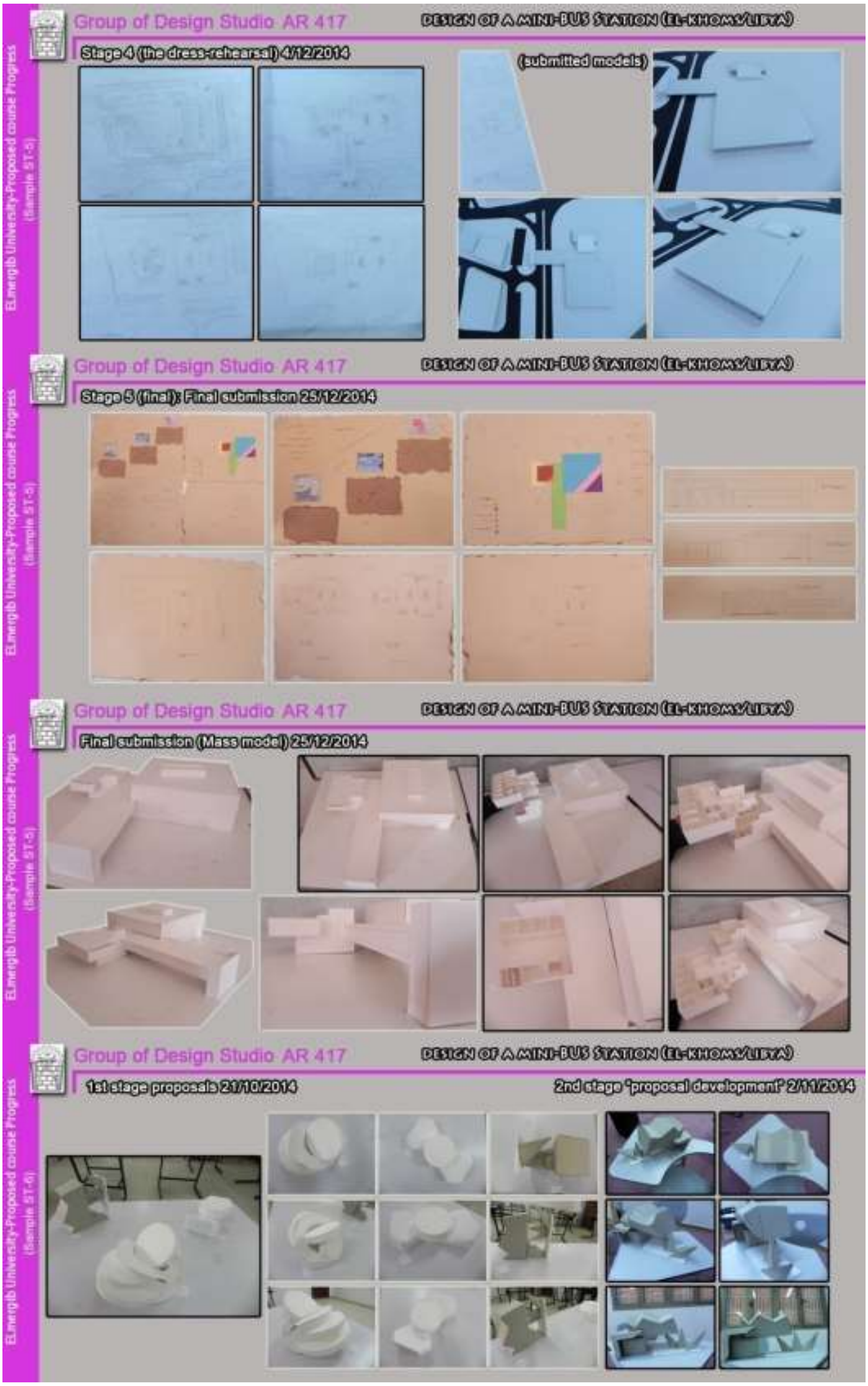


Figure F18. Models photographs of AR417 design group at Elmergib University's students (Samples 5-6)

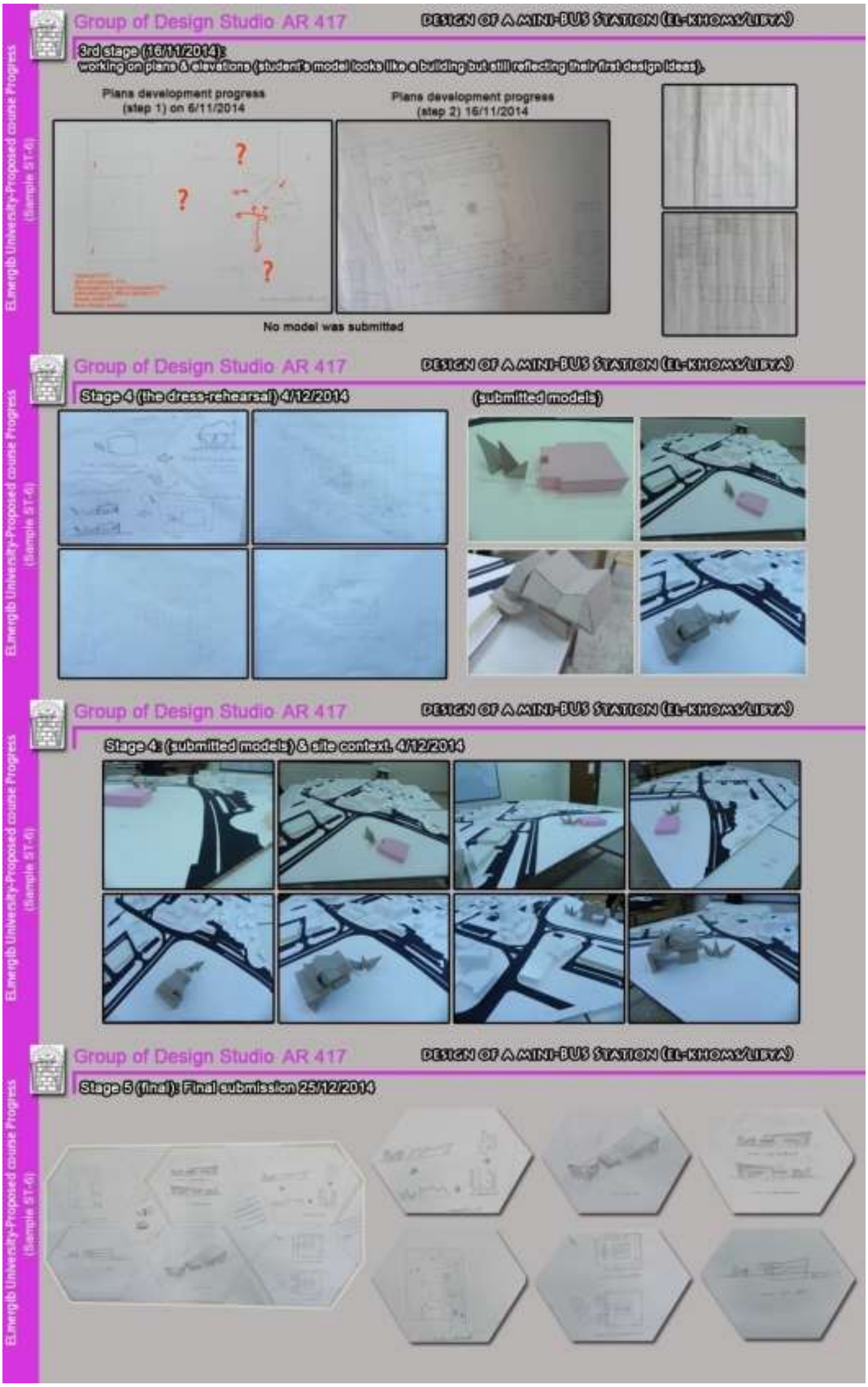


Figure F19. Models photographs of AR417 design group at Elmergib University's students (Sample 6)

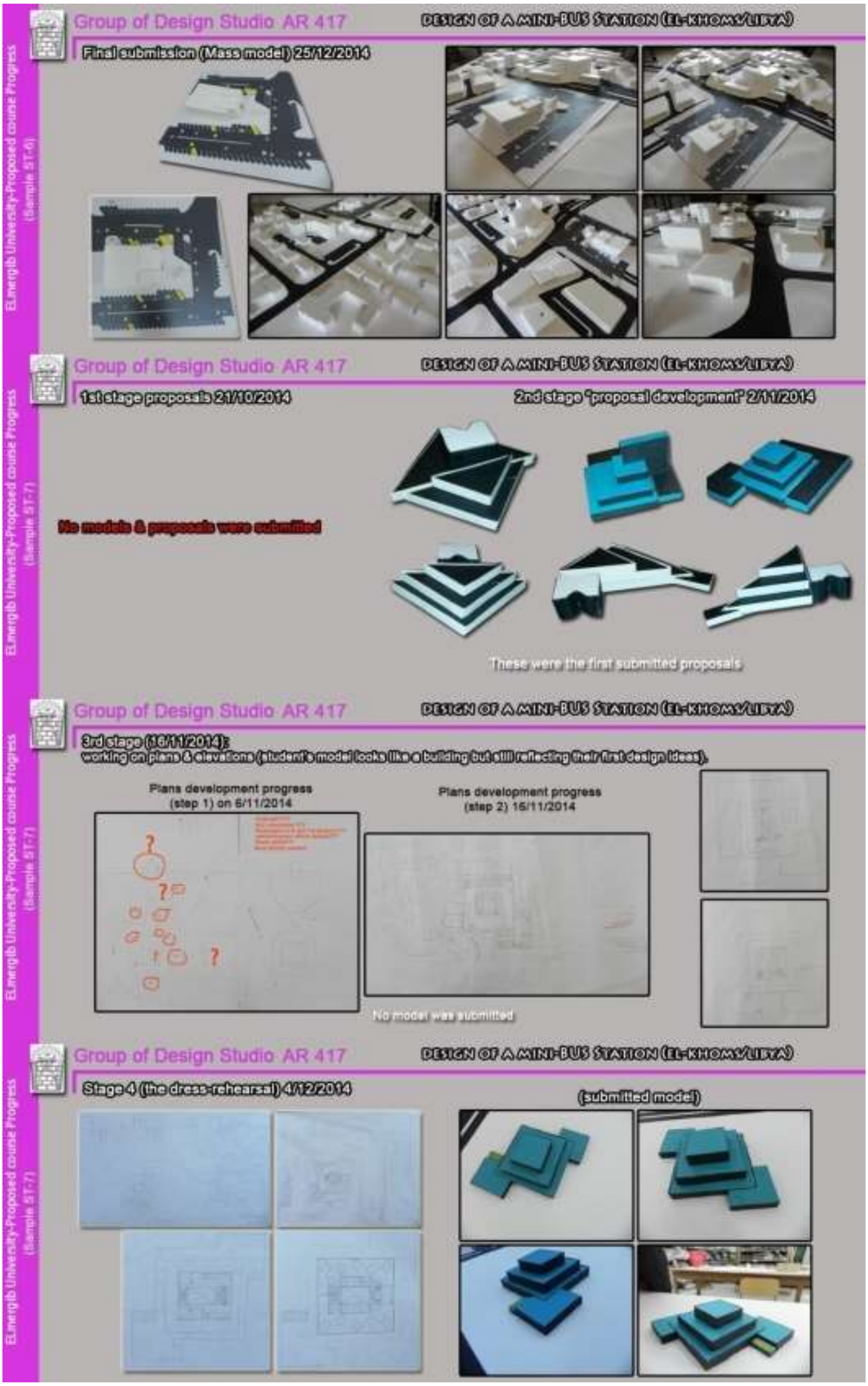


Figure F20. Models photographs of AR417 design group at Elmergib University's students (Samples 6-7)

Figure F21. Models photographs of AR417 design group at Elmergib University's students (Sample 7)

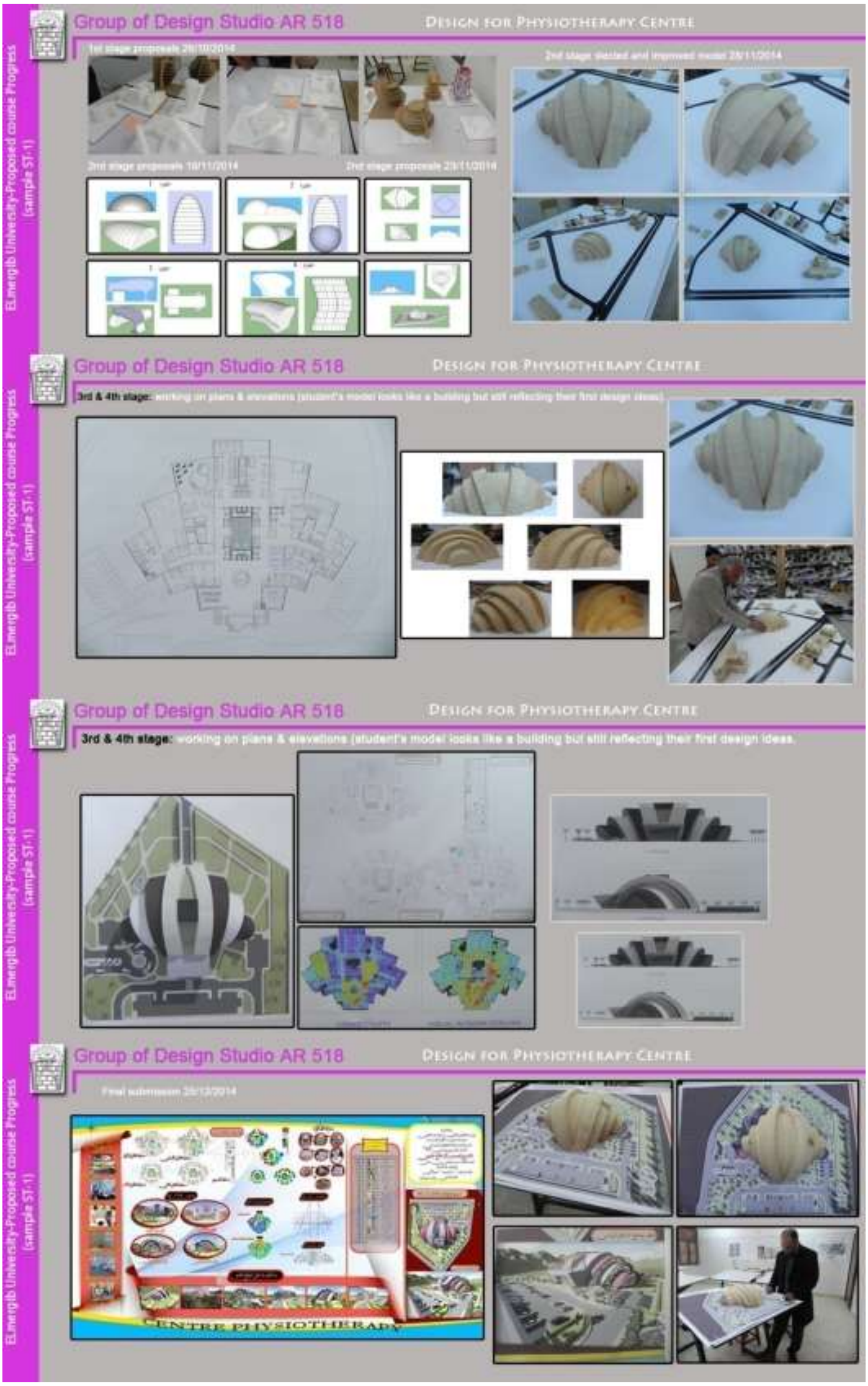


Figure F22. Models photographs of AR518 design group at Elmergib University's students (Sample 1)

Figure F23. Models photographs of AR518 design group at Elmergib University's students (Samples 2-3)

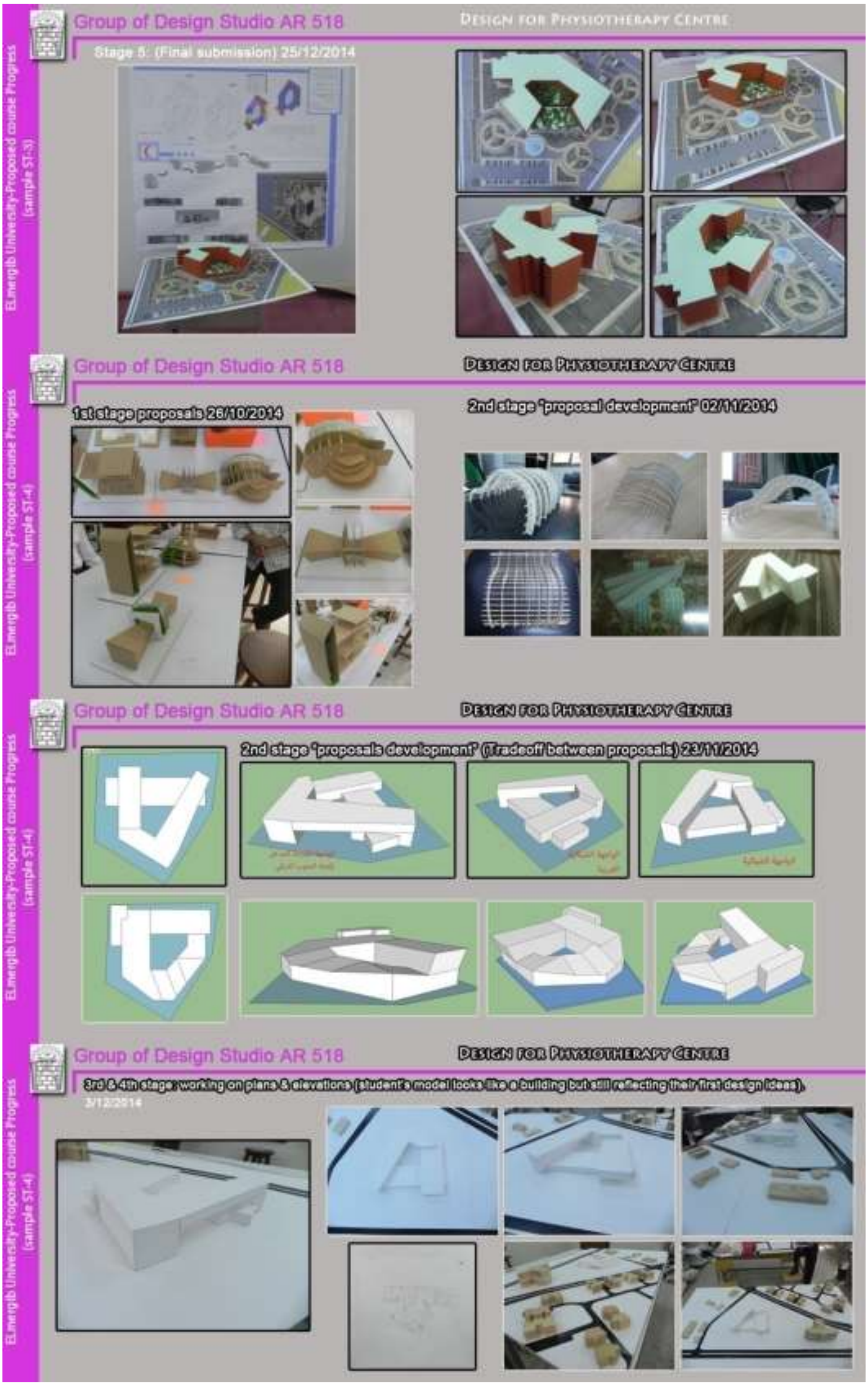


Figure F24. Models photographs of AR518 design group at Elmergib University's students (Samples 3-4)

Figure F25. Models photographs of AR518 design group at Elmergib University's students (Samples 4-5)

Figure F26. Models photographs of AR518 design group at Elmergib University's students (Samples 5-6)

Figure F27. Models photographs of AR518 design group at Elmergib University's students (Samples 7-8)

Figure F28. Models photographs of AR518 design group at Elmergib University's students (Samples 8-9)

Figure F29. Models photographs of AR518 design group at Elmergib University's students (Samples 9-10)

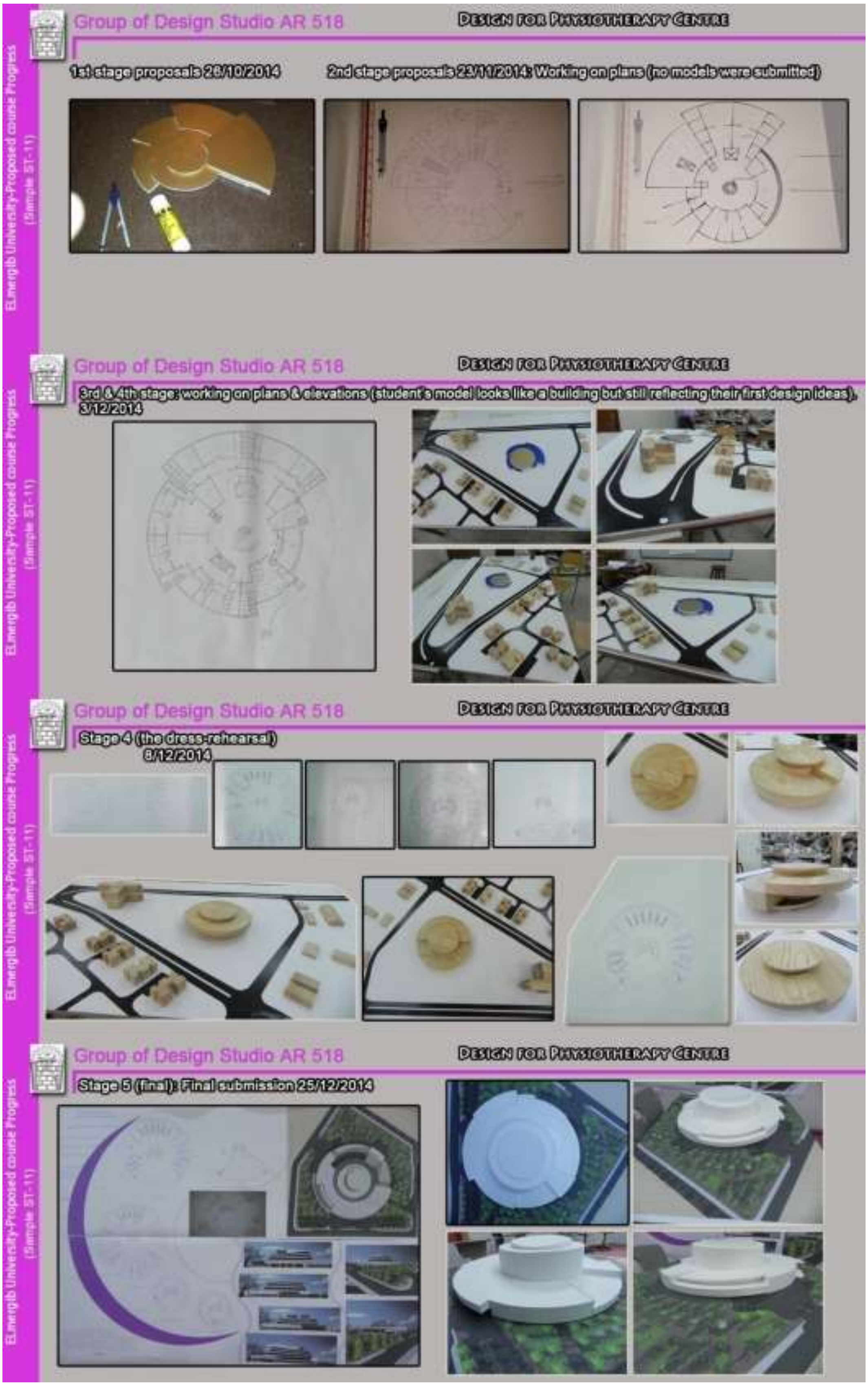


Figure F30. Models photographs of AR518 design group at Elmergib University's students (Sample 11-10)

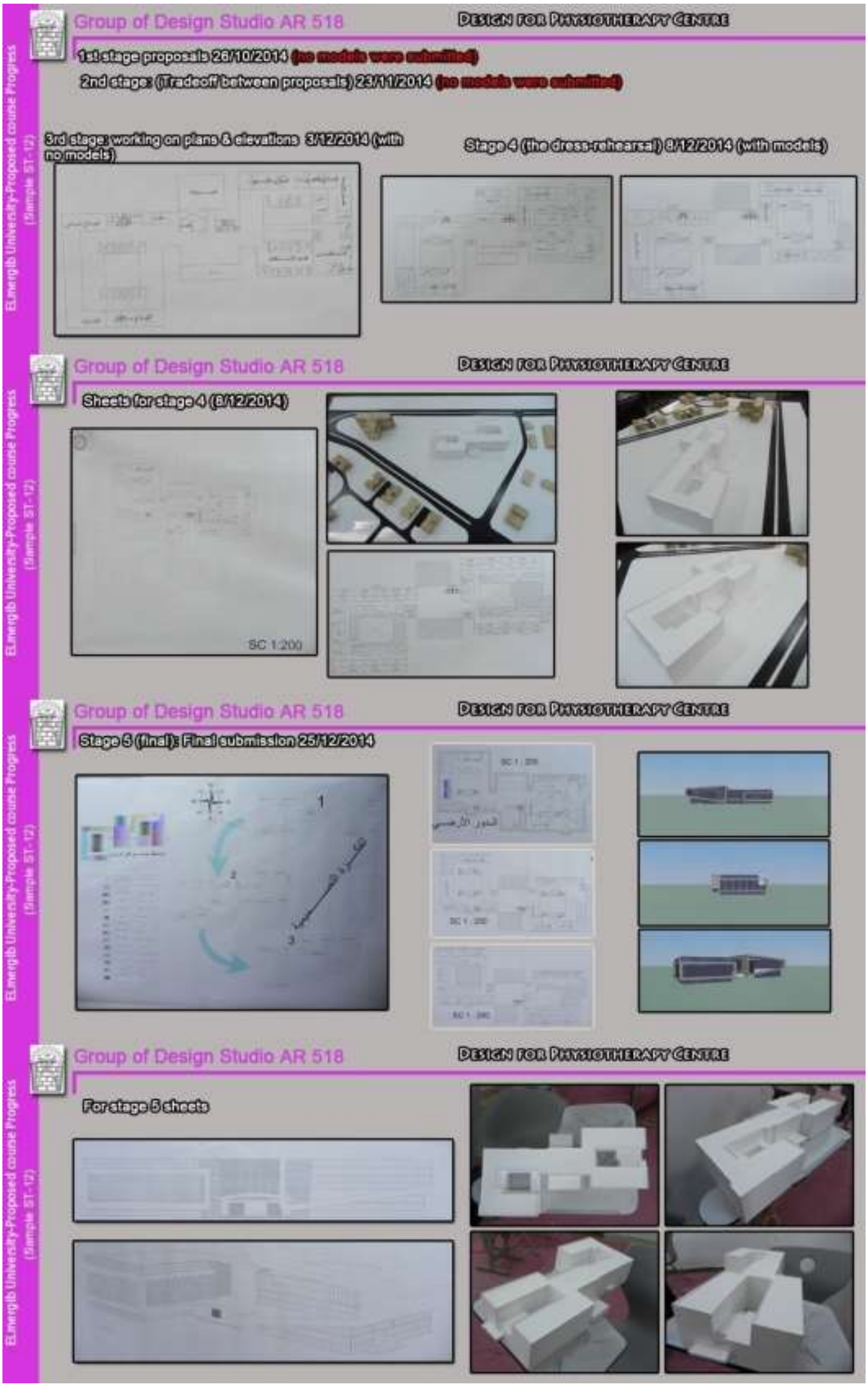


Figure F31. Models photographs of AR518 design group at Elmergib University's students (Sample 12)

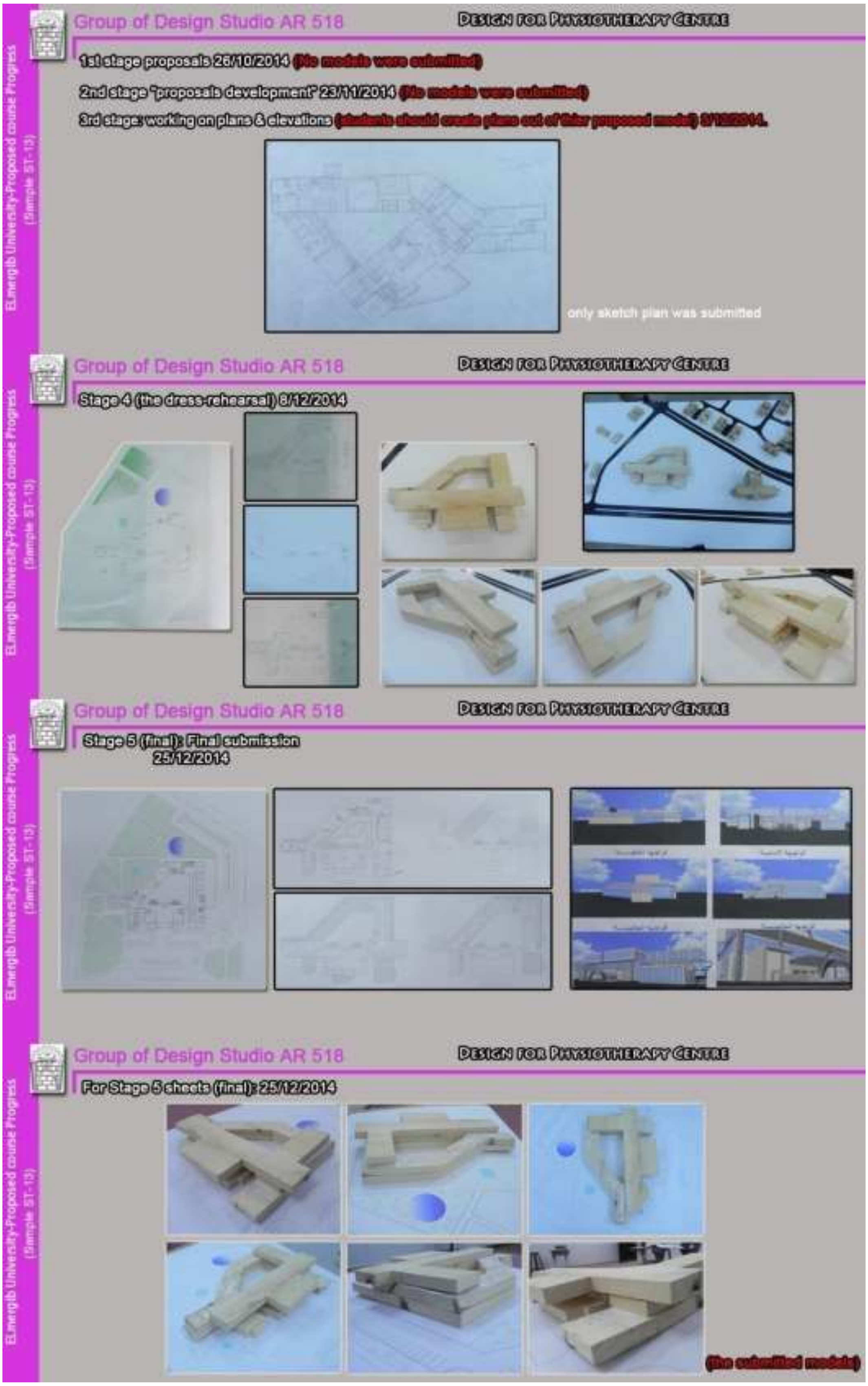


Figure F32. Models photographs of AR518 design group at Elmergib University's students (Sample 13)

Figure F33. Models photographs of AR518 design group at Elmergib University's students (Samples 14-15)

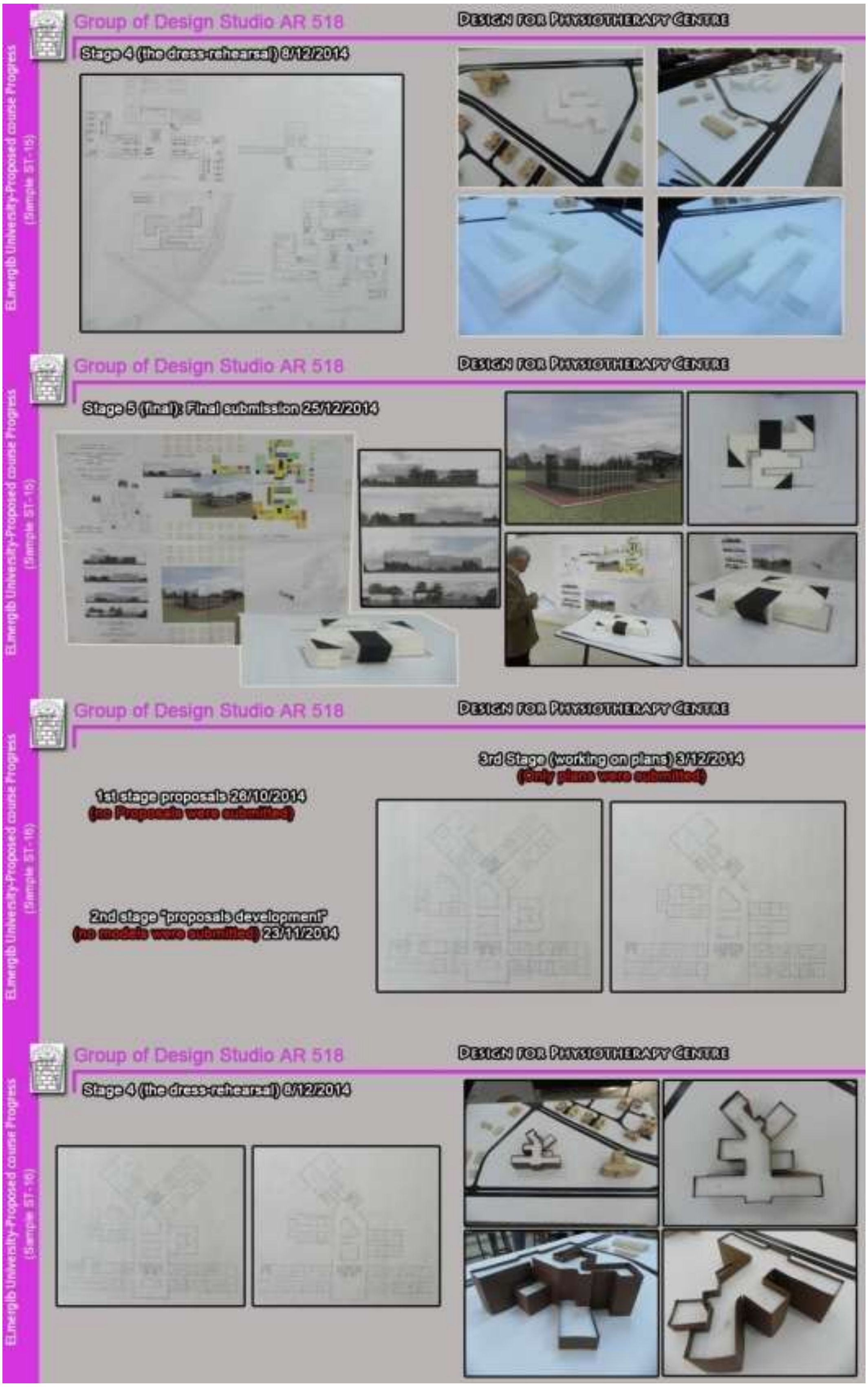


Figure F34. Models photographs of AR518 design group at Elmergib University's students (Samples 15-16)

Figure F34. (Continued) Models photographs of AR518 design group at Elmergib University's students (Sample 16)

RAW DATA USED FOR THE CORRELATION ANALYSIS FOR ELMERGIB UNIVERSITY

Table F22. Raw data used for correlation analysis between the students modelling skills grades and their building science courses' GPA.

Classification of grades for the 32 students enrolled in the proposed				
NO	**Sample code**	**Modeling skills (10)**	**Modeling skills (100)**	**Building Science courses GPA**
1	**ST-5/6**	6.07	60.7	55.188
2	**ST-1/5**	6.61	66.1	63.923
3	**ST-5/5**	7.235	72.35	54.611
4	**ST-4/5**	6.51	65.1	75.412
5	**ST-7/5**	5.36	53.6	62.692
6	**ST-2/5**	5.856	58.56	70.75
7	**ST-6/5**	5.845	58.45	67.222
8	**ST-15/6**	4.96	49.6	59.722
9	**ST-12/6**	5.75	57.5	51.643
10	**ST-16/6**	5.168	51.68	63.313
11	**ST-6/6**	5.543	55.43	57
12	**ST-4/6**	8.668	86.68	65.467
13	**ST-2/6**	5.735	57.35	48.5
14	**ST-7/6**	6.248	62.48	60.773
15	**ST-3/6**	6.316	63.16	64.375
16	**ST-10/6**	4.25	42.5	56.167
17	**ST-9/6**	5.915	59.15	59.3
18	**ST-1/6**	7.988	79.88	73.333
29	**ST-13/6**	6.263	62.63	57.545
20	**ST-14/6**	6.238	62.38	60.095
21	**ST-11/6**	6.93	69.3	61.158
22	**ST-8/6**	6.39	63.9	59.833
23	**ST-5/3**	6.86	68.6	70.083
24	**ST-6/3**	6.62	66.2	73
25	**ST-8/3**	6.88	68.8	68.071
26	**ST-7/3**	7.34	73.4	63.571
27	**ST-9/3**	7.12	71.2	54.833
28	**ST-1/3**	4.39	43.9	55.375
29	**ST-2/3**	7.04	70.4	62.083
30	**ST-3/3**	6.177	61.77	64.125
31	**ST-4/3**	6.763	67.63	61.455

Table F23. Raw data used for correlation analysis between the students modelling skills grades and CGPA.

Classification of grades for the 31 students enrolled in the proposed design studio course.				
NO	**Sample code**	**Modeling skills (10)**	**Modeling skills (100)**	**CGPA**
1	**ST-5/6**	6.07	60.7	**56.97**
2	**ST-1/5**	6.61	66.1	**62.89**
3	**ST-5/5**	7.235	72.35	**57.95**
4	**ST-4/5**	6.51	65.1	**73.99**
5	**ST-7/5**	5.36	53.6	**59.92**
6	**ST-2/5**	5.856	58.56	**68.52**
7	**ST-6/5**	5.845	58.45	**65.11**
8	**ST-15/6**	4.96	49.6	**58.67**
9	**ST-12/6**	5.75	57.5	**55.7**
10	**ST-16/6**	5.168	51.68	**60.91**
11	**ST-6/6**	5.543	55.43	**58.19**
12	**ST-4/6**	8.668	86.68	**67.8**
13	**ST-2/6**	5.735	57.35	**55.44**
14	**ST-7/6**	6.248	62.48	**62.39**
15	**ST-3/6**	6.316	63.16	**65.31**
16	**ST-10/6**	4.25	42.5	**57.65**
17	**ST-9/6**	5.915	59.15	**59.53**
18	**ST-1/6**	7.988	79.88	**72.6**
29	**ST-13/6**	6.263	62.63	**60.02**
20	**ST-14/6**	6.238	62.38	**61.3**
21	**ST-11/6**	6.93	69.3	**64.58**
22	**ST-8/6**	6.39	63.9	**61.35**
23	**ST-5/3**	6.86	68.6	**67.74**
24	**ST-6/3**	6.62	66.2	**71**
25	**ST-8/3**	6.88	68.8	**64.24**
26	**ST-7/3**	7.34	73.4	**64.29**
27	**ST-9/3**	7.12	71.2	**58.32**
28	**ST-1/3**	4.39	43.9	**55.99**
29	**ST-2/3**	7.04	70.4	**64.24**
30	**ST-3/3**	6.177	61.77	**63.46**
31	**ST-4/3**	6.763	67.63	**61.83**

Table F24. Raw data used for correlation analysis between the students modelling skills grades and Basic of Model making (AR214).

Data and analysis are done only for the students who took Basic of model making (AR214)				
NO	**Sample code**	**Modeling skills (10)**	**Modeling skills (100)**	**Basic of model making (AR214)**
1	**ST-5/5**	7.235	72.35	50
2	**ST-4/5**	6.51	65.1	55
3	**ST-7/5**	5.36	53.6	57
4	**ST-6/5**	5.845	58.45	50
5	**ST-4/6**	8.6675	86.68	60
6	**ST-11/6**	6.93	69.3	55
7	**ST-5/3**	6.8575	68.6	59
8	**ST-6/3**	6.6225	66.2	65
9	**ST-8/3**	6.8825	68.8	73
10	**ST-7/3**	7.3425	73.4	70
11	**ST-9/3**	7.1075	71.2	50
12	**ST-1/3**	4.3875	43.9	70
13	**ST-2/3**	7.04	70.4	58
14	**ST-4/3**	6.7625	67.63	60

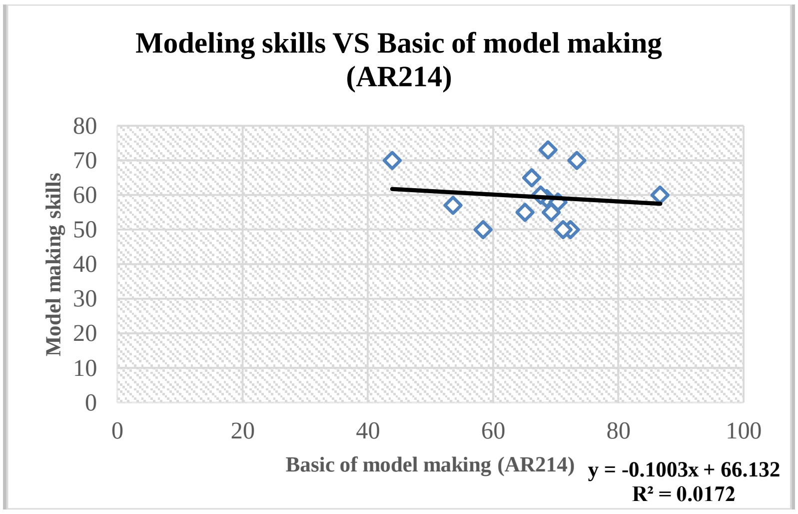


Figure F35. Correlation coefficient between modeling skills grades VS Basic of model making course (AR214) for the students of Elmergib University.

Table F25. Raw data used for correlation analysis between the students modelling skills grades and Building Construction I, II, III and IV (AR221, AR222, AR323, AR324).

The listed grades are for 22 students out of 32 enrolled in the research proposed design								
NO	Sample code	Modeling skills (10)	Modeling skills (100)	AR221	AR222	AR323	AR324	Building construction GPA
1	ST-5/6	6.07	60.7	51	51	50	66	50.67
2	ST-1/5	6.61	66.1	50	50	51	0	50.33
3	ST-5/5	7.235	72.35	56	61	50	54	55.67
4	ST-4/5	6.51	65.1	68	66	73	86	69
5	ST-7/5	5.36	53.6	55	77	0	0	66
6	ST-2/5	5.856	58.56	67	88	71	82	75.33
7	ST-6/5	5.845	58.45	69	50	51	68	56.67
8	ST-	4.96	49.6	50	60	58	61	56
9	ST-	5.75	57.5	50	56	50	62	52
10	ST-	5.168	51.68	53	51	58	60	54
11	ST-6/6	5.543	55.43	50	50	69	59	56.33
12	ST-4/6	8.668	86.68	51	71	64	74	62
13	ST-2/6	5.735	57.35	0	0	59	56	59
14	ST-7/6	6.248	62.48	63	51	62	65	58.67
15	ST-3/6	6.316	63.16	63	51	61	63	58.33
16	ST-	4.25	42.5	58	53	69	64	60
17	ST-9/6	5.915	59.15	50	58	51	76	53
18	ST-1/6	7.988	79.88	62	51	78	82	63.67
19	ST-	6.263	62.63	53	52	57	50	54
20	ST-	6.238	62.38	50	54	69	50	57.67
21	ST-	6.93	69.3	59	64	50	70	57.67
22	ST-8/6	6.39	63.9	65	56	50	60	57

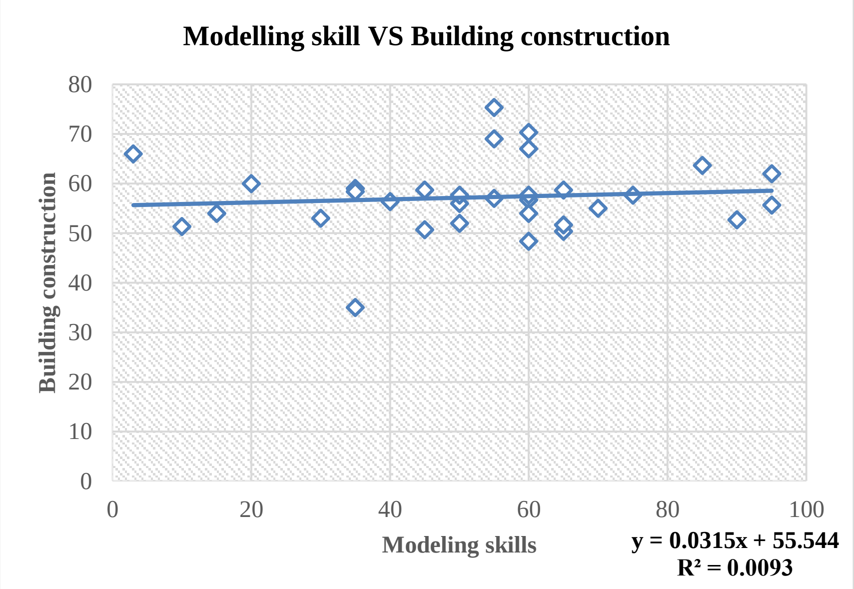


Figure F36. Correlation coefficient between modeling skills grades VS Building Construction I, II, III and IV (AR221, AR222, AR323, AR324). for the students of Elmergib University.

Table F26. Raw data used for correlation analysis between the students modelling skills grades and Implementation Drawing I & II (AR425, AR426).

11 students' grades that has completed both parts of Implementation Drawing AR425/426 and enrolled in the study proposed studio course.					
NO	**Sample code**	**Modeling skills (100)**	**AR425**	**AR426**	**AR425/AR426 GPA**
1	**ST-5/5**	72.35	51	52	51.5
2	**ST-15/6**	49.6	60	62	61
3	**ST-16/6**	51.68	62	53	57.5
4	**ST-2/6**	57.35	55	0	27.5
5	**ST-7/6**	62.48	62	57	59.5
6	**ST-3/6**	63.16	75	73	74
7	**ST-10/6**	42.5	51	65	58
8	**ST-9/6**	59.15	54	51	52.5
9	**ST-13/6**	62.63	59	67	63
10	**ST-14/6**	62.38	57	53	55
11	**ST11/6**	69.3	74	65	69.5

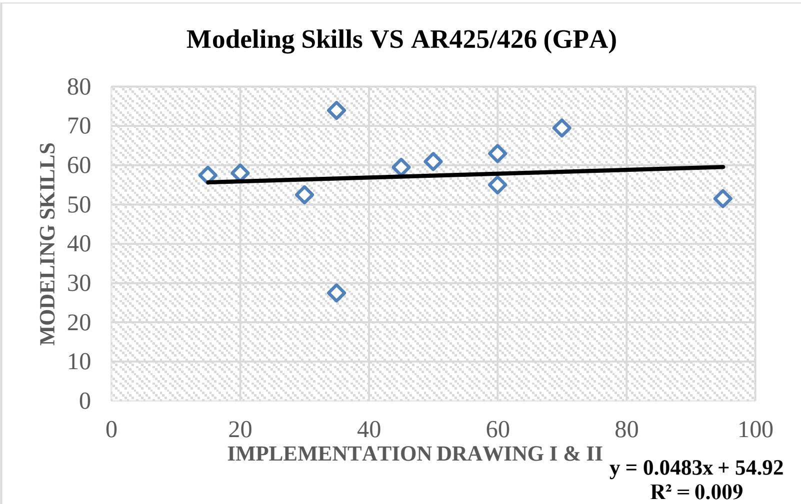


Figure F37. Correlation coefficient between modeling skills grades VS Implementation Drawing I & II (AR425, AR426). for the students of Elmergib University.

Table F27. Raw data used for correlation analysis between the students modelling skills grades and Environmental control (AR490).

Only 15 students out of 32 had taken the Environmental control. The			
NO	**Sample code**	**Modeling skills**	**AR490**
1	**ST-5/5**	72.35	31
2	**ST-6/5**	58.45	55
3	**ST-16/6**	51.68	71
4	**ST-4/6**	86.68	50
5	**ST-7/6**	62.48	67
6	**ST-10/6**	42.5	25
7	**ST-9/6**	59.15	81
8	**ST-13/6**	62.63	62
9	**ST-14/6**	62.38	31
10	**ST-11/6**	69.3	77
11	**ST-8/6**	63.9	53
12	**ST-5/3**	68.6	73
13	**ST-6/3**	66.2	78
14	**ST-7/3**	73.4	59
15	**ST-2/3**	70.4	69

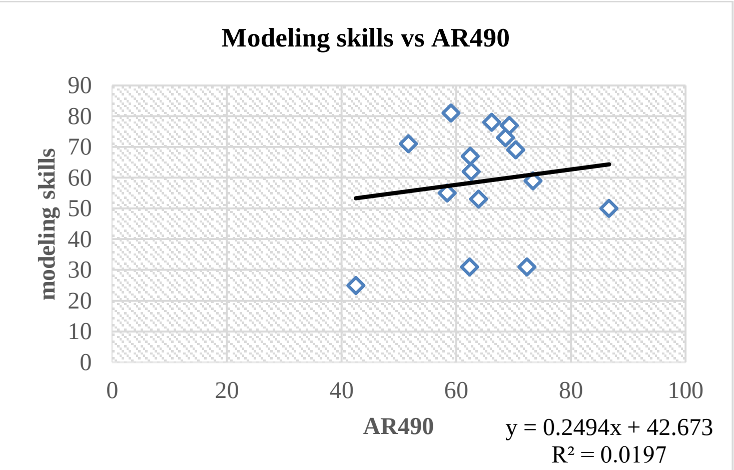


Figure F38. Correlation coefficient between modeling skills grades VS Environmental control (AR490) for the students of Elmergib University.

Table F27. Raw data used for correlation analysis between the students modelling skills grades and Building Materials (AR224).

30 Students out of 32 are involved in the analysis; only 2 students have not taken AR224.			
NO	**Sample code**	**Modeling skills (100)**	**AR224**
1	**ST-5/6**	60.7	54
2	**ST-1/5**	66.1	68
3	**ST-5/5**	72.35	55
4	**ST-4/5**	65.1	90
5	**ST-7/5**	53.6	61
6	**ST-6/5**	58.45	78
7	**ST-15/6**	49.6	67
8	**ST-12/6**	57.5	53
9	**ST-16/6**	51.68	52
10	**ST-6/6**	55.43	55
11	**ST-4/6**	86.68	62
12	**ST-2/6**	57.35	51
13	**ST-7/6**	62.48	69
14	**ST-3/6**	63.16	55
15	**ST-10/6**	42.5	56
16	**ST-9/6**	59.15	66
17	**ST-1/6**	79.88	62
18	**ST13/6**	62.63	65
19	**ST-14/6**	62.38	64
20	**ST-11/6**	69.3	52
21	**ST-8/6**	63.9	76
22	**ST-5/3**	68.6	70
23	**ST-6/3**	66.2	77
24	**ST-8/3**	68.8	66
25	**ST-7/3**	73.4	77
26	**ST-9/3**	71.2	52
27	**ST-1/3**	43.9	55
28	**ST-2/3**	70.4	74
29	**ST-3/3**	61.77	71
30	**ST-4/3**	67.63	51

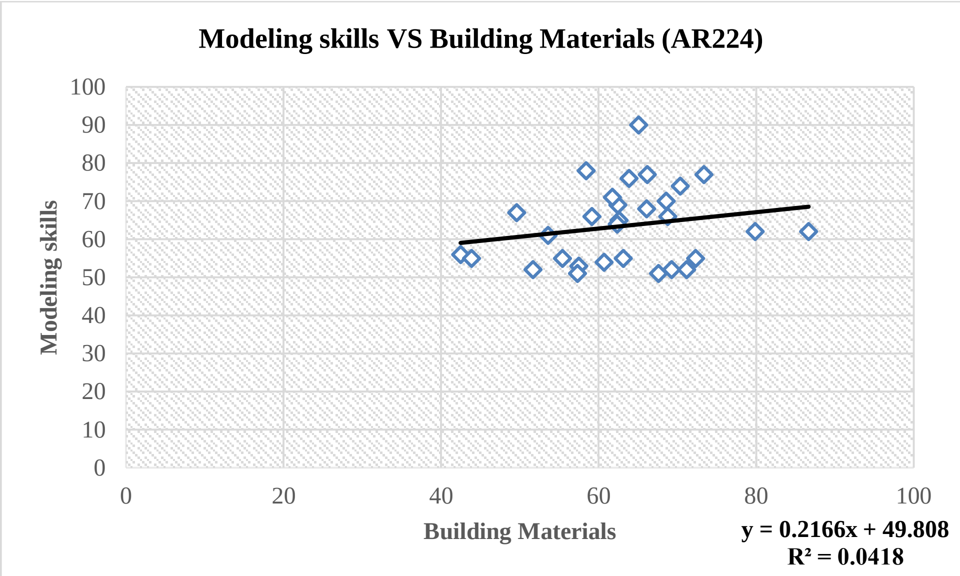


Figure F39. Correlation coefficient between modeling skills grades VS Building Materials (AR224).for the students of Elmergib University.

APPENDIX G

RAW DATA FOR GENERAL GUESTIONNAIRE.

Table G1. RAW DATA FOR GENERAL GUESTIONNAIRE
Note: This data is given in an excel files called “General Questionnaire-ENGLISH.xls” and “General Questionnaire-ARABIC.xls” in the CD submitted with the thesis. Since the questionnaire was done in two languages (English and Arabic) both excel files are given in the CD.

Table G2. Information obtained from the interview with architects

<table>
<tr><th>Architects</th><th>Design approach</th><th>Preferred modeling technique</th><th>Advantages & disadvantages</th><th>Notes</th></tr>
<tr><td>Arch-1</td><td>2D zoning & image references for the project</td><td>3D digital modeling</td><td rowspan="4">• Working on computer screen does not give a sense of the 3^{rd} dimension (2D planes)
• The 3^{rd} dimension can be felt only when working on site or when dealing with 3D tangible compositions (when presence and direct interaction occur).
• Isometric: determined a 3D appearance due to its real scale and numeric dimension.
• Working directly in 3D helps to maintain every single part of “ideation & conception process”.
• 2D sketching is regarded as technical drawing rather than professional expression.
• Working by hands or manual conceptualizing (in design) often comes out with an incomprehensible
• Working by hands or manual conceptualizing (in design) has a clear and definite reference in the designer’s mind.
• Any computer program or software can be regarded as a tool to translate ideas to a numeric language.
• Some design ideas done on 1:1 scale.
• Modeling regarded as the core of the design conception
• Modeling references usually obtained from clients (project requirements)
• Design references: unborn ideas are always seen 3 dimensionally (in the designer’s brain)
• Matter of scale: prefer isometric due its real scale and dimensions.
• Materials: Preparing comprehensive library materials in advance.
• Presence & depth: in digital modeling still problematic.
• Tangibility: can be felt only in physical communication.
• Learning & practicing: in both types of modeling they are positively</td><td rowspan="4">Types of clients are identified:
a) Inexperienced client.
b) Organized client.
c) Client with prior experience.
d) Client looking for draftsman rather than a designer.</td></tr>
<tr><td>Arch-2</td><td>3D compositing: Both (handmade & 3D digital model)</td><td>Handmade</td></tr>
<tr><td>Arch-3</td><td>2D hand sketching & 3D compositions by hand</td><td>Handmade model making</td></tr>
<tr><td>Arch-4</td><td>3D compositing: (digitally)</td><td>3D digital modeling</td></tr>
</table>

			appreciated (learning from errors and mistakes) • Time issue: digital model consumes too much time comparing with physical modeling. • Software limitations: all digital software have Limited possibilities, so combination between digital media still needed. (Plugins & Scripting & Postproduction) • Objects that are represented or created by digital software remain virtual and illusionary until they're physically 'reproduced'. However, they are tools of 'representation' not for designing.	
Arch-5 (Autodesk expert)	3D compositing: Both (handmade & 3D digital model) • Usually Isometric (by hand)	• Handmade • It depends on the size of project		• Creating digital library (materials) helps to discover and invent some new material textures. • Scale and dimensions: accurate in physical communication & estimated in digital communication. • Design details: Handmade modeling is more effective to discover and test design details. • hand-sketches are considered as the "alphabet" of architectural design • Model-making is an "Innate talent" that might be improved but almost impossible to acquire in schools. • "Presence & depth" should be considered as they are among the most crucial factors to define and determine the 3D characteristics of any form.

APPENDIX H

MODELS IN PROFESSIONAL DOMAIN

Figure H1. Projects & models samples of the interviewed architect (AR-1)

Figure H2. Projects & models samples of the interviewed architect (AR-2)

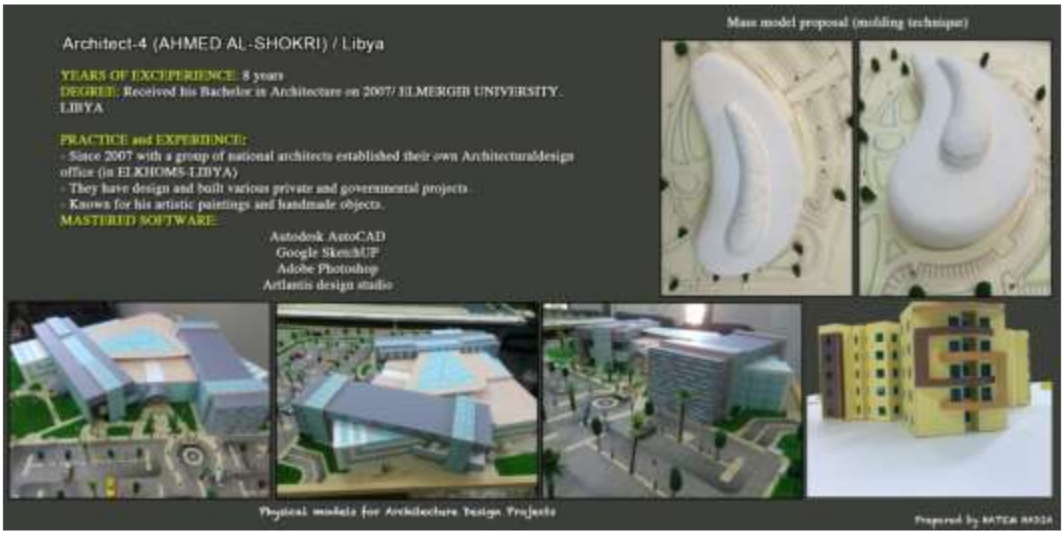


Figure H3. Projects & models samples for the interviewed architect (AR-4)

Figure H4. Projects & models samples of the interviewed architect (AR-5)

APPENDIX I

SAMPLES OF READING MATERIALS FOR EXPERIMENTAL STUDIO COURSE

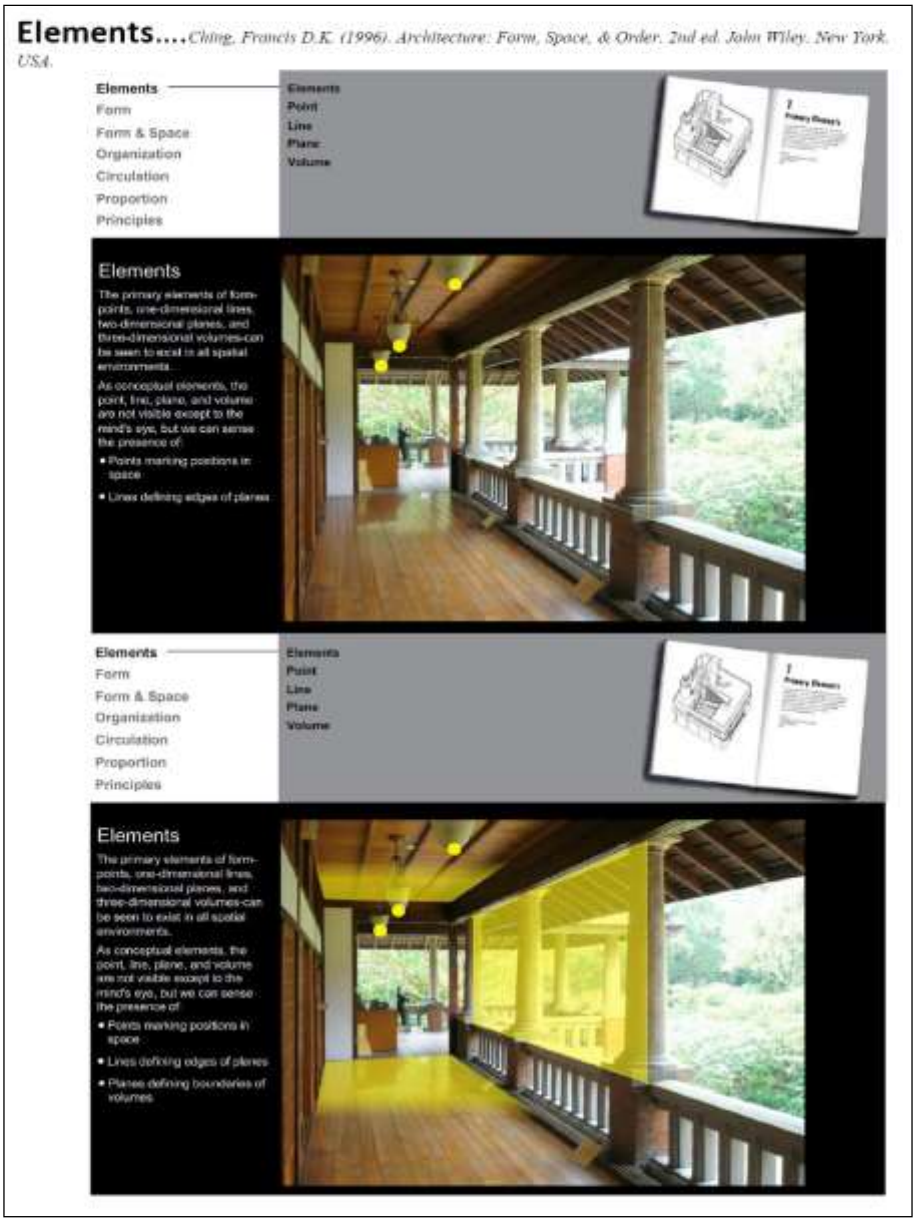


Figure I-1: 1st page (out of 30 pages) of the studio handout on primary elements of form in architecture: Point (top); Point and plane relationship (bottom) (Source of illustrations: Ching, F, D.K. (1996))

Elements.... *Ching, Francis D.K. (1996). Architecture: Form, Space, & Order. 2nd ed. John Wiley. New York. USA.*

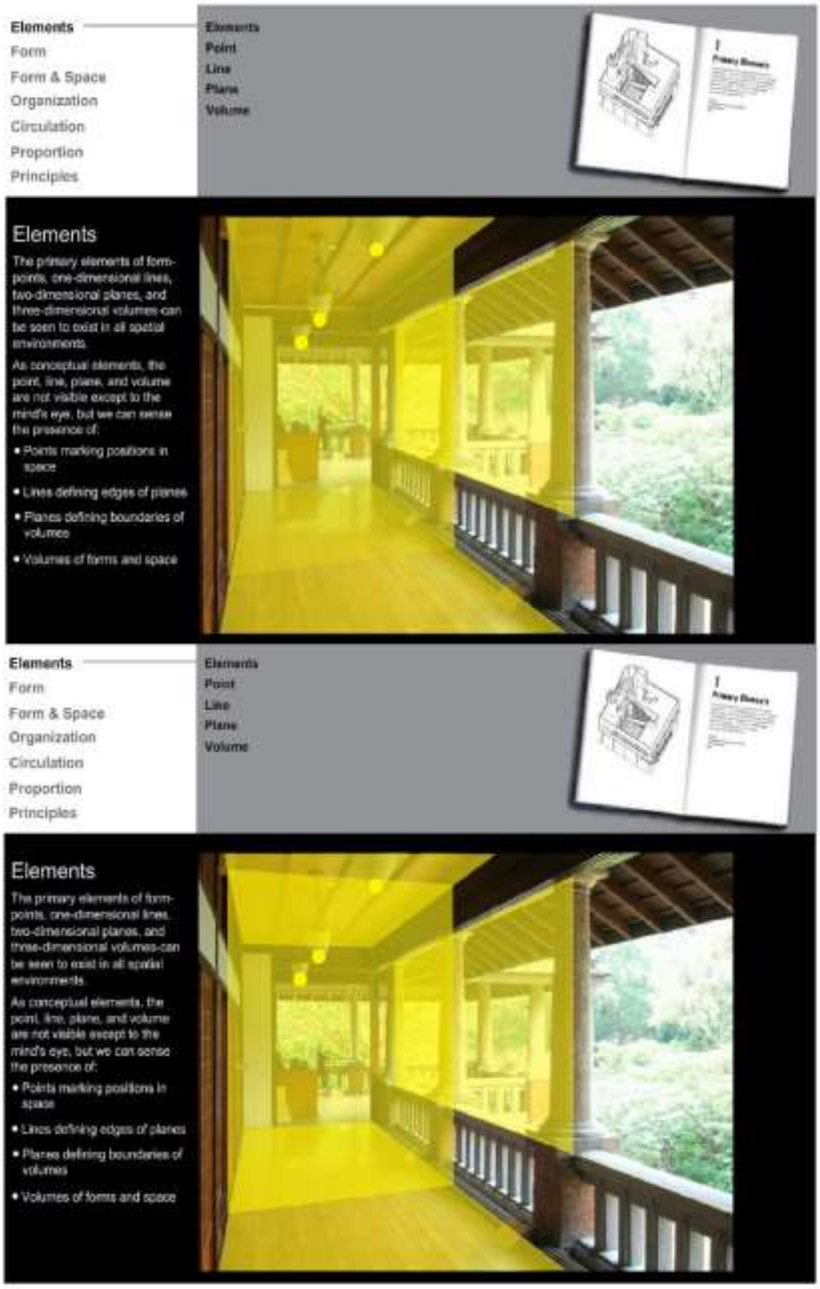


Figure I-2: 2nd page (out of 30 pages) of the studio handout on primary elements of form in architecture: Point and plane relationship (top and bottom)
(Source of illustrations: Ching, F, D.K. (1996))

Elements.... *Ching, Francis D.K. (1996). Architecture: Form, Space, & Order. 2nd ed. John Wiley. New York. USA.*

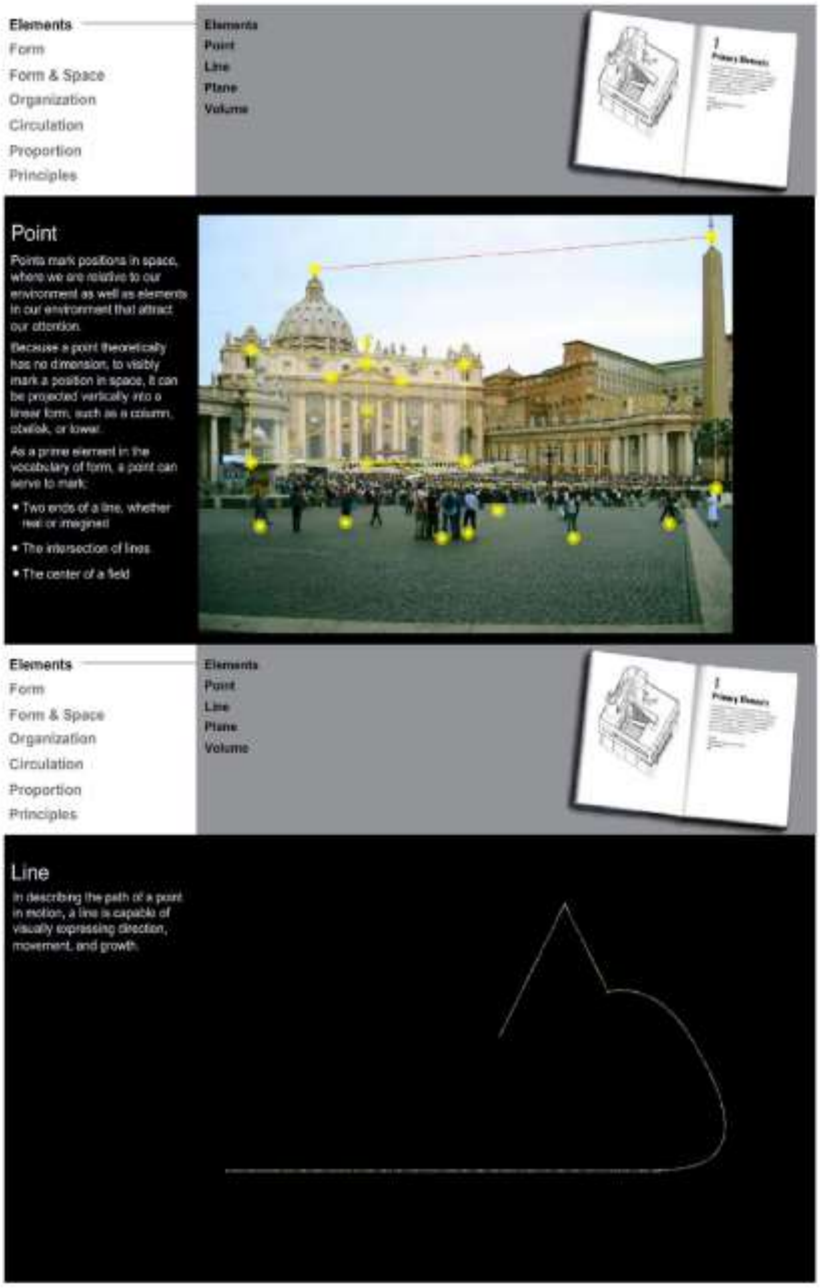
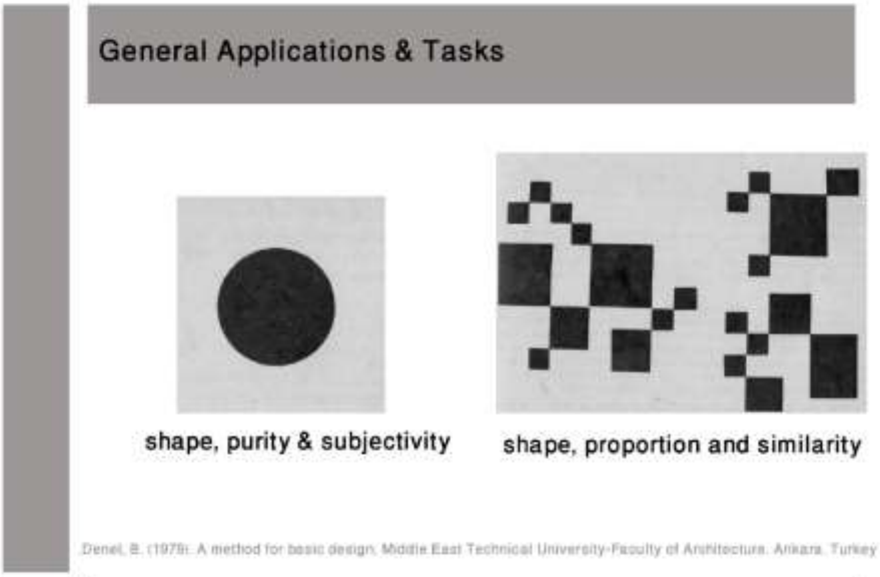


Figure I-3: 3rd page (out of 30 pages) of the studio handout on primary elements of form in architecture: Point (top); Line (bottom) (Source of illustrations: Ching, F, D.K. (1996))

General Applications & tasks.... *Denel, B. (1979). A method for basic design. Middle East Technical University-Faculty of Architecture. Ankara. Turkey.*



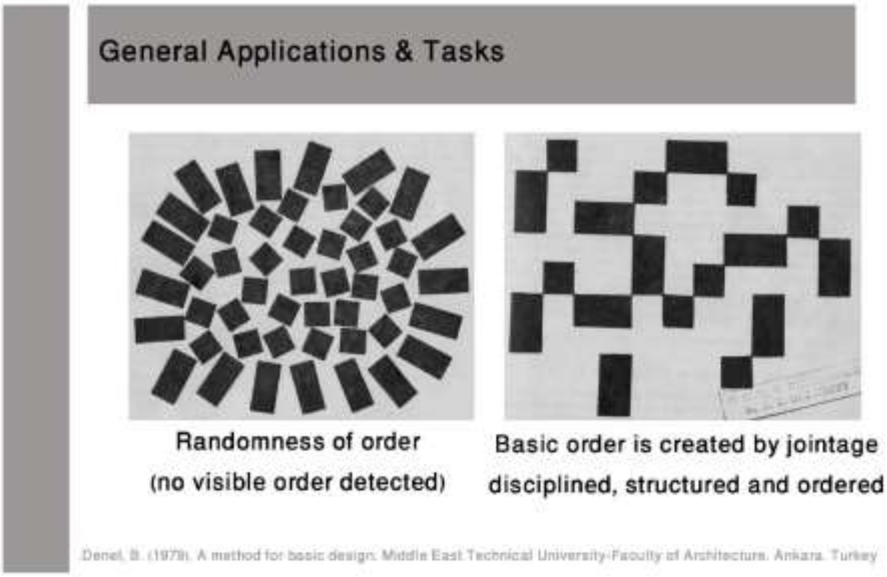


Figure I-30: 5th page (out of 8 pages) of the studio handout on the principles of architectural design: Illustration of some general applications with respect to the principles design (shape, purity and subjectivity, etc) (top and bottom) (Source of illustrations: Denel, B. 1979).

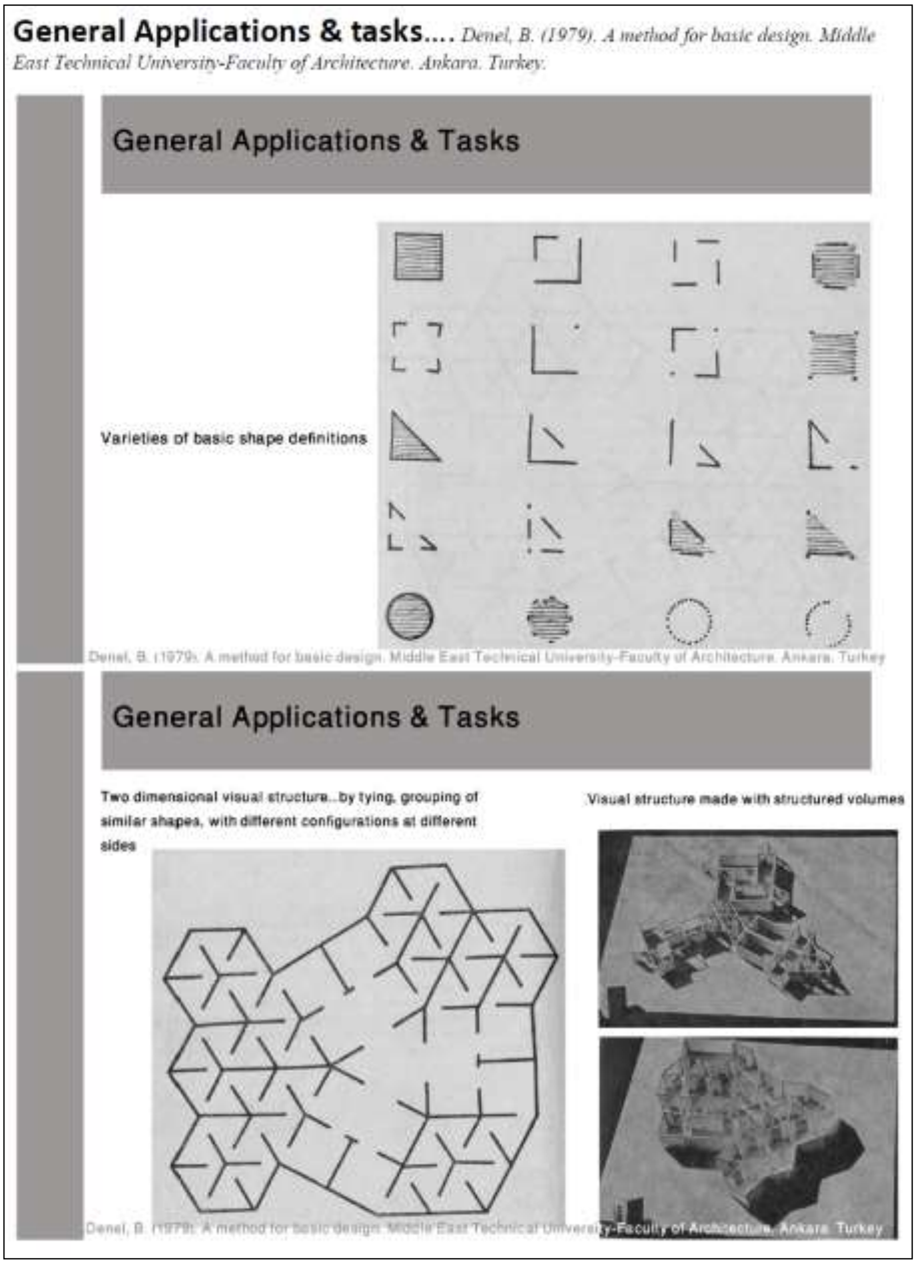


Figure I-31: 7th page (out of 8 pages) of the studio handout on the principles of architectural design: Varieties of basic shapes definitions (top), applications of 2D and 3D visual structures (bottom) (Source of illustrations: Denel, B. 1979).

Note: The above mentioned figures are just samples of the reading materials dedicated for the experimental studio course. The complete set of the handout materials are given in PDF files namely: "Elements, Form, Form & Space, Organization, Circulation, Proportion, Principles and general applications and tasks" in the CD submitted with the thesis

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Hadia, Hatem
Nationality: Libyan
Date and Place of Birth: 17/02/1974, Benghazi-Libya
Marital Status: Married
Phone: 05449562026

EDUCATION

Degree	Institution	Year of Graduation
M.SC in Architecture	Istanbul Kültür University	2007-2008
B.SC in Architecture	University of Benghazi	1999-2000
High School	Abu-Baker Al-Razy	1993-1994

PROFESSIONAL EXPERIENCE

Year	Place	Position
2000-2002	Zangaz Company	Project management
2002-2003	Elemrgib University	Academic Assistant
2007-2008	Elemrgib University	Design studio instructor

PUBLICATIONS

International Conference Publications:

HADIA, H, Model making as Value-Added Design: The role of Model-Making and its impacts in Maintaining the Value of Architectural Design. The 1st International Graduate Research Symposium on the Built Environment. Middle East Technical University, Ankara, Turkey, 15-16 October 2010.

Elias-Ozkan, S.T. and Hadia, H, *Teaching and Learning Building Performance Virtualisation*, In ASCAAD-2013 International Conference on Digital Crafting, Jeddah, KSA, 31 March-2 April 2014